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Vertical Root Fracture and Root Distortion: Effect of Spreader Design

Darrell A. Dang, DDS, MS, and Richard E. Walton, DMD, MS

The incidence of vertical root fractures and the amount of root distortion created during lateral condensation of gutta-percha with either D11 spreaders or B-finger pluggers were evaluated in vitro. Fifty-five extracted human, single-rooted teeth were instrumented using the step-back flare technique. Ten teeth served as positive controls (obturation to the point of fracture) and five teeth as negative controls (prepared but not obturated). Strain gauges were attached to the root surfaces. In the experimental group, 20 teeth were obturated using a D11 spreader and 20 with a B-finger plugger. Recordings were made of root distortion (expansion) created during obturation. Then, after sectioning the teeth, root surfaces of obturated samples were examined for fractures under the scanning electron microscope. Only the more tapered spreader, the D11, produced vertical root fractures, although very few in number. Also, the D11 spreader caused greater root distortion than did the B-finger plugger.

Vertical root fractures have a poor long-term prognosis. Their effect on the periodontium is profound and usually results in rapid bone loss, swelling, and suppuration. Probing often reveals a deep localized periodontal defect (1–4). Most of these cases require extraction of the affected tooth or, in molars, removal of the fractured root.

There are several theoretical causes of vertical root fractures; however, most of these fractures occur in teeth that have been endodontically treated (5). It has been suggested that excessive forces during lateral condensation are the primary reason for the high incidence of vertical root fractures found in this group (1, 5–7). Subsequent restorative procedures have also been suggested to be contributory (1, 5, 6). Significantly, it has not been established whether fractures occur at the time of canal obturation or manifest themselves some time later.

Incomplete (secondary) fractures may be created in dentin at the time of canal obturation as has been shown by Walton et al. (8) and Lin and Langeland (9). During histological examination of root segments, these investigators identified incomplete fractures. The location of the fracture was usually the middle third of the root; the fracture would emanate in either a facial or lingual direction. These secondary fractures were described as blind cracks which originated from the canal space or from an existing fracture but did not extend to the root surface. Walton et al. (8) speculated that dentin may have sufficient elasticity to permit some separation of root segments during canal obturation without creating a through-and-through (complete) fracture.

Forces generated during lateral condensation of gutta-percha is a probable major cause of root fractures. Lommel et al. (1) and Meister et al. (5) reviewed clinical cases with diagnosed vertical root fractures. They speculated that most resulted from the use of excessive pressure at the time of obturation of the canals. As confirmation, many of the patients recalled a noise indicative of the root fracturing during obturation. It was also proposed that some fractures did not occur at the time of obturation/restoration, but became evident months or years later.

Experiments have verified that condensation of gutta-percha produces lateral stresses with the potential of creating fractures. Pitts et al. (7) demonstrated that a mean spreader load of 7.2 kg (15.8 lb) was sufficient to vertically fracture the root of a maxillary central incisor. The forces (15.8 lb mean) applied in this study with an Instron testing instrument were greater than those (5 to 7 lb mean) of an operator during clinical obturation. The mean fracture load necessary to cause the fractures were considerably greater than those clinically exerted during lateral condensation. Interestingly, in this study and a later investigation by Holcomb et al. (10), occasional fractures occurred at much lower forces.

Other experiments have also demonstrated that stresses are transmitted laterally during condensation. Harvey et al. (11) developed a photoelastic model to study strains induced by canal obturation in flared and unflared canals. Forces similar to clinical conditions, i.e. 1 to 3 kg (2.2 to 6.6 lb), were applied to the models during condensation. They were sufficient to create strains along and into the wall of the simulated canal.

The measuring of stresses and strains on tooth structure is also feasible. The use of strain gauge technology on teeth was introduced by Douglas (12) and Hood (13). Douglas (12) measured deformation of cusp tips with an occlusal load, whereas Hood (13) used strain gauges to determine fracture resistance after cavity preparation and composite restoration. Because these authors were concerned only with measurement of coronal distortions, strain gauges were confined to the crowns of teeth. As yet, root distortion has not been determined by applying a strain gauge to the surface of the root.

The strain gauge is an electrical transducer that detects and converts force or small mechanical displacements into electrical signals. Strain gauges are so named because when they undergo a strain (distortion) there is a change in electrical resistance. They have a length of special wire bonded to a plastic base. When attached to a surface, the gauge deforms in the same manner as the surface. With this deformation, the cross-section of the wire decreases, thus increasing its electrical resistance. The change in electrical resistance is monitored by a digital strain indicator. Thus, the strain gauge may be adopted to measure distortions (expansion) of root structure that could result in immediate or eventual fractures.

It is evident from the literature that little research has been done to determine the etiology of incomplete fractures. Most clinical studies are retrospective and relate a root fracture to the procedure which was previously performed on the tooth. However, there are other potential etiologies of fractures, such as the design or physical properties of a spreader, that have not been investigated. Some important questions: Are stresses caused by different types of spreaders? Are vertical root fractures created during canal obturation? Do vertical root fractures begin as small, incomplete fractures in dentin, and then grow and subsequently manifest themselves with time?

OBJECTIVES

The purpose of this study was to determine in vitro both the incidence of incomplete/complete vertical root fractures and the amount of root distortion (expansion) during lateral condensation of gutta-percha comparing two different types of spreaders.

MATERIALS AND METHODS

Materials

Sixty-seven extracted straight, single-rooted teeth were stored in deionized water with thymol. The root surfaces of the specimens were thoroughly cleansed of soft tissue and debris. All surfaces were examined by transillumination and a dissecting stereomicroscope at ×40. Twelve teeth, which had preexisting cracks or fractures, were eliminated, leaving 55 for experimental testing. To avoid dehydration and artificial crazing, the teeth were stored in a humidor (100% humidity) at 37°C throughout the experimental period. To facilitate straight line access for instrumentation and obturation, crowns were removed 3 mm coronal to the cementoenamel junction.

Each sample was prepared using the step-back flare technique and Gates Glidden burs to enlarge the coronal aspect of the canal. A #10 file was placed into the canal to determine the location of the apical foramen and instrumentation was completed to within 1 mm of its exit. Flaring was complete when both the D11 and a B-finger plugger (Star, Valley Forge, PA) could be easily inserted to within 1 mm of the prepared length. Teeth were randomly assigned to experimental and control groups and procedures done as outlined in Fig. 1.

EXPERIMENTAL GROUPS

Forty teeth were divided into two groups of 20. Teeth in the two groups to be compared were obturated with one of two spreaders of different design (Fig. 2): The D11 spreader (more tapered, less flexible) (Star) was used for obturation in group 1 and the B-finger plugger (less tapered, more flexible) in group 2.

CONTROL GROUP

Ten teeth served as positive controls and five teeth as negative controls.

SPECIMEN PREPARATION

After instrumentation, an acrylic resin collar was closely adapted to the cervical aspect of each root occlusal to the cementoenamel junction. These collars stabilized the samples

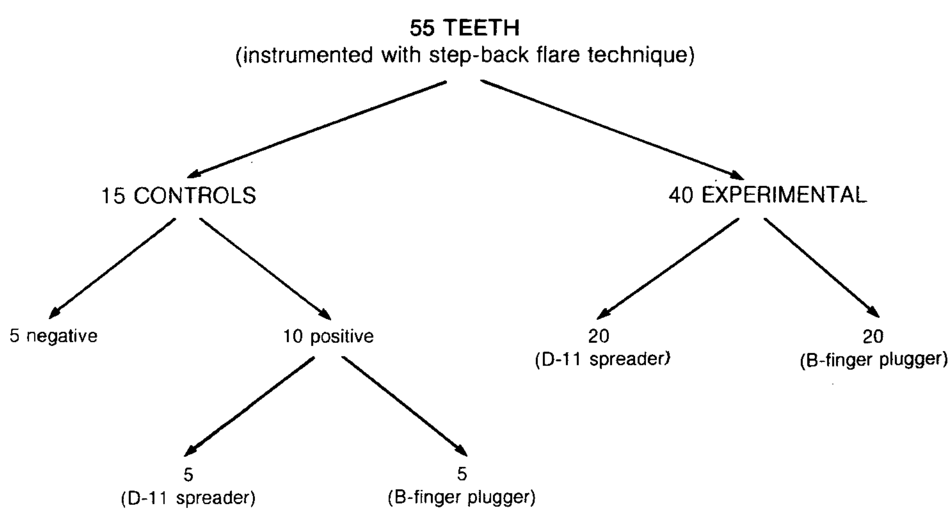

FIG 1. Designation of experimental and control groups by procedure.

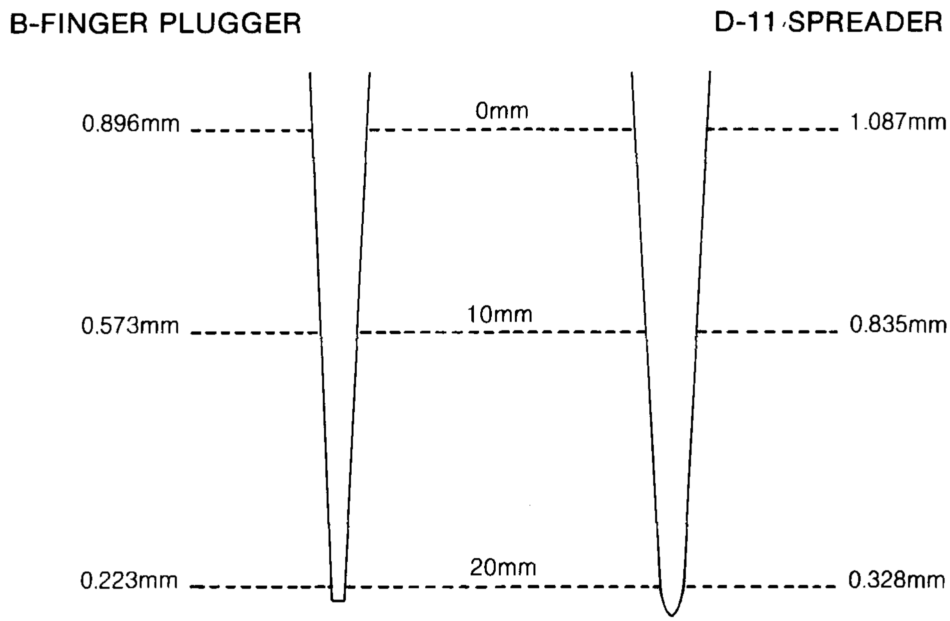

FIG 2. Basic design of spreader types. Note the difference in degrees of taper. In addition, the more tapered D11 spreader is stiffer.

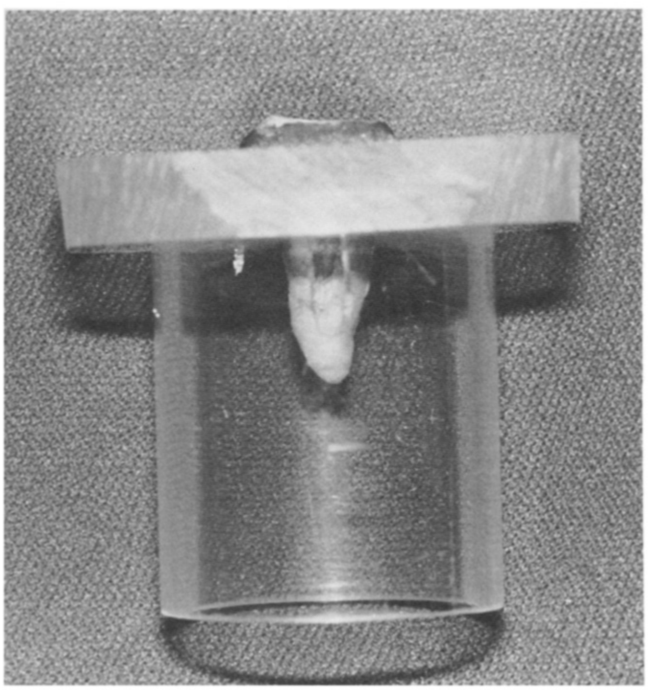

FIG 3. Plexiglas ring stand to support sample during obturation. The opening in the ring permits wire leads to pass from the strain gauge to connect with the digital strain indicator.

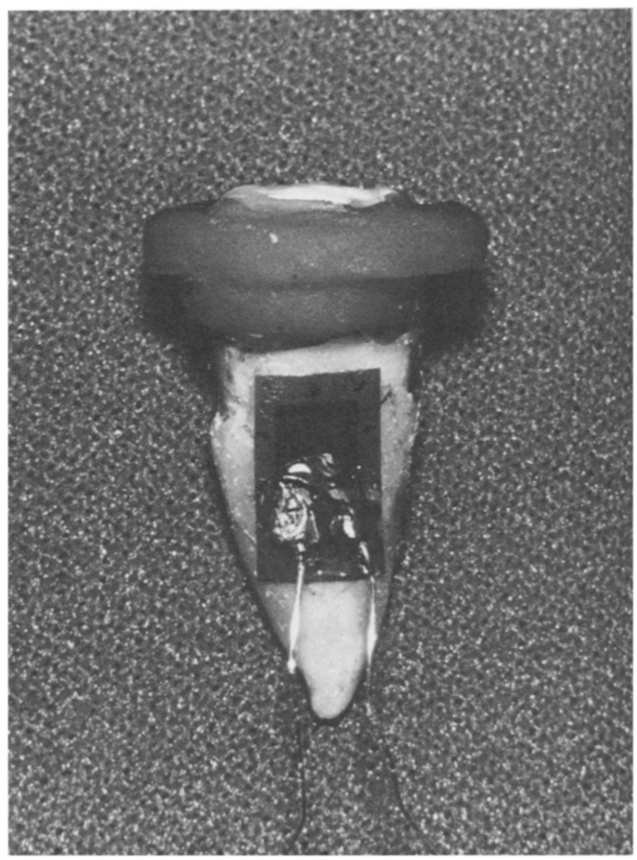

FIG 4. Acrylic resin collar adapted to cervical aspect of the sample. Strain gauge with wire leads must be closely adapted to root surface.

during obturation but were positioned away from the area to be stressed in order to not interfere with root distortion. A custom ring stand positioned and stabilized the samples during the testing procedure (Fig. 3). The sample could then be placed into a center hole with support from the acrylic resin collar leaving the root surface free from impingement. Before obturation, a strain gauge was attached to the root surface with cyanoacrylate adhesive (Fig. 4). To standardize and minimize sample differences, the gauge was carefully adapted to the root surface 7 mm below the coronal section of the root. Wire leads were soldered to the gauge and connected to a digital strain indicator and strip chart (Fig. 5).

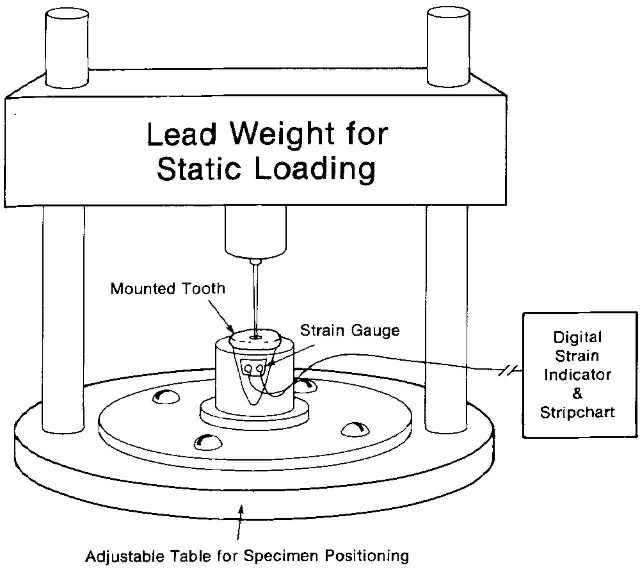

FIG 5. Obturation apparatus for testing specimens. Note the position of the spreader which is attached to the weight and is positioned over the canal.

The strain gauge detected the amount of distortion of the root surface and relayed these signals to a digital strain indicator, which recorded the information on a moving graph paper. Continuous recordings of root distortion could then be made while the canal was being obturated.

Methods

OBTURATION TECHNIQUE—EXPERIMENTAL GROUP

The D11 spreader or B-finger plugger was used to obturate samples with gutta-percha (Kerr Co., Romulus, MI) and Roth's 801 sealer (Roth Drug, Chicago, IL) using the lateral condensation technique. Master and accessory cones were both fine taper. In every sample, a uniform and consistent force was applied to the spreaders with a static weight (Fig. 5). The weight was machined from a rectangular piece of lead and weighed 3 kg (6.6 lb). The weight of 3 kg was determined by measuring and averaging the lateral condensation pressure produced by six endodontists on an individual and blind basis. In a similarly designed study (7), it was shown that 7.2 kg (15.8 lb) was sufficient to produce root fractures in teeth with single canals. The 3-kg weight used in the present study was well below this limit and corresponded to the force applied clinically.

The weight was positioned over two parallel metal rods that were mounted to a base where the ring stand was attached. The platform of the base was movable, which enabled the ring stand to be positioned so that the sample was centered relative to the spreader. The weight was freely movable in a vertical plane but was stabilized against lateral or torquing movements (Fig. 5).

The tooth was positioned so that the canal was centered under the spreader. Teeth in both experimental groups were done similarly, the only difference being the type of spreader used. The wires from the strain gauge were connected to the digital strain indicator. Roth's 801 sealer was placed into the canal and the master cone was placed. The weight with either the D11 spreader on B-finger plugger attached was lowered onto the sample; each initial penetration of the instrument was to within 1 mm of the prepared canal length. The instrument was allowed to compact the gutta-percha for 30 s before it was removed. An accessory cone was placed immediately after removal of the spreader. The instrument was then reinserted into the canal for another 30 s. This sequence of procedures was repeated until the canal was completely obturated.

OBTURATION TECHNIQUE—POSITIVE AND NEGATIVE CONTROLS

Ten positive control teeth were divided into two groups of five (Fig. 1). One group was obturated with the D11 spreader and the other with the B-finger plugger. These teeth were obturated using lateral condensation with progressively more force, applied by an Instron Testing instrument, until a root fracture was visualized in each sample.

Negative controls were unobturated, but examined for fractures following canal preparation and placement of the strain gauge.

ROOT DISTORTION MEASUREMENT

During the obturation procedure, strain gauge changes were continuously monitored. Any degree of root distortion that occurred while the gutta-percha was being laterally condensed was continuously recorded on the strip chart. This produced a stair-step curve which represented placement of the spreader into the gutta-percha (Fig. 6). The D11 spreader, a more tapered instrument, would not penetrate the gutta-percha to the extent of the B-finger plugger. Thus, fewer gutta-percha cones and fewer spreader insertions were used to obturate the canal using the D11 spreader.

The area produced by the curve was measured using a Digitizer SAC GP6-50 (Science Accessory Corp., Southgate, CT) to quantify the relative root distortion produced during condensation (Fig. 7). Means of the measurements of total distortion were determined for each experimental group, then compared using the Student *t* test.

STEREOMICROSCOPIC AND SCANNING ELECTRON MICROSCOPIC EXAMINATION

All teeth were transilluminated and viewed at ×40 with a dissecting stereomicroscope to determine the presence of fractures on the root surfaces. The location and extent of any fracture were recorded. A sample of 10 teeth from group 1 (D11 spreader) and group 2 (B-finger plugger) were serially sectioned at right angles to the long axis of the root into 1-mm sections with a diamond disc attached to a slow-speed handpiece. Then the sections were mounted on a wax bed (Fig. 8). For clear visualization, the smear layer on the sections was removed by acid etching with 37% phosphoric acid for 1 min. The cross-sectioned surfaces were then examined for fractures under the stereomicroscope (×40).

Subsequently, all sections in which fractures were suspected, as well as other random samples, were then remounted on aluminum stubs. Surfaces were sputter coated with gold-palladium for viewing under the scanning electron microscope (SEM). All fractures were examined for the presence of sealer, which would indicate that the fracture was created at the time of condensation.

Thus, samples obturated with the D11 spreader and B-finger plugger were evaluated before and after sectioning. The incidence and location of complete and incomplete fractures were recorded for both obturation groups. Statistical comparisons of the two groups were made using the Student *t* test.

RESULTS

Control Groups

There were no fractures detected in any negative control samples. Positive controls, which were intentionally fractured, showed a characteristic appearance, with splits extending from pulp space to facial and/or lingual surface (Fig. 9).

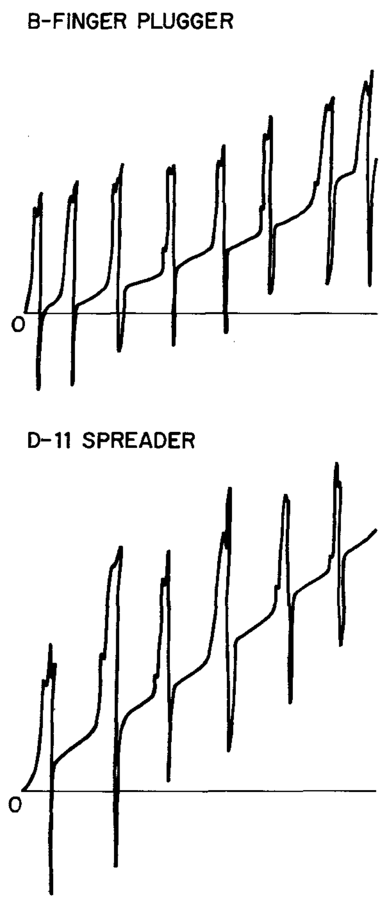

FIG 6. Stair-step curve produced by strip chart. Peaks represent the root distortion with each spreader compaction of the gutta-percha within the canal. Valleys represent the removal of the spreader with a rebound of the distorted root. Note the gradual increase in distortion (strain).

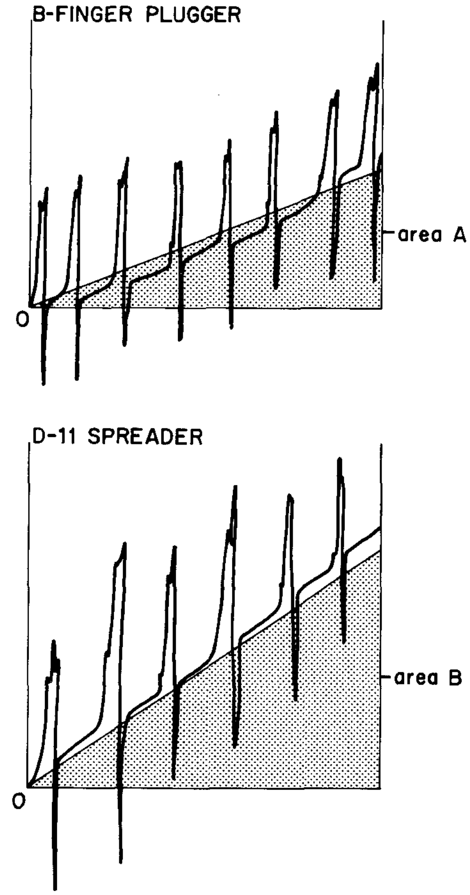

FIG 7. *Shaded area* is the mean of sample measurements of area under the stair-stepped curve. This indicates the total amount of root distortion created during obturation. The mean area created by the D11 spreader is significantly greater than that of the B-finger plugger.

Experimental Groups

INCIDENCE OF FRACTURES

As visualized with the stereomicroscope and SEM, the incidence of incomplete/complete vertical root fractures using lateral condensation occurred in only 2 of 40 (5%) samples obturated. These were incomplete vertical fractures in the samples obturated with the D11 spreader. Both were small and were located in the middle third of the root and extended in a coronal-apical direction. Examination of these sections with the SEM showed no sealer within the fracture line, indicating that the fracture did not occur before or during obturation. The fractures may have occurred during sectioning or from preparation for the SEM.

Samples obturated with the B-finger plugger did not demonstrate fractures.

ROOT DISTORTION

Obturation using the more tapered D11 spreader produced significantly greater root distortion than did the B-finger

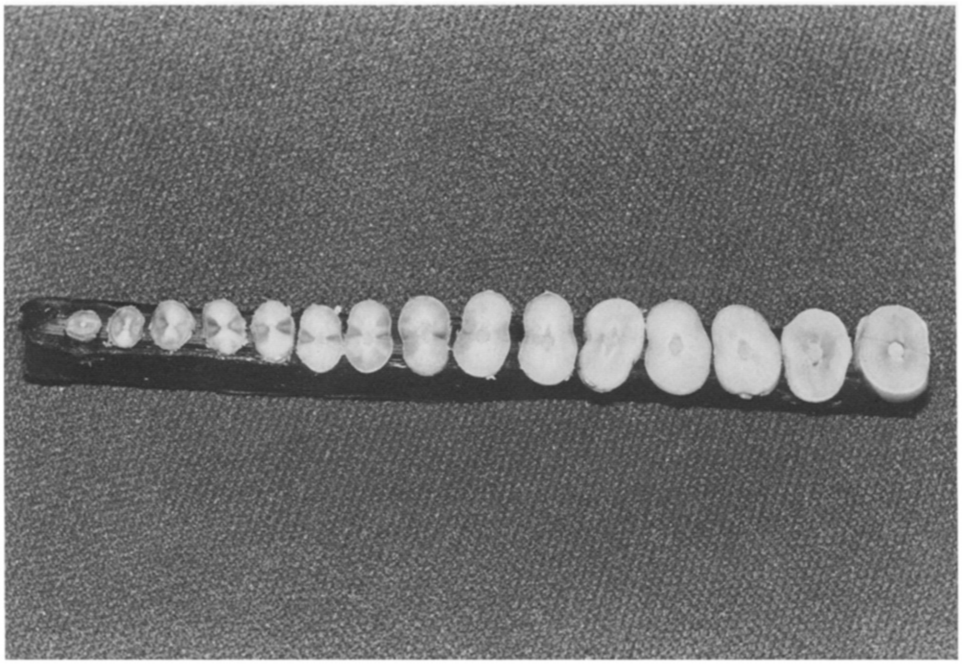

FIG 8. Serially sectioned samples after surfaces were cleansed with 30% phosphoric acid. The surface of each section was examined under both stereo and scanning electron microscopes for fractures in the dentin.

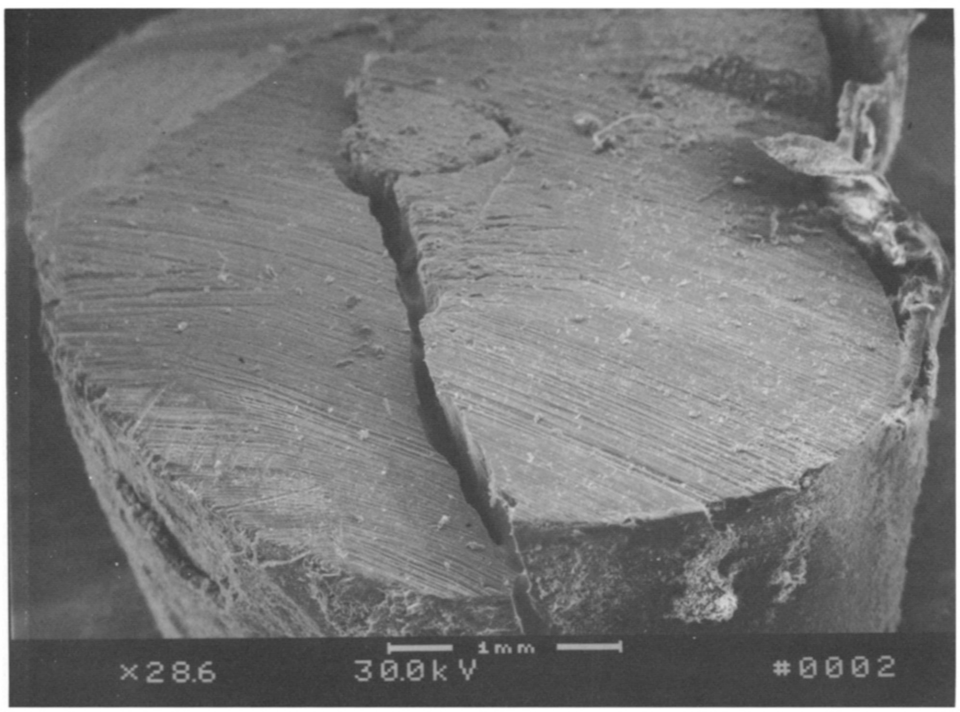

FIG 9. Positive control as viewed under the SEM. A vertical root fracture was created intentionally. It extends from the gutta-percha-filled canal to the facial surface.

plugger. The average area, as shown on the strip charts (Fig. 7), produced by the D11 spreader and the B-finger plugger is shown in Table 1. The two fractures in the D11 spreader group produced the two largest areas, 30.17 and 30.1 cm^2, indicating that these two samples had undergone the greatest amount of root distortion.

DISCUSSION

In agreement with other reports (7, 10), our study showed that stresses are applied to roots during condensation of gutta-percha with spreaders or finger pluggers. These instruments may be driven, with force, deep into the canal to attempt to

TABLE 1. Comparison of root deformation using two spreader types*

	Total No. of Teeth	Mean Deformation	SD
B-finger plugger	20	5.387	2.101
D11 spreader	20	21.070	7.647

* $t = -1.981$; $p < 0.05$.

achieve a seal closer to the apical foramen (14). The wedging forces created by an excessively tapered, inflexible spreader may be very damaging.

However, in this study, the incidence of root fracture during lateral condensation of gutta-percha was very low. This is in contrast to clinical reports, which show a significant percentage of root fractures during obturation (1, 2, 4, 7). In these reports, the only evidence which indicated that a fracture had occurred during obturation was when the operator and/or patient heard or felt a sharp "cracking" or "popping" sound. However, these cases represented only a small percentage of the total number of those with root fractures in root canal-treated teeth.

To account for the remaining cases of root fractures (those that occurred sometime after obturation), it has been proposed that dentin has sufficient elasticity to permit some root expansion without creating a total fracture (8). That this may occur was demonstrated in our study by data obtained from the strain gauge. The root surface underwent distortion without fracturing, but produced a permanent deformation. It is possible that small, "blind" fractures could be produced which would not extend to the root surface at the time of obturation. However, even these types of small, incomplete fractures were not created in our study. It is also possible that the distortions (strains) are stored in the dentin and remain quiescent for life or, with additional stresses applied through restoration or mastication, these latent fractures may manifest themselves as complete fractures months or years later.

The technology we used did not measure the actual amount of distortion (root expansion). Rather the technology demonstrates *relative* changes. Also, the use of strain gauges has limitations and is prone to errors. Accuracy in measurements is dependent upon the ability of the gauge to be fully adapted to the surface and that the area covered by the gauge is of a uniform thickness. Sample differences also would account for individual differences: roots do vary in thicknesses in relation to the canal and to the surface of the root. Due to these variations between samples, measurements from one individual sample could not be accurately compared with another; therefore, group means were compared. However, there was a statistically significant difference in distortion as measured between the two spreader types. Therefore, variations in root morphology presumably had balanced out and equalized among the samples.

Spreader design apparently played a significant role on the amount of distortion created in the dentin surrounding the canals. The D11 spreader, which is made of a harder and stiffer metal, also has a greater degree of taper than the B-finger plugger. The D11, indeed, produced the most distortion. Thus, a greater chance of creating secondary fractures probably occurs while using the D11 (or a similar type) spreader for canal obturation.

Tip configuration is another factor that may have had a role in stress production. The D11 is a true spreader (pointed tip) whereas the B-finger spreader has a blunt tip (a true plugger). The effects of these differences is unknown.

The preparation of flared canals in this study may explain why so few fractures occurred. The flaring was such that the spreader penetrated to within 1 mm of prepared length. A flared canal preparation, especially in the coronal third of the canal, must be created in order to achieve this goal. This allows the spreader to penetrate the canal without binding at the coronal aspect. It has been shown that the flared preparation, as compared with the unflared, distributes condensation forces the length of the preparation (11). Therefore, there would be less likelihood of a concentration of stresses in an isolated area.

An interesting comparison is between our study and the experiments of Holcomb et al. (10). In their study, spreader loads as small as 1.5 kg (3.3 lb) created root fractures. This force was less than the spreader loads used in our study in which only two fractures were created. It is probable that the differences between the two studies relate to the differences in tooth types. In the Holcomb et al. study (10), mandibular incisors were used; these would have less mesiodistal dimension, and therefore would be more susceptible to distortion and fracture at a lesser load.

In this study, a simulated periodontal ligament was not used because of the limitations of strain gauge utilization. However, the modifying effect of a simulated periodontal ligament on the prevalence or factors related to vertical root fractures is unknown.

CONCLUSIONS

Within the limitations of this study, it was determined that:

1. The incidence of fractures created during obturation was low regardless of the spreader type used.
2. Distortion of the root was significantly greater with the more tapered D11 spreader as compared with the less tapered B-finger plugger.
3. In step-back flared preparations, lateral condensation alone did not often create immediate fractures during obturation.
4. Distortions created during lateral condensation may be stored in the root. It is possible that those may manifest as root fractures in the future, particularly as enhanced by the addition of other stresses.

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Dr. Dang is a former endodontic graduate student, University of Iowa and is now in private practice in Los Angeles, California. Dr. Walton is chairman and professor, Department of Endodontics, College of Dentistry, University of Iowa, Iowa City, IA. Address requests for reprints to Dr. Richard Walton, Department of Endodontics, College of Dentistry, University of Iowa, Iowa City, IA 52242.

References

1. Lommel TJ, Meister F, Gerstein H, Davies EE, Tilk MA. Alveolar bone loss associated with cervical root fractures. Oral Surg 1978;45:909–19.

2. Meister F, Lommel TJ, Gerstein H, Bell WA. An additional clinical observation in two cases of vertical root fracture. Oral Surg 1981;52:91–6.

3. Ingle JI, Beveridge EE. Endodontics. 2nd ed. Philadelphia: Lea & Febiger, 1976:719–22.

4. Weine FS. Endodontic therapy. 2nd ed. St. Louis: CV Mosby, 1976;10–5.

5. Meister F, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fractures. Oral Surg 1980;49:243–53.

6. Pitts DL, Natkin E. Diagnosis and treatment of vertical root fractures. J Endodon 1983;9:338–46.

7. Pitts DL, Matheny HE, Nicholls JI. An in vitro study of spreader loads required to cause vertical root fractures during lateral condensation. J Endodon 1983;9:544–50.

8. Walton RE, Michelich RJ, Smith GN. The histopathogenesis of vertical root fractures. J Endodon 1984;10:48–56.

9. Lin LM, Langeland K. Vertical root fractures. J Endodon 1982;8:558–62.

10. Holcomb JQ, Pitts DL, Nicholls JI. Further investigation of spreader loads required to cause vertical root fracture during lateral condensation. J Endodon 1987;13:277–84.

11. Harvey TE, White JT, Leeb IJ. Lateral condensation stress in root canals. J Endodon 1981;7:151–5.

12. Douglas WH. Posterior composite resin dental restorative materials. St. Paul: 3M Co., 1985:433–41.

13. Hood JA. Posterior composite resin dental restorative materials. St. Paul: 3M Co., 1985:443–50.

14. Allison DA, Weber CR, Walton RE. The influence of the method of canal preparation on the quality of apical and coronal obturation. J Endodon 1979;5:298–304.