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Stiffness, elastic limit, and strength of newer types of endodontic posts

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Abstract

Objectives: To determine the stiffness, elastic limit, and strength of a selection of endodontic posts recently introduced onto the market.

Methods: Endodontic posts of zirconia (Biopost, Cerapost), titanium (PCR), and carbon fiber (Composipost) were cemented in a brass block and loaded at an angle of 45° in an Instron Testing Machine. From the recorded relationships between force and deflection the three mechanical properties were determined ($n = 10$ in each group).

Results: The ceramic posts were very stiff and strong, with no plastic behavior. The PCR post was as strong as, but less stiff than, the ceramic posts. Composipost had the lowest values for stiffness, elastic limit, and strength of the posts investigated.

Conclusion: The posts under investigation differed significantly with respect to mechanical properties.

Keywords: Root canal posts; Root fracture; Carbon posts; Ceramic posts; Titanium posts; Mechanical properties

1. Introduction

In many cases, endodontically treated teeth are provided with restorations involving endodontic posts. The endodontic post may be individually cast together with the core, or the post may be prefabricated, in which case amalgam, resin composite, or glass ionomer cement is used as core material [1,2]. In either case, the post and core build-up is an integral part of the restoration and must meet a number of requirements. The ideal post provides retention to the core, supports the core in such a manner that the cemented crown does not lose its attachment, and transfers forces in a strategic fashion to the tooth in order not to cause undue susceptibility to root fracture.

Restorations involving endodontic posts have been investigated in quite a few clinical studies in which the causes of failure have been recorded [3–8]. From these studies it appears that the main causes of failure were identified as: caries, loss of retention of the post, loss of retention of the crown, root fracture, post distortion and post fracture. Although several factors are involved, some of these failures are related to the mechanical properties of the posts. Obviously, this is the case with distortion and fracture of the post, where a relatively high elastic limit and strength will reduce the risk. Loss of retention of a crown is undoubtedly related to the quality of the support of the crown, which again reflects the stiffness of the post. Concerning root fracture, there is consensus that a post that is too short or too long places the tooth at risk [2,8,9]. Increasing the thickness of the post will make it stronger, but less tooth structure remains, and the combined effect may well be a reduction of the strength of the assembly [2,8]. The situation is less obvious when the stiffness of the post is considered. The goal is to reduce the stresses in the root dentin to a minimum, but some researchers support the view that a post of high stiffness leads to a more even distribution of the stresses [2], while others maintain that an endodontic post of low stiffness should be preferred [10–12].

However this may be, the mechanical properties of endodontic posts and post and core restorations have been studied extensively in the past [10–18]. Previously, posts were cast in a precious alloy, or prefabricated posts made of stainless steel, titanium, or precious alloy were used. Recently, several new types of post material have been introduced to the dental community: These are zirconia, titanium specially treated to give adherence to a composite core, or resin reinforced with carbon fibers. These posts are intended to be adhesively cemented into the root canal. The literature is sparse with information on the mechanical properties of these new types of endodontic posts. It was the aim of the present study to measure stiffness, elastic limit, and

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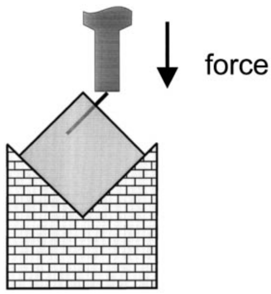

Fig. 1. Schematic illustration of the experimental design. The brass block, provided with prefabricated canals, carries the endodontic post, which in turn is loaded in the testing machine. The brass block is supported by the V-shaped rest (hatched).

strength of a selection of endodontic posts recently introduced to the market.

2. Materials and methods

Four types of posts were investigated. Two were made of zirconia (Biopost, Incermed, Lausanne, Switzerland: diameter 1.6 mm; and Cerapost, Brasseler, Lemgo, Germany: diameter 1.6 mm). One post was made of titanium (PCR, Brasseler, Lemgo, Germany: diameter 1.6–2.0) and had a specially treated head for adherence to the resin composite to be used as core material. The last type of post was based on carbon fibers (Composipost, RTD, Meylan, France: diameters 1.4 and 1.8 mm).

Table 1
Stiffness (*N*/0.05 mm), elastic limit (*N*) and strength (*N*) of the investigated endodontic posts. The free length of the posts was 4.8 mm. Means and standard deviations

Post	Diameter (mm)	Stiffness	Elastic limit	Strength
Biopost	1.6	136 ± 19	237 ± 16	237 ± 16
Cerapost	1.6	137 ± 15	228 ± 27	228 ± 27
PCR	1.6–2.0	64 ± 10	189 ± 18	229 ± 21
Composipost	1.8	38 ± 5	140 ± 17	179 ± 10
Composipost	1.4	22 ± 2	80 ± 12	107 ± 13

A number of artificial root canals were drilled in a brass block (3 × 3 × 8 cm), the canals having diameters corresponding to those of the posts. The depth of the individual canals was adjusted in such a manner that the posts protruded 4.8 mm from the canal. The posts were then cemented into the holes with Panavia 21 (Kuraray, Osaka, Japan) as luting agent. After hardening of the luting agent for 24 h at 37°C, the assembly was placed in an Instron Universal Testing Machine (Fig. 1) and loaded at a cross head speed of 5 mm/min to produce a force–deflection curve (Fig. 2). The stiffness of the post, the elastic limit, and strength were read from the force–deflection curve. Referring to Fig. 2, the stiffness was defined as the force necessary to deflect the post 0.05 mm, the elastic limit was taken as the force at which the force–deflection curve began to deviate from a straight line, and the strength of the post as the force characterized by the maximum of the curve.

Ten specimens of each post were investigated. The means

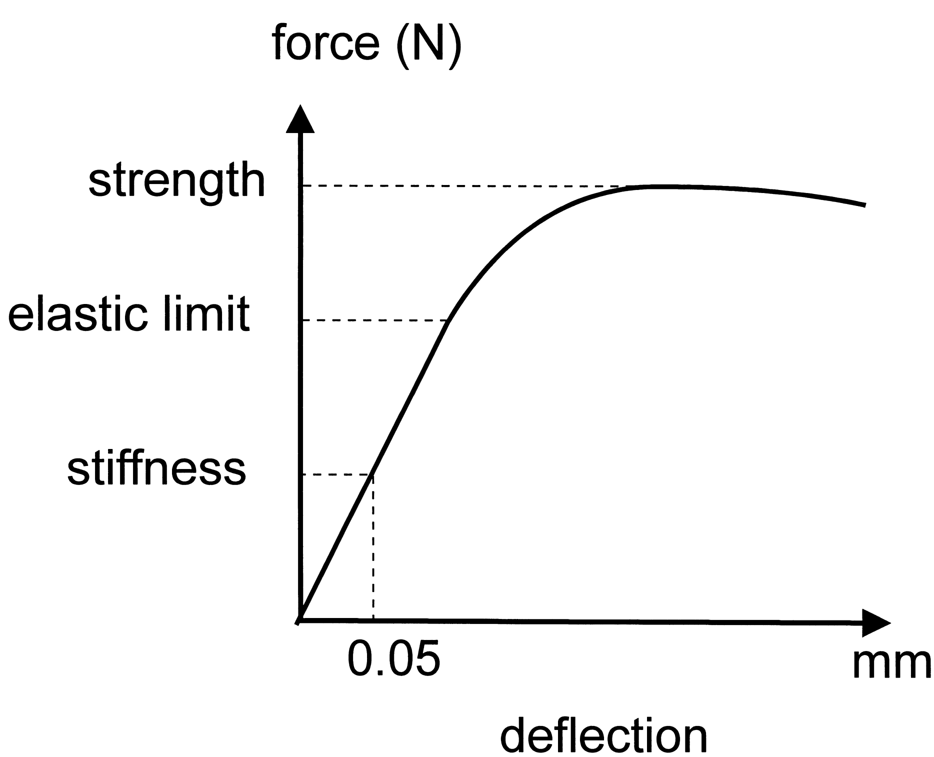

Fig. 2. Relationship between force and deflection, from which the stiffness, elastic limit and strength of the post were determined.

Table 2
Stiffness (*N*/0.05 mm), elastic limit (*N*) and strength (*N*) of a selection of earlier investigated endodontic posts [17]. The values are recalculated to a free post length of 4.8 mm. Means and standard deviations

Post	Diameter (mm)	Stiffness	Elastic limit	Strength
Unimetric 215T	1.4	33	144	201
Parapost	1.5	20	79	147
Maillefer RS	1.5	36	77	212
Boston	1.6	23	63	122
Flexipost	1.7	31	116	218

and the standard deviations were calculated, and the data were analyzed by means of analysis of variance and the *t*-test at a level of significance of $P = 0.05$.

3. Results

The results are presented in Table 1. The statistical analysis showed that there was no difference in mechanical properties between Biopost and Cerapost. The PCR post was less stiff and had a lower elastic limit than Biopost and Cerapost, but was of the same strength. The Composiposts had values for all three mechanical properties that were lower than those of the other three posts. The value of the elastic limit was identical to the strength for Biopost as well as for Cerapost. This indicates that these posts are brittle and have no ductility. On the contrary, the PCR post and the Composiposts had elastic limits that were lower than the strength value, indicating a certain amount of plastic behavior.

4. Discussion

The results show that considerable differences exist with respect to mechanical properties between the investigated, newer types of endodontic posts. In particular, the ceramic posts Biopost and Cerapost were very stiff and strong. These posts are manufactured from the ceramic material zirconia, and the elevated values of mechanical properties found are in agreement with earlier measurements on such materials [19–21].

The stiffness of the Composiposts was less than that of the PCR post. The PCR post is manufactured from titanium, whereas the Composiposts are based on carbon fibres embedded in a matrix of epoxy resin. A direct comparison between the Composiposts and the PCR post may be misleading, however, because the diameter of the PCR post extending from the brass test block was not constant, but increased from 1.6 to 2.0 mm. A better comparison may be made if data from the literature on older types of titanium posts are used. A nearly identical method was used by Lambjerg-Hansen and Asmussen [17], and their results, in an adapted version, lend themselves to a comparison. The difference between that study and the present one is that in the former the free length of the loaded post was 7.0 mm, and not 4.8 mm as in the present study. However, simple formulas [22] for stress S and deflection y in the two-point loading test enable a conversion to data for 4.8 mm, so that a comparison can be made. The formulas employed are:

$$S = \frac{32}{\pi} \frac{F \cdot l}{d^3}$$

and

$$y = \frac{64}{3\pi} \frac{F \cdot l^3}{E \cdot d^4},$$

where F is the force, l is the length, and d is the diameter of the post. Table 2 gives an adapted and abbreviated version of the data of Lambjerg-Hansen and Asmussen that can be compared with the data of the present study. The comparison shows that the Composipost is in fact quite stiff and strong, to a degree comparable to several posts made of metal. This finding is in agreement with other studies on the stiffness of the Composipost [10,18]. In the first of these, water immersion was found to reduce the strength and stiffness to about 70% and 60% of the dry values. Even so, the stiffness is considerably higher than that claimed by the manufacturer, whose brochures indicate a modulus of elasticity close to that of dentin.

Obviously, a post of high elastic limit and high strength is desirable, as the risk of distortion and fracture, other things being equal, is reduced. As regards the stiffness of the post, the situation is much less obvious. As mentioned in the introduction, two opposite views have been expressed in this regard, and both cannot be true. In a recent study, the fracture resistance of teeth restored with full crowns, composite core and either Parapost or Composipost, was investigated [11]. It was found that the teeth restored with Composipost had significantly higher resistance to fracture under repeated loading than the teeth restored with Parapost. This can be construed as evidence that the less stiff Composipost provides a more uniform distribution of the stresses in the tooth, and thus less risk of root fracture. However, a closer look at the experimental conditions reveals that the posts differed in diameter. The diameter of the Composipost was 1.8 mm, whereas that of the Parapost was 1.5 mm. A look at the data in Tables 1 and 2 will show that the 1.8 mm Composipost is, in fact, stiffer than the 1.5 mm Parapost. This means that the results could be used to argue in favor of a high stiffness of the post. As discussed by the authors, another factor may have played a role for the results obtained, namely the bonding of the Composiposts to the walls of the root canal. The transfer of forces from the post to the tooth undoubtedly depends on whether the post is bonded or not. It has been shown that a bonded post will increase the strength of the restored tooth [23]. In a study using finite element analysis it was calculated that a gold post gave rise to the development of smaller stresses in the root than did a steel post [24]. As gold has less than half the modulus of elasticity of steel, the view that a post of low stiffness leads to a more even distribution of the stresses is not supported.

It follows that the question as to whether a high or low stiffness of the endodontic post is advantageous from the viewpoint of stress distribution is still moot and cannot be answered without further research. However, there are still other factors related to the mechanical properties of endodontic posts that should be considered when choosing a post. A number of in vitro studies indicate that the fracture type is more benign when Composipost is used than when metal posts are used: with the Composipost a relatively high proportion of the tooth fractures occurred above the (simulated) bone level [11,12,16,25]. Further, because of the hardness of the ceramic posts, it may be very difficult to remove a cemented post from a failed restoration.

References

[1] Manning KE, Yu DC, Yu HC, Kwan EW. Factors to consider for predictable post and core build-ups of endodontically treated teeth. Part I: Basic theoretical concepts. Journal of the Canadian Dental Association 1995;61:685–695.
[2] Manning KE, Yu DC, Yu HC, Kwan EW. Factors to consider for predictable post and core build-ups of endodontically treated teeth. Part II: Clinical application of basic concepts. Journal of the Canadian Dental Association 1995;61:696–707.
[3] Sorensen JA, Martinoff JT. Clinically significant factors in dowel design. Journal of Prosthetic Dentistry 1984;52:28–35.
[4] Lewis R, Smith BGN. A clinical survey of failed post retained crowns. British Dental Journal 1988;165:95–97.
[5] Hatzikyriakos AH, Reisis GI, Tsingos N. A 3-year postoperative clinical evaluation of posts and cores beneath existing crowns. Journal of Prosthetic Dentistry 1992;67:454–458.
[6] Mentink AGB, Meeuwissen R, Käyser AF. Survival rate and failure characteristics of the all metal post and core restoration. Journal of Oral Rehabilitation 1993;20:455–461.
[7] Torbjörner A, Karlsson S, Ödman PA. Survival rate and failure characteristics for two post designs. Journal of Prosthetic Dentistry 1995;73:439–444.
[8] Morgano SM, Milot P. Clinical success of cast metal posts and cores. Journal of Prosthetic Dentistry 1993;69:11–16.
[9] Holmes DC, Diaz-Arnold AM, Leary JM. Influence of post dimensions on stress distribution in dentin. Journal of Prosthetic Dentistry 1996;75:140–147.
[10] Torbjörner A, Karlsson S, Syverud M, Hensten-Pettersen A. Carbon fiber reinforced root canal posts, Mechanical and cytotoxic properties. European Journal of Oral Sciences 1996;104:605–611.
[11] Isidor F, Ödman P, Brøndum K. Intermittent loading of teeth restored using prefabricated carbon fiber posts. International Journal of Prosthodontics 1996;9:131–136.
[12] Sidoli GE, King PA, Setchell DJ. An in vitro evaluation of a carbon fiber-based post and core system. Journal of Prosthetic Dentistry 1997;78:5–9.
[13] Eshelman EG Jr, Sayegh FS. Dowel materials and root fracture. Journal of Prosthetic Dentistry 1983;50:342–344.
[14] Greenfeld RS, Roydhouse RH, Marshall FJ, Schoner B. A comparison of two post systems under applied compressive-shear loads. Journal of Prosthetic Dentistry 1989;61:17–24.
[15] Peutzfeldt A, Asmussen E. Flexural and fatigue strengths of root canal posts. Scandinavian Journal of Dental Research 1990;98:550–557.
[16] Isodor F, Brøndum K. Intermittent loading of teeth with tapered, individual cast or prefabricated parallel-sided posts. International Journal of Prosthodontics 1992;5:257–261.
[17] Lambjerg-Hansen H, Asmussen E. Mechanical properties of endodontic post. Journal of Oral Rehabilitation 1997;24:882–887.
[18] Purton DG, Payne JA. Tenons radiculaires: fibre de carbone ou acier inoxydable? Clinic 1996;17:275–279.
[19] Taira M, Nomura Y, Wakasa K, Yamaki M, Matsui A. Studies on fracture toughness of dental ceramics. Journal of Oral Rehabilitation 1990;17:551–563.
[20] Li J, Hermansson H, Söremark R. High-strength biofunctional zirconia: mechanical properties and static fatigue behaviour of zirconia–apatite composites. Journal of Material Science: Materials in Medicine 1993;4:50–54.
[21] Cales B, Stefani Y, Lilley E. Long term in vivo and in vitro aging of a zirconia ceramic used in orthopaedy. Journal of Biomedical Material Research 1994;28:619–624.
[22] Schwickerath H. Werkstoffe in der Zahnheilkunde. Berlin: Buch und Zeitschriften-Verlag ''Die Quintessenz'', 1977:23–25.
[23] Mendoza DB, Eakle WS, Kahl EA, Ho R. Root reinforcement with a resin-bonded preformed post. Journal of Prosthetic Dentistry 1997;78:10–15.
[24] Ko C-C, Chu C-S, Chung K-H, Lee M-C. Effects of posts on dentin stress distribution in pulpless teeth. Journal of Prosthetic Dentistry 1992;68:421–427.
[25] King PA, Setchell DJ. An in vitro evaluation of a prototype CFRC prefabricated post developed for the restoration of pulpless teeth. Journal of Oral Rehabilitation 1990;17:599–609.