A Comparison between In Vivo Radiographic Working Length Determination and Measurement after Extraction

Clayton B. Williams, DDS, Anthony P. Joyce, DDS, and Steven Roberts, DDS

Abstract

The purpose of this study was to compare the difference between the in vivo working length established by viewing a periapical radiograph and the in vitro measurement from the file tip to the apical foramen of the extracted tooth. Twenty-six canals from teeth that had been treatment planned for extraction were accessed under rubber dam isolation. The coronal portion of each canal was flared using Gates Glidden drills, and a K-type file was inserted down the canal until an electronic apex locator indicated that the file had reached the apex. A size 20 K-type file was locked into place with glass ionomer cement at this position. A radiograph was exposed and the tooth was extracted. Each tooth was viewed using a videomicroscope at 30× original magnification, and the distance from the file tip to the most coronal aspect of the major foramen was measured. Six examiners viewed each radiograph and assessed the working length of each canal. χ^2 analysis of the data revealed a significant difference ($p < 0.01$) between the estimation of working lengths and the microscopic measurements. The examiners overestimated the distance between the file tip and the apical foramen of the tooth when the file was placed short, and underestimated the distance when the file was placed long. In conclusion, when the file is short it is actually closer to the apical foramen than it appears radiographically; when it is long it is actually longer than it appears radiographically. *(J Endod 2006;32: 624–627)*

Key Words

Electronic apex locator, major foramen, minor diameter, radiographic working length, working length, working length determination

From the U.S. Army Endodontic Residency Program, Fort Gordon, Georgia.

Address requests for reprint to LTC Steven Roberts, DDS, USA DENTAC, Tingay Dental Clinic, Fort Gordon, GA 30905. E-mail address: Steven.Roberts@se.amedd.army.mil.

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A primary objective of nonsurgical endodontic therapy is a thorough cleaning and shaping of the entire root canal system. The ideal apical endpoint of endodontic instrumentation and obturation has been determined to be the cementodentinal junction (1). This anatomic landmark is called the minor diameter of the canal and represents the transition between the pulpal and the periodontal tissues (2). When instrumented and obturated to the minor diameter, the contact between root canal filling material and the apical tissue is minimal. This is also the narrowest point in the canal and contains the smallest diameter of blood supply, thus creating the smallest wound site and the best condition for healing (3).

Microscopic studies estimate the distance of the minor diameter to be from 0.5 to 1.0 mm from the external foramen or major diameter (4). A working length beyond the minor diameter may result in instrumentation beyond the root apex that can lead to postoperative pain and long-term failure. A recent meta-analysis by Schaeffer et al. concluded that obturation 0 to 1 mm short of the apex was better than obturation 1 to 3 mm short of the apex; both groups were superior to obturation beyond the apex (5). Working lengths short of the minor diameter, however, may result in inadequate cleaning and underfilling of the canal. In phase II of the "Toronto Study," Farzaneh et al. concluded that adequate root-filling length had a significantly ($p < 0.05$) higher healed rate than inadequate root-filling length (6).

Although apex locators are a useful adjunct in locating the terminus of the canal during endodontic therapy, they do not replace the need for radiographs. The ability of apex locators to accurately locate the apex varies from 55 to 93% (7–12). Studies also indicate that false readings are often obtained from electronic apex locators indicating the need for radiographic check films (8, 9). Radiographic information includes canal width, degree of canal curvature, and relationship of multiple canals within the same root. An investigation by Hembrough et al. concluded that radiographs are indispensable for determining working length (13). Pagavino et al. stated that electronic apex locators are acceptable for locating the foramen and that radiographic confirmation of electronically positioned instruments is not a valid means to evaluate the accuracy of these apex locators. During treatment of teeth with an eccentric foramen, the radiographic method to locate the apex is again poorly reliable (14).

Burch and Hulen demonstrated a 0.59-mm average distance from the anatomical apex to the most coronal point of the apical foramen in 877 teeth (15). Bone and Moule found that in 85% of first molars and in 71% of second molars, the palatal canal curves toward the buccal (16). The results of a study by Kim-Park et al. suggested that because of a frequent buccal curvature in the palatal roots of maxillary molars, the ability of a clinician to accurately determine working length base solely on radiographic interpretation may be impaired. The study also suggested that this discrepancy between actual length and radiographic length will increase significantly as the degree of curvature increases (17). Factors such as these challenge the practitioner's clinical judgment in utilizing the two-dimensional radiograph in conjunction with the apex locator to determine the most ideal location to use as the end point of instrumentation and obturation.

To date no studies have compared working length established by an in vivo clinical radiograph to a microscopic examination of the apex of the subsequently extracted tooth. The purpose of this study was to compare the difference between the in vivo working length established by viewing a periapical radiograph and the in vitro measurement from the file tip to the apical foramen of the extracted tooth.

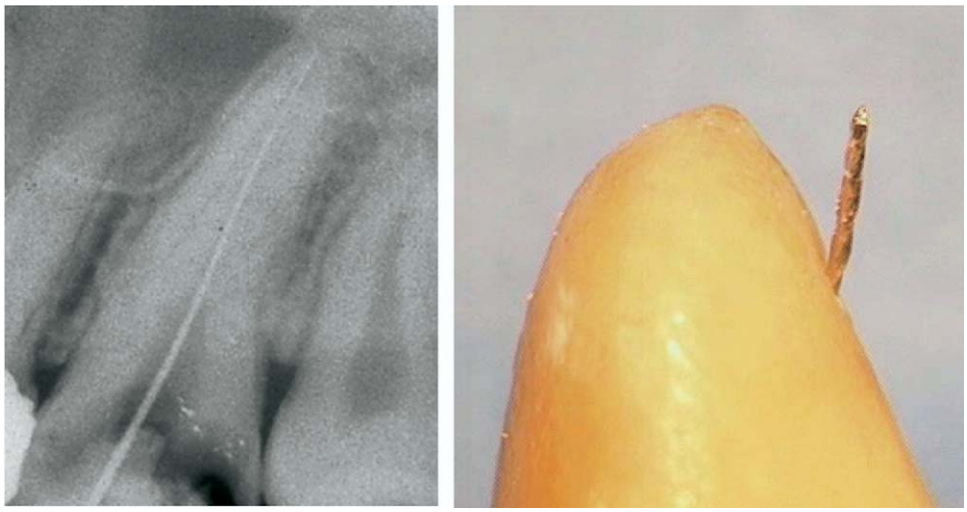

Figure 1. The photograph of the extracted tooth illustrates the file beyond the apical foramen. Examiners indicated that the file was at the correct radiographic working length. This is an example of an underestimation of the distance by which the file was long.

Materials and Methods

Eleven healthy adult patients between the ages of 18 and 45 who were scheduled to have teeth extracted for restorative or other reasons participated in this study. Informed written consent was obtained from each patient in accordance with approval by the Eisenhower Army Medical Center Institutional Review Board. Fifteen molar, premolar, and incisor teeth with completely formed apices were used in this study.

Local anesthetic was appropriately administered, and the experimental teeth were isolated with a rubber dam. The cusps were reduced using a sterile high-speed handpiece with a tapered fissured bur to create a flat reference point. Endodontic access was made, and the canals were identified. The coronal portions of the canals were flared using Gates Glidden drills sizes 2 to 4 (Dentsply Tulsa Dental, Tulsa, OK). The canals were irrigated with 5.25% sodium hypochlorite, and excess fluid was removed with paper points.

The Root ZX was used to estimate a working length. The lip clip was attached to the patient's lip, and the electrode was connected to a size 15 K-type file with a silicone stop. The file was advanced into the canal until the display indicated the apex had been reached. The silicone stop was set on the nearest flattened cusp, and the length was measured to the nearest one-half millimeter. After the length was determined for each canal, a size 20 K-type or Hedstrom file was placed into the canal at the established working length and cemented in place using GC Fuji Plus glass-ionomer cement (GC Corporation, Tokyo, Japan). The file handles were then removed using a tapered fissure bur with a high-speed handpiece. The rubber dam was removed, and a radiograph of the tooth with the files in place was exposed using an XCP Rinn Positioning Device (Dentsply Tulsa Dental).

The teeth containing the cemented files were extracted, placed in 5.25% sodium hypochlorite for 10 min to remove all organic tissue

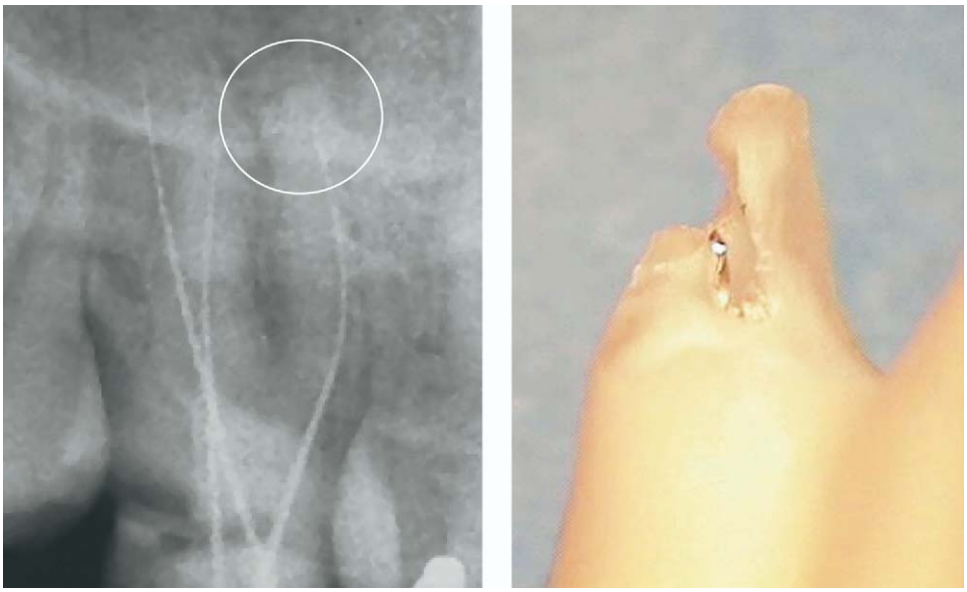

Figure 2. The photograph of the extracted tooth illustrates both the modified root as well as the file tip at the most coronal aspect of the major foramen (measuring point). Examiners indicated that the file was an average of 1.5 mm short of radiographic working length. This is an example of overestimation of the distance by which the file was short.

TABLE 1. Percentage of error in estimation of the radiographic working length

A. When the file tip in the extracted tooth was observed under magnification to be beyond the measuring point:

Percent of discrepancy by radiographic examiners ($p < 0.01$)		
Underestimated	Correct	Overestimated
61.11%	23.65%	15.27%

B. When the file tip in the extracted tooth was observed under magnification to be short of the measuring point:

Percent of discrepancy by radiographic examiners ($p < 0.01$)		
Underestimated	Correct	Overestimated
15.47%	21.43%	63.09%

C. Average amount error in estimations (mm):

	Underestimated	Overestimated
Mean	1.21	0.47
Standard Deviation	0.17	0.29

remnants, and stored in 0.2% sodium azide solution. One tooth fractured during extraction; 26 canals remained for analysis. The teeth were examined to ensure that the files had remained cemented in position and that no damage to the apex of the tooth had occurred. The teeth were viewed under a surgical microscope (Global Surgical Corporation, St Louis, MO) at 8× magnification. The most coronal aspect of the major foramen was identified and established as the measuring point. If the file tip was located beyond the measuring point, there was no need to modify the root (Fig. 1). If the file tip was short of this point, the lateral surface of the root was shaved with a carbide finishing bur to expose the file tip and leave the measuring point intact (see Fig. 2).

The distance between the file tip and the most coronal aspect of the major foramen was measured to the nearest one-thousandth of a millimeter under a noncontacting videomicrometer microscope (Opticpec, Micro Enterprises Inc., Norcross, GA) at 30× magnification. The teeth were randomly selected, and measurements from each root were taken three different times. The same investigator performed all measurements, which were recorded and averaged.

Six examiners were chosen to evaluate the "working length" radiographs. The examiners consisted of three general dentists, one board certified endodontist, one second year endodontic resident, and one first year endodontic resident. The examiners were provided with a 13" × 6" radiograph view box and a Viewscope 2X (Flow X-Ray Corporation, Hempstead, NY). They were asked to use clinical judgment in evaluating the distance from the file tip to the radiographic apex to the nearest one-half millimeter. Each examiner viewed the radiographs individually with the same view box. The examiners were blinded to the results of the microscopic measurements.

A χ^2 analysis was used to examine the differences between the investigators' estimation of working length and the microscopic measurements.

Results

Estimates that were within 0.25 mm of the microscopic measurement were considered to be accurate. The remaining estimates were then categorized as an overestimation or underestimation of file position. Canals with the file tip located beyond the measuring point were calculated separately from those with the file tip located short of the measuring point.

Table 1 describes the percentage of error in estimation of radiographic working length; this represents the discrepancy between the estimations by the radiographic examiners and the measurements taken under magnification from the extracted teeth. When the file tip was located beyond the measuring point, as illustrated in Fig. 1, examiners underestimated the distance the file actually exceeded the major foramen (Table 1A). When the file tip was located short of the measuring, as illustrated in Fig. 2, examiners overestimated the distance it was short (Table 1B). The average amounts of underestimated and overestimated errors are described in Table 1C.

Discussion

Several studies have concluded that the use of a combination of methods to determine an appropriate working length may be more successful than relying on just one method (18, 19). Methods of working length determination include the use of radiographs, electronic apex locators, tactile sense, and the observation of bleeding points or moisture at the end of a paper point. Our results support findings from authors such as Hembrough et al. (13) that radiographs are an indispensable aid in working length determination. However, our study reveals shortcomings associated with radiographic check films and points out compensatory trends. When the file is short, it is actually closer to the apical foramen than it appears radiographically. When the file is long, it is actually longer than it appears radiographically.

The ideal apical endpoint of endodontic instrumentation and obturation has been determined to be the cementodentinal junction or minor constriction (1). In our study the most coronal aspect of the major foramen was established as the measuring point to maintain a consistent reference (14). This reference point is located beyond the minor constriction by an average 0.5 mm in younger patients and 0.7 mm in older patients (1). Therefore, when the examiners evaluated the file as short in the radiograph, it was not only closer by the distance described in Table 1C, but it was possibly closer to the minor constriction by an additional 0.5 to 0.7 mm. When it was viewed as long in the radiograph, it was not only longer than the distance described in Table 1C, but it was possibly further from the minor constriction by an additional 0.5 to 0.7 mm.

When the anatomic apex and apical foramen do not coincide, radiographic estimation of working length becomes more questionable, and other methods of working length determination become more important. The larger the distance between these two points, the more difficult it is to make a clinical judgment regarding working length. This fact may be more significant when treating premolars and molars where there is a higher probability of inconsistency in foramen position. It was demonstrated that the apical foramen is located laterally in 78 to 93% of posterior teeth (20). A smaller distance between these two points, as may be the case in anterior teeth, results in a smaller discrepancy between radiograph estimation and microscopic measurement. This makes the radiographic check film much more reliable in anterior teeth

than in posterior teeth. ElAyouti et al. found that the frequency of overinstrumentation was greater in posterior teeth than in anterior teeth when working with an acceptable in vitro working length radiograph (21).

Further clinical studies should be performed to establish trends that are specific to each tooth and to each root. Understanding specific trends regarding the appearance of a file in a canal would enable the practitioner to use clinical evidence in his or her decision making when using a radiograph to establish working length.

In conclusion, our findings suggest that radiographs are a useful adjunct in establishment of an appropriate working length; however, two trends should be considered. When a file is long radiographically it is actually longer than it appears by an average of 1.2 mm ($p < 0.01$). When a file is short radiographically it is closer to the apical foramen than it appears by an average of 0.46 mm ($p < 0.01$).

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