# *In Vitro* Comparative Study of the Working Length Determination with Radiovisiography and Conventional Radiography in Dilacerated Canals

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**Abstract**

**Introduction:** The aim of this study was to compare digital and conventional radiography in determining the working length of dilacerated canals. **Methods:** Thirty nine human extracted single-rooted teeth with root curvature more than 35 degrees were included in this study. After access preparation, a file was inserted into the canal and advanced until the file tip was visualized at the foramen. With measurement of the file length using a millimeter ruler, true canal length was determined for each canal. Then, teeth were mounted in acrylic blocks and canal length was estimated by using on-screen digital radiography with both 3- and 6-clicks measurement and from conventional radiography by conforming a preserved file on the image of the root canal. **Results:** There were no significant differences in measurement accuracy between the true canal length and conventional radiographic length, but there were significant difference between both digital radiographic techniques with true canal length. There was no significant correlation between root curvature and canal length estimation error of studied methods. **Conclusion:** In dilacerated canals, the accuracy of determination of working length by using conventional radiography is higher than digital radiography.

**Key words:** Digital radiography; conventional radiography; working length; root curvature; dilaceration.

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## Introduction

An important part of successful endodontic treatment is a true working length determination for root canal cleaning, shaping, and obturation. The working length refers to the distance from the coronal reference point to the point at which canal preparation should be terminated (1).

To estimate the canal length before instrumentation in endodontic treatment, conventional radiography and digital radiography may be used. Radiographic technique described by Ingle is the most common method used for determination of the working length; however, its accuracy is under question. A major limitation in this technique is that the apical constriction cannot be recognized correctly. The clinicians' bias in radiographic interpretation is another concern (2).

Measurement of the working length may be much more difficult in dilacerated canals because of different tactile sense in these canals and curvature of the canal in radiograph which make the measuring difficult (3, 4).

Nowadays, digital radiography is used in different fields of dentistry. It may have some potential benefits in endodontics, too. It has some advantages over the conventional radiography including less exposure time, image acquisition, manipulation, storage, retrieval, and transmission to remote site in a digital format, elimination of wet processing and considerable reduction in the time lapse between image acquisition and display (5). This technique may be helpful in working length determination in dilacerated canals because of its ability to choose some points in the canal and electronic measurement of the line between these points. The purpose of this study was to compare digital and conventional radiography in determining the working length of dilacerated canals.

## Materials and Methods

Thirty nine human single-rooted extracted teeth with severe root curvature, closed apex, and no root crack/fracture were obtained and periapical radiograph was taken. The images were used to select teeth based on inclusive criteria consisting of the presence of a radiographic visible root canal, the absence of external or internal resorption, presence of only 1 orifice and one foramen, and the root curvature≥35 degrees, as established by the Schneider method (6).

Standard endodontic access cavity preparation was made in all teeth and canal patency verified with a #8 K-file (Dentsply, Maillefer, Ballaigues, Switzerland). Then the incisal/occlusal surface of all teeth were flattened perpendicular to the long axis of the roots to obtain a reliable incisal/occlusal reference point. The actual working length for each tooth was obtained by inserting #8 K-file (Dentsply, Maillefer, Ballaigues, Switzerland) into the canals until it passed the apical foramen, and then pulling back onto a smooth metallic surface. A rubber stop was used to mark the file at its coronal reference point. The file was removed and canal length was determined using an endodontic ruler.

To simulate alveolar bone tissue and clinical conditions, the teeth were mounted in plastic tubes, using an opaque acrylic material. Specimens then were imaged with both conventional and digital radiography using long cone and parallel technique. E-speed films (AGFA, Osaka, Japan) was chosen for the conventional radiography which were exposed with X-ray generated by a Planmecca unit (Planmecca, Helsinki, Finland) operating at 70 KVP and 8 mA. Optimal exposure time was selected to be 0.12 s. To obtain digital radiographs, the techniques were similar to that of conventional radiography, the only difference was using CCD sensor (Schick Technologies, New York, USA) instead of conventional film.

The specimens were placed over the packet film or sensor using a polyvinyl siloxane jig to allow changing of the image recording medium without moving the specimen or losing the relationship between the tooth and the image recording surface and an XCP device was used to ensure consistency of angulation and source-to-object distance for the radiographs and the radiovisiographic (RVG) images. In all cases, a distance of 36 cm was established between the X-ray source and the film/sensor and the object was in the closest contact with the image recording surface. For each tooth, the direction of exposure was based on the direction of root curvature, which means teeth with mesiodistal curvature were radiographed in a buccal to lingual orientation and teeth with buccolingual curvature were radiographed in a mesial to distal orientation.

In the case of digital system, the canal length was estimated by digital ruler feature of the RVG system with both 3-clicks measurement (the first click at the flat coronal reference point, the second click at the tip of the angle along the coronal curvature, and the final click at the radiographic apex) and 6-clicks measurement (three clicks as mentioned above and three intermediate clicks). Each RVG image was calibrated using the orthodontic arch wire of known diameter.

Measurements of the conventional radiographic images were made directly on the film with the aid of a precurved file. A #15 K-file (Dentsply, Maillefer, Ballaigues, Switzerland) was adapted to the radiograph to simulate its canal curvature from the flat occlusal reference point to radiographic apex and this length was marked. After straightening the file, the measurement was done with the aid of an endodontic ruler.

All images were assessed under ideal conditions and measurements were made by two trained examiners. Statistical Package for the Social Sciences (SPSS) 16.0 for Windows (SPSS Inc., Chicago, IL, USA), and Microsoft Office Excel 2007 were used to carry out statistical analysis. Pearson Correlation Coefficients and GLM repeated measures were used for statistical analysis. The critical level of significance was set at $P<0.05$.

## Results

The minimum, maximum, and mean ± S.D. of the root curvature were 35, 83 and 46.15±12.19 degrees. The normality of the data distribution for root curvature and working length measurements in different methods was analyzed with the Kolmogorov-Smirnov test ($P>0.05$). Table 1 shows that there is a strong Pearson's correlation coefficient between two observers in 3 methods; since the mean values for each type of measurement was used. Also, it was concluded that the agreement between two observers in conventional method is the lowest. GLM repeated measures showed that there was a significant value for Mauchly's Test of Sphericity that indicates the assumption of sphericity has been violated (Approx. Chi-Square=102.08, P<0.001). In this condition, a correctional adjustment called Greenhouse-Geisser was used.

ANOVA with repeated measures with a Greenhouse-Geisser correction revealed that the mean measurements for root canal length were statistically significantly different (F (1.63, 62.24) =27.84, P<0.001). Table 2 presented the results of the Bonferroni post-hoc test, which allows us to discover which specific means differed. There were no significant differences in measurement accuracy between the true working length and conventional radiographic length (mean conventional) (P=0.356), but there were significant difference between the both digital radiographic techniques with working length and mean conventional length (P<0.05) (Table 2, Fig. 1). The maximum percentage of magnification was related to 3-click digital radiography and the minimum was related to working length estimation with conventional radiography (Table 3, Fig. 1). Both digital radiographic techniques underestimated the working length but conventional radiographic techniques overestimated that. There was no significant correlation between root curvature and canal length estimation error of these three methods (P>0.05) (Table 4).

**Table 1.** Pearson correlation coefficients and p-values for comparing two practitioners in determining the working length by digital radiography and conventional radiography

| | | RVG3_2 | RVG6_2 | Conventional_2 |
|---|---|---|---|---|
| RVG3_1 | Pearson Correlation | .998** | .998** | .957** |
| | Sig. (2-tailed) | .000 | .000 | .000 |
| | N | 39 | 39 | 39 |
| RVG6_1 | Pearson Correlation | .997** | .998** | .953** |
| | Sig. (2-tailed) | .000 | .000 | .000 |
| | N | 39 | 39 | 39 |
| Conventianal_1 | Pearson Correlation | .973** | .973** | .954** |
| | Sig. (2-tailed) | .000 | .000 | .000 |
| | N | 39 | 39 | 39 |

**. Correlation is significant at the 0.01 level (2-tailed).

**Table 2.** The results of the Bonferroni post-hoc test

| (I) Measurement | (J) Measurement | Mean Difference (I-J) | P | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| WL[a] | Mean RVG3[b] | .488* | .000 | .229 | .747 |
| | Mean RVG6[c] | .390* | .001 | .126 | .654 |
| | Mean Conventional[d] | -.135 | .356 | -.327 | .058 |
| Mean RVG3 | WL | -.488* | .000 | -.747 | -.229 |
| | Mean RVG6 | -.098* | .000 | -.142 | -.053 |
| | Mean Conventional | -.622* | .000 | -.873 | -.372 |
| Mean RVG6 | WL | -.390* | .001 | -.654 | -.126 |
| | Mean RVG3 | .098* | .000 | .053 | .142 |
| | Mean Conventional | -.525* | .000 | -.774 | -.276 |
| Mean Conventional | WL | .135 | .356 | -.058 | .327 |
| | Mean RVG3 | .622* | .000 | .372 | .873 |
| | Mean RVG6 | .525* | .000 | .276 | .774 |

[a]WL: Working Length, [b]Mean RVG3: The average of two observers findings in 3-clicks method, [c]Mean RVG6: The average of two observers findings in 6-clicks method, [d]Mean Conventional: The average of two observers findings in conventional method

**Table 3.** Mean error percentage of working length in 3 studied methods.

| | Conventional | RVG (3-clicks) | RVG (6-clicks) |
|---|---|---|---|
| Mean Error (%) | 0.78 | - 2.45 | - 1.93 |

**Table 4.** Pearson correlation coefficients between root curvature (angle) and canal length estimation error in 3 different methods

| | | Angle | RVG3 Error Percent | RVG6 Error Percent | Conventional Error Percent |
|---|---|---|---|---|---|
| Angle | Pearson Correlation | 1 | -.099 | -.059 | .001 |
| | Sig. (2-tailed) | | .547 | .721 | .995 |
| | N | 39 | 39 | 39 | 39 |

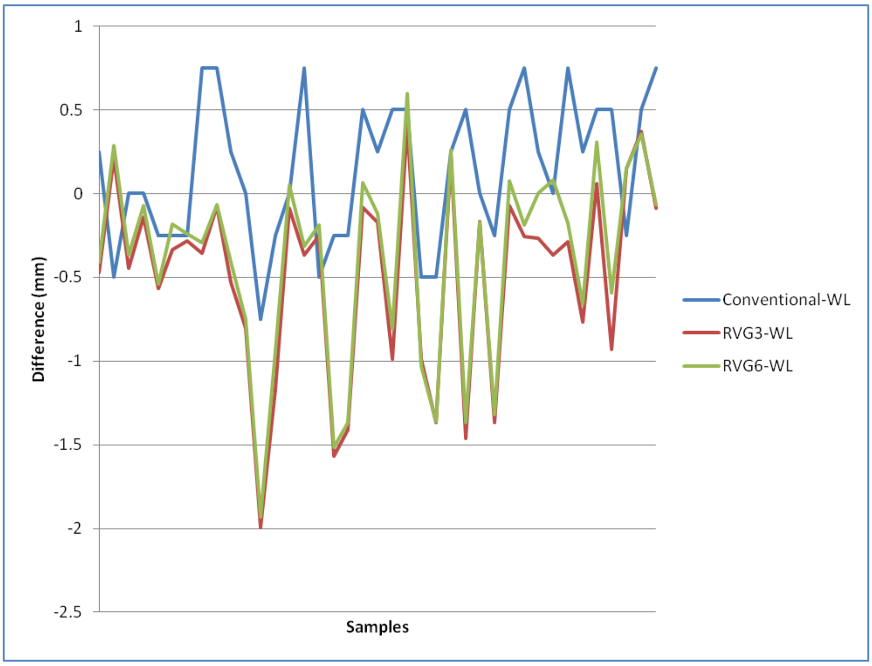


**Figure 1.** The difference between three studied methods in determining the working length
WL: Working Length
RVG3: Mean 3-clicks method measurement
RVG6: Mean 6-clicks method measurement

## Discussion

Determination of working length is considered as an important stage in endodontic treatment. Various methods are used to do this, including patient reflex, paper point, conventional radiography, and digital radiography (7, 8). Considering the fact that the use of digital radiography can lead to a lower radiation dose for the patient and lower number of radiographs, this study has been designed to compare the efficiency of the conventional and the digital radiography systems in regard to actual working length in dilacerated canals.

Magnification has been defined as enlargement of the image of an object in radiographic films and it can be minimized by placing the object and the film as close to each other as possible and to increase the distance between the X-ray source and the film. On the other hand, paralleling technique can be used to place the object at the center of the X-ray beams, thus minimizing distortion (5). In this study, the object and the film were placed as close to each other as possible and paralleling technique was used in imaging.

To increase measurement accuracy in our study two independent observers were used. Inter-observer correlation coefficients, at the level of 0.01, showed a significant correlation. Some researchers reached similar results (9-13). In all these studies significant inter-observer correlation at the level of 0.01 was found.

Lack of meaningful difference between working length and the conventional method has also been found by other researchers (2, 13-18). However, Shearer et al. (19) and Burger et al. (10) found a meaningful difference between the conventional method and working length. The difference found in the study carried out by Shearer et al. (19) may be due to greater volume of the sample size (60 teeth) and not using enhancement while employing digital radiography, while in the study conducted by Burger et al. (10) it may be caused by a more accurate measurement of working length through the use of ×2 magnification and difference in the curvature of the roots used (7 to 47 degrees) in comparison to our study.

Moreover, in a study carried out by Mehdizadeh et al. (14) the reason for the difference in measurements gained through the conventional method and working length could be attributed to the higher volume of the sample pool (65 extracted teeth), not using severely curved teeth, the use of dry human mandibles instead of mounting them in acrylic resins and superimposition of a grid on the film for a more precise working length measurement.

The existence of meaningful difference between measurements gained by the application of RVG method with working length was in line with results produced by many past studies (10, 14, 15, 20, 21). However, Almenar Garcia et al. (17) and Mohtavipour et al. (13) did not find a meaningful difference between the two. In the study conducted by Almenar Garcia et al. (17) this may be due to the use of vernier caliper in the measurements yielded by conventional radiography. Mohtavipour et al. (13) declared that there is no difference between working length and measurements produced by RVG, and this may be due to the use of 60 extracted mandibular first molar with root curvature ranging from 0 to over 30 degrees and employment of 2- and 3-clicks.

Our findings showed a meaningful difference in length measurement between the conventional and digital methods and this is in line with views expressed by Lamus et al. (16) and Shearer et al. (19). Other studies have concluded that a meaningful difference does not exist between conventional and digital methods (9-15, 20, 22-26). Among the factors accounting for the finding that no meaningful difference between the two methods exists, we can point to differences in the size of the sample pool, the kind of teeth used, the way they are mounted and measurement methods different from the one we employed in our study.

An examination of the results of the present study indicates that the conventional method of measuring root canal length tended to error by overestimation. This confirms the findings of Shearer et al. (19) Ezoddini Ardakani et al. (24) and Brito-Junior et al. (12). However, it does not apply to canals with moderate curvature (20-36 degrees) in the study conducted by Mentes et al. (15). This may be due to the difference in root canal curvature of the teeth used compared to those we used in our study, or to the use of ×2 magnification in measurement of working length while using the conventional method. The study carried out by Mohtavipour et al. (13) demonstrated under-estimation in measuring canal length using the conventional method which may be attributed to differences in the kind of teeth used (mandibular first molar) and the degree of their curvature (from 0 to over 30 degrees) in comparison to our study.

Huang et al. (27) reported that in using RVG with 2-clicks, as the degree of curvature increases a tendency toward underestimation in measurements is observed. Mehdizadeh et al. (14) have also demonstrated that while employing the RVG method to measure the length of canals with severe curvatures, a degree of underestimation occurs.

The results of studies undertaken by Burger et al. (10), Mentes et al. (15), Huang et al. (27) (in the application of RVG using 3-clicks), Brito-Junior et al. (12), Mohtavipour et al. (13) (in teeth with mild and moderate curvature) were different from ours, and in measuring canal length with RVG they demonstrated a certain amount of overestimation. Among the causes for this difference, we may point to differences in the size of the sample pool, root curvature, kinds of teeth, methods and instruments used to measure canal length.

In our study, when we employed RVG to measure canal length, the greatest percentage of errors occurred during the use of 3-clicks. When the number of clicks increased the percentage of measurement errors decreased, confirming results obtained by Huang et al. (27).

Burger et al. (10) have shown that while employing RVG, use of multiple measuring points compared to the use of only the starting and the finishing points, without any regard for the curve of the canal, does not yield a more precise measurement of the canal length. They have stated that possibly the underestimation in the measurement of the length of the canal produced by the use of only two clicks offsets the overestimation caused by the intrinsic error of magnification. Some other studies reached similar results (15, 25).

In the present study, the most precise method of measurement with the least percentage of error was the conventional one, a fact fully consistent with the findings of other researchers (2, 15, 16, 18). Moreover, Ezoddini Ardakani et al. (24) demonstrated that in canals with curves of less than 25 degrees, precision of ordinary radiography is higher than that of the digital one, while the reverse is true in the case of canals with curves of more than 25 degrees. However, this was not statistically meaningful which may be attributed to the difference in the kind of teeth used (extracted first molar), range of root curvature (from 5 to 45 degrees), the way the teeth were mounted (on blue gypsum with the tip of the apex visible), the use of vernier caliper with the precision of 0.1 mm when measuring the true canal length, and the use of the conventional method.

In this study, a meaningful correlation between root curvature degree and the percentage of measurement error in different methods could not be found. Results obtained by Burger et al. (10), Mohtavipour et al. (13), and Avinash et al. (25) demonstrated the same thing.

Finally it should be added that the recent study of Dastmalchi et al. (4) showed that most of Dilplomates of the American Board of Endodontics believe that a dilacerated canal should have a curvature >40 degrees. This is near the curvature (≥ 35 degrees) we used in this study. These Diplomates also believed that apex locator may be the best choice for measurement of the working length in dilacerated canals (4). This may be studied in the future studies.

## Conclusion

In severe curved canals, the accuracy of working length determination by using conventional radiography via adapting the precurved file on the radiograph is higher than digital radiography. Also, 6-click digital radiographic working length evaluation is closer to the true canal length than 3-click ones.

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