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In Vitro Comparison of Dowel and Core Techniques for Endodontically Treated Molars

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The restoration of broken down pulpless molar teeth generally implies the provision of a cast post and core with a crown. In this research the failure resistance of some restoration methods utilizing amalgam was investigated under an oblique load. The results suggest that intracoronal reinforcement with a prefabricated dowel did not significantly increase the in vitro resistance. It is expected that both investigated amalgam techniques are strong enough to function within normally occurring forces in the oral environment. The main advantage is the possibility to subsequently rebuild the coronal portion of the teeth in amalgam after the endodontic therapy is finished.

The restoration of broken down and endodontically treated teeth is one of the most frequent treatments in restorative dentistry. Restoration of these teeth is often complicated because a large amount of the coronal tooth structure may be missing as a result of decay, previous restorative procedures, the endodontic access, and fractures. As a result, the necessary retention and resistance for the restoration is difficult to achieve.

Until several years ago, the advised treatment option for the restoration of mutilated pulpless posterior teeth was a cast dowel and core covered by a partial or full crown (1, 2). Dowels were indicated to increase the resistance and the retention of the restoration (3, 4). The assumption that application of a dowel increases the strength of an endodontically treated tooth may no longer be valid (5, 6). Instead of a cast post and core other treatment options have surfaced. Methods are described in which composite resins are used in combination with a prefabricated dowel which is cemented into a root canal (7–9). However, with this technique a cast crown is still necessary to restore the occlusal function of the tooth more permanently due to the low wear resistance of composite resins. Methods in which amalgam is used as a core material have the advantage that in the same session and with the same material the occlusal surface can be reconstructed. Increased corrosion resistance of the dental amalgams makes it possible that such an interim treatment can function for years without gross failures (5, 10–12). In these methods the large pulp chamber, with its irregular-shaped walls and undercuts, provides excellent retention and resistance for dental amalgam. Amalgam can be condensed into the entrance of the various root canals or around a dowel, which is cemented into the largest root canal (13–20).

A method has been described where retention for an amalgam core restoration is created by introducing parapulpal pins in the dentin around the pulp chamber for a pin-retained amalgam core (21, 22). This must be regarded as an unnecessarily complex solution because the pulp chamber itself and the entrances of the root canals can provide sufficient retention.

Questions are asked as to whether or not these time and money-saving amalgam restorations can adequately resist forces acting upon them. Earlier studies have shown a great variety of research designs. The variations in the type of teeth used, the materials and dowels examined, the loading speed and the direction of the testing, as well as the variable use of full veneer crowns over the dowel and core foundation prohibit specific conclusions.

However, some in vitro research is available where comparable amalgam restorative methods for molars were tested (Table 1) (15, 19, 23–25). Forces exerted on restorations in the molar region are a combination of axial, shearing, and predominantly oblique forces. So resistance of the restoration to these forces is important. Forces in the tensile direction are less intense and only occurring with sticky food (26). For this reason, the resistance to oblique forces is an important parameter for a successful restoration.

The objective of this study was to determine the in vitro resistance level to oblique force of some amalgam systems that restored endodontically treated molars. The experimental groups were compared with a cast dowel and core and with an amalgam core in a nonendodontically treated molar.

TABLE 1. Results of previous in vitro studies of amalgam dowel and core techniques for endodontically treated molars

Reference	Technique	Force Direction to Long Axis (°)	Mean Results (N)
Michelich et al., 1980 (23)	Pin-retained amalgam core	45	2176 ± 169
	All-amalgam core		2941 ± 271
Christian et al., 1981 (15)	Dowel plus amalgam	90	632
	All-amalgam core		547
Hoag et al., 1982 (24)	All-amalgam core	45	2415 ± 439
	Cast dowel and core		6227 ± 842
Gelfand et al., 1984 (25)	2 dowels (parapost) plus amalgam	45	No values given
	All-amalgam core		
	Cast dowel and core		
Kern et al., 1984 (19)	Dowel (Dentatus) plus amalgam	60	1187 ± 493
	All-amalgam core		798 ± 212

MATERIALS AND METHODS

The two amalgam techniques for restoring pulpless multirooted teeth evaluated were (a) amalgam cores used in conjunction with a cemented dowel and (b) all-amalgam cores without dowels. They were compared with the conventional cast post and core and with an amalgam restoration with auxiliary retention on a non-endodontically treated molar.

From extracted sound human lower molars which were endodontically opened, 12 specimens were selected using the following criteria: normal anatomical structures (two mesial root canals and one distal); closed apices; comparable root length and uniform shape; and the floor of the pulp chamber situated 2 mm apical to the cementoenamel junction.

The teeth were stored in 100% humidity except for those periods required to complete the experimental procedures. The molars were embedded individually in a cylinder with cold-curing acrylic resin to a level 2 mm apical to the cementoenamel junction. The occlusal surfaces were reduced perpendicular to the long axis of the cylinder so as to provide a flat tooth surface 2 mm coronal to the cementoenamel junction. Then these 12 teeth were divided at random into three experimental groups, so that each group consisted of four molars. The experimental groups and control group were (Fig. 1) as follows.

A: The Cast Dowel and Core

The distal canal was prepared to a depth of 7 mm from the bottom of the pulp chamber with hand reamers to fit a Permador dowel #2042 (Degussa, Federal Republic of Germany). Gross undercuts in the pulp chamber were eliminated with a diamond stone. Small undercuts and the entrances of the mesial canals were filled with zinc phosphate cement. After separating the tooth surfaces with Vaseline and placing the dowel into the canal, a dowel and core was made by using burnout acrylic resin (Palavit G; Kulzer, Federal Republic of Germany). After curing, the core was prepared to a height 4 mm above the cementoenamel junction perpendicular to the long axis of the cylinder. Also, a buccol-occlusal bevel was prepared necessary for applying the force to the specimens (Fig. 1, *a*). After this the resin core with a Permador dowel was cast in silver alloy following standardized procedures. It was cemented with zinc phosphate cement.

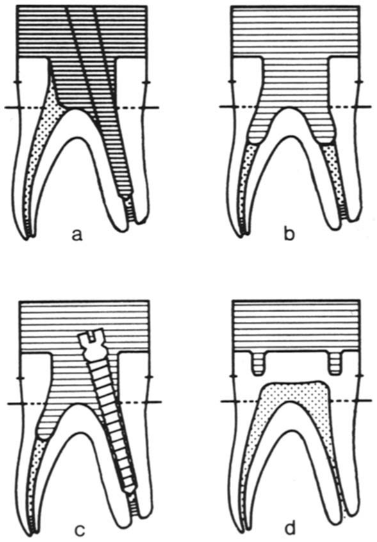

FIG 1. Schematic representation of the restoration designs (*a* to *d*) as seen from the buccal surface. *a*, cast dowel and core; *b*, all-amalgam core; *c*, cemented dowel with amalgam core; *d*, amalgam core with four amalgam pins. The oblique force was applied from the buccal side under 45 degrees to the long axis.

B: The All Amalgam Core

The distal and mesial root canals were prepared with a round bur to a depth of 3 mm apical to the floor of the pulp chamber.

The amalgam core restorations were made using a matrix band in a Tofflemire retainer. An additional piece of matrix, wooden wedges, and Stent's impression compound were used to close the gap between the matrix flanges. The alloy used was Cavex non-gamma 2 (Keur en Sneltjes, The Netherlands). A mechanical vibrator (Bergendahl, Kavo, Federal Republic of Germany) was used to pack the amalgam into the pulp chamber and root canal entrances. The amalgam restoration was made to a height approximately 5 mm above the cementoenamel junction. The matrix was removed at least 30 min after final condensation. The samples were aged at an ambient temperature for 1 wk. Then the specimens were trimmed perpendicular to the long axis of the cylinder. After trimming, the amalgam extended 4 mm above the cementoenamel junction. A diamond stone was used to remove overhanging margins of the amalgam and to prepare the bucco-occlusal bevel in the amalgam necessary for applying the force to the specimens (Fig. 1, *b*).

C: The Dowel Plus Amalgam Core

This amalgam core with a prefabricated dowel was prepared as follows. The distal root canal was enlarged with the corresponding burs of the Unimetric (Maillefer, Switzerland) set to a depth of 7 mm apical to the floor of the pulp chamber. The two mesial canals were prepared by round burs to a depth of 3 mm. After fitting the titanium dowel into the canal in some instances, the endodontic access had to be enlarged to create adequate space for amalgam around the dowel. After this, the dowel was cemented with zinc phosphate cement. The excess of cement was removed. Next the amalgam core restorations were completed as described in group B (Fig. 1, *c*).

D: Control

The control group D was introduced in order to check whether the experimental methods, which were also used in comparable previous research, were independent of the factor time. In this way the results of the three restorative methods could be compared with previous research data (27). The control group consisted of four randomly selected nonendodontically treated molars. The occlusal surfaces were reduced to a level 2 mm above the cementoenamel junction. To create auxiliary retention for the amalgam restoration, four 2-mm deep amalgam pinholes were made in the corners of the reduced occlusal surface with a round-nosed bur as described by Shavell (28). The amalgam restorations were made according to the procedure as described in group B (Fig. 1, *d*).

All preparations were done by the same operator. All test specimens were placed in a mounting jig and loaded in an Instron (Instron Corp.) mechanical testing device. During the tests the crosshead speed was 0.5 mm per min. Crosshead displacement and load were recorded continuously. Each specimen was subjected to a slowly increasing force from the buccal side at 45° to their long axis. This angle was used to simulate the combination of forces on natural teeth as opposed to only compressive or shear forces. A round metal bar (3 mm in diameter) was used to apply the oblique force to the specimens. The resistance level was defined as the point at which a specimen could no longer withstand increasing load. So the first dip in linearity was taken as point of failure. This first dip in linearity is defined as the point at which a decrease in force level can be recorded (early sign of failure). This does not necessarily mean that the specimen already has reached its maximum resistance level. After this first dip the load was increased until visible failure occurred. After this breakdown all fractured specimens were classified as restorable or not re-restorable. This was judged on the basis of whether a fracture extended more than 2 mm below the cementoenamel junction. The data were analyzed with the analysis of variance test.

RESULTS

The results of the different restorative methods are shown in Fig. 2. The resistance level is given for ech specimen. The mean resistance level and the standard deviation in Newtons were as follows: group A, >2,000 N; group B, 1,180 ± 240; group C, 1,320 ± 100; and group D, 1,180 ± 160. Application of loads above the 2,000 N level resulted in some instances in failure of the investment holding the teeth or in displacement of the entire specimen in the experimental setting. However, this only occurred with the cast dowel and core restorations (A). It was not considered important to investigate the maximal loads a cast dowel and core construction could withstand above this level. It may be concluded that all specimens of this type can easily withstand 2,000 N and are stronger than all other tested restorative methods. For the other restorative methods no significant differences could be detected among them.

In Table 2 the results of an analysis of variance are shown. It can be stated that intracoronal reinforcement with a dowel (C) did not significantly increase the in vitro resistance level of amalgam cores. Also, the resistance level of the control group (D) was not significantly different from the two amalgam core build ups (B and C). There was not a very wide range in resistance levels within each group. Also the specimens within each group tended to fracture in a similar fashion. Due to the direction of the force application from the buccal side, the lingual sides of the specimens usually fractured.

DISCUSSION

Reconstruction of endodontically treated teeth with amalgam is mainly restricted to the molars because of

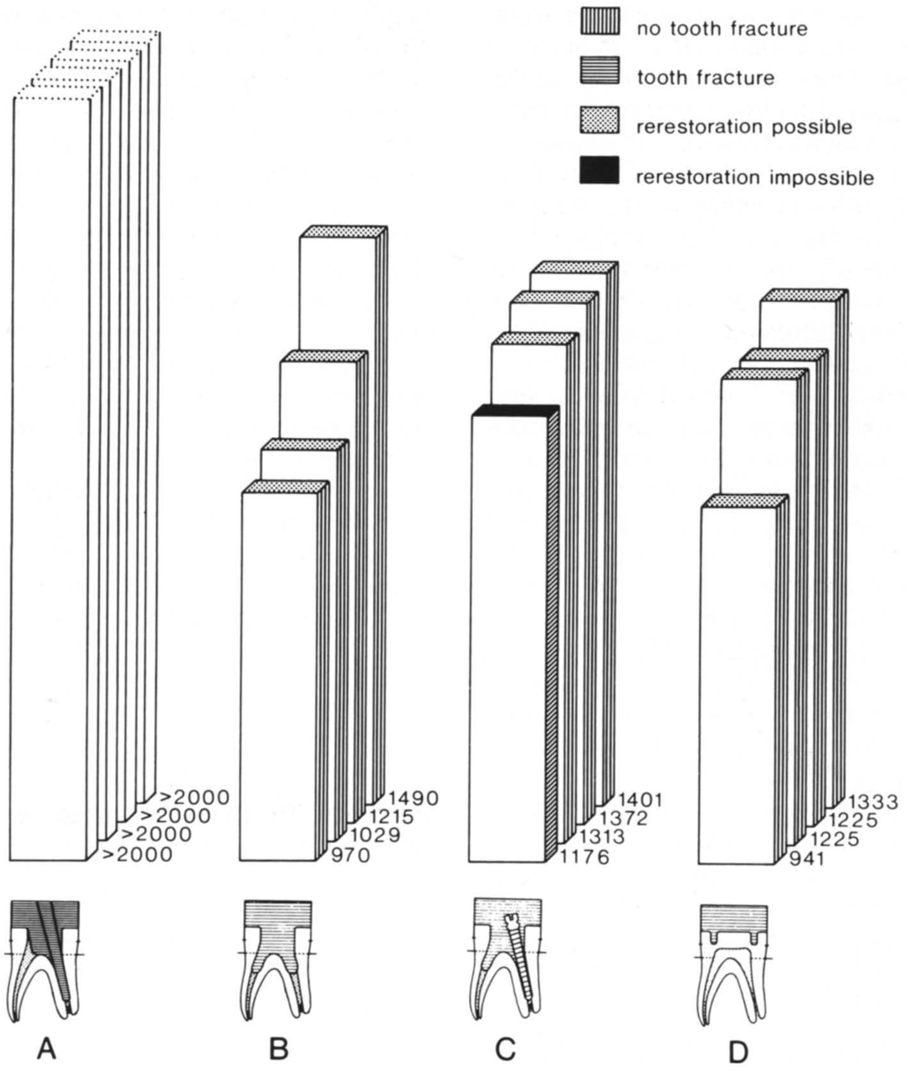

FIG 2. Distribution of the resistance levels of the four restoration types. For each specimen of groups B, C, and D, the recorded failure resistance (in Newtons) and the failure character are given. For the specimens of group A, the failure level and mode could not be recorded (maximum load, 2,000 N).

TABLE 2. The levels of significance* (p) of the contrast among the methods B, C, and D

	D†	C	B
B	0.969	0.291	
C	0.308		
D			

* Significance = 0.05.

† D, amalgam core with four amalgam pins; C, cemented dowel with amalgam core; B, all-amalgam core.

esthetic reasons. In discussing the requirements of restorations for pulpless teeth, one should distinguish between single-rooted teeth such as incisors, cuspids and premolars, and multirooted molar teeth which often have diverging and irregular-shaped canals. Besides, anterior teeth are subjected to greater lateral forces resulting from the normal overbite-overjet relationship, whereas in the posterior area the occlusal force is more vertically oriented. So both the requirements as well as the restorative possibilities for single-rooted teeth and anterior teeth are different than for molars. In our study only lower molars were used. A limitation of this study was that only resistance to forces as represented by an oblique force were studied. The resistance to tensile forces (=retention) was not investigated.

The number of samples tested for each restorative method was small and the standard deviation of the experiments seems to be relatively high. However, it can be computed that only a very small percentage of the samles will have resistance levels in the range of the maximum reported bite forces. For this reason, the results must be regarded as indicative but not as absolute conclusions.

It is generally admitted that in vitro experiments cannot conceivably copy every important detail of an in vivo situation. Difficulties also exist in the registration of the extent, shape, direction, and point of application of forces in the in vivo situation. Further limitations of this in vitro research are that the acrylic resin block holding the specimens does not simulate the clinical situation. A continuous single force was also applied to the teeth at 45 degrees to the long axis. This does not imitate the dynamic forces of mastication. An occasional blow or unexpected occlusion with a hard object could generate forces which were not investigated in this study.

The forces that all of the experimental groups could withstand in this study are well above the maximum reported biting forces (29). Oblique forces can be regarded as a vector of these axial forces; therefore, it may be expected that all tested restoration designs are strong enough to function in the oral environment as far as bite and chewing forces are concerned.

The results of the experiments imply that with regard to resistance to oblique forces, the introduction of auxiliary retention by means of pinholes in the dentin wall surrounding the pulp chamber (group D) would also be an adequate restorative method for pulpless molar teeth. However, this implies the additional elimination of sound dentin where a large pulp chamber of an endodontically treated molar could offer at least the same amount of resistance. So application of amalgam pinholes is not recommended for pulpless molar teeth.

The results for the control group D are in accordance with earlier research to the resistance level of restorations with auxiliary retention, so the experimental method seems to be time independent (27).

The relatively less damaging failure characteristics of the amalgam cores to the remaining tooth structure might be preferable to a cemented casting where probable root fracture will occur when the restoration fails. Direct comparison of our findings with other in vitro studies of dowel and core foundations for endodontically treated teeth is difficult because of the reasons mentioned in the beginning of this article (Table 1).

Michelich et al. (23) studied pin-retained amalgam cores and all-amalgam cores in molars under an oblique force. No statistical difference was observed between these two techniques. Hoag and Dwyer (24) found high values for the cast dowel and core and values comparable to Michelich et al. (23) for the all-amalgam cores. These higher values for the all-amalgam core in comparison with our study may be attributable to a deeper and wider preparation of the root canals. Gelfand et al. (25) tested six different post and core systems for posterior teeth with and without complete veneer crowns. As a result of the testing under a load at 45 degrees, the tested systems exhibited varying strengths. However, with complete crown coverage there was no difference in the strengths of the different systems. In their research however, the authors failed to provide the values at which failure occurred, so it is difficult to compare these results to our own research.

In a study by Kern et al. (19), the resistance to shear compressive loading of an all-amalgam core for molars was compared with that of a commercially available post and core system. The load was applied at 60 degrees to the long axis. Their results indicate that cemented dowels and an amalgam core have greater strength (mean 1187 ± 493 N) than a system in which only amalgam was used to create a dowel and core (mean 798 ± 212 N). The addition of crowns to these systems did not produce a significant increase in strength. In a pilot study by these authors the load was applied at 45 degrees. In that situation, forces of 2,000 N or more were required to initiate fractures and these loads frequently resulted in failure of the laboratory setting as occurred in our study. Kern et al. (19) changed the loading angle to 60 degrees. It is evident that when the loading angle is changed and shear forces become more dominant lower resistance levels will be recorded.

Clinical studies of the success rates of various amalgam restorative techniques for posterior teeth have shown encouraging results for the amalgam cores. During 4 yr of observation, Nayyar et al. (14) found that for 400 posterior teeth treated with an all-amalgam core and a cast crown no evidence of failure occurred in relation to the amalgam technique. Sorensen and Martinoff (12) found that intracoronal reinforcement did not influence the clinical success rate of teeth with coronal coverage. In single-rooted teeth with coronal coverage, the presence of intracoronal reinforcement surprisingly decreases the success rate. Coronal coverage of endodontically treated posterior teeth, however, significantly improved the clinical success rate (5). Coronal coverage of endodontically treated posterior teeth to resist vertical fractures is also considered to be essential by other authors (2, 11, 13, 18).

CONCLUSIONS

This in vitro study supports the approach of not removing too much remaining tooth structure to adapt the tooth for a cast dowel and core. Preservation of sound dentin and adapting the amalgam core to the teeth leaves more tooth structure and makes easy rebuilding possible with a restoration which is strong enough to resist forces of about 1,000 N. The present study indicates that all-amalgam cores and amalgam dowel cores are acceptable alternatives in comparison with the cast metal dowel and core foundation for the restoration of endodontically treated molars. In cases where the requirements for the restoration are greater than normal, such as in bruxism or in case the molar has to function as an abutment, one should be mindful of the proven qualities of cast dowels and cores.

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