CLINICAL ANALYSIS OF A DIGITAL METHOD FOR
RADIOGRAPHIC ROOT CANAL LENGTH DETERMINATION
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ABSTRACT
Aim of the study The objective of this analysis was to investigate a digital method for radiographic working
length determination. Material and methods 300 scanned periapical radiographs for 240 clinical cases with
undergoing endodontic treatment had the working length digitally measured using a distance measurement
program. A mathematical algorithm of calculus based on proportionality ratio between clinical and radiological
dimensions of dental crown and root was used for each tooth. The data (before and after treatment) obtained for
each analysed case from 10 observers were used to evaluate the accuracy of the method for each group of teeth.
Results The mean determinations for initial and postoperative working length were in the range of the golden
standard provided by the statistical data. The accuracy of the method varied for the pre and post treatment
measurements in a direct correlation with the root particularities (degree of curvature, apex spatial orientation).
Conclusions The results of this study suggest that the digital measurement tool combined with an appropriate
algorithm of calculus can be used for clinical working length determination regardless the morphological
endodontic particularities.

Key words: digital radiography, working length, endodontics

INTRODUCTION
Radiographic examination is an essential part of any endodontic treatment. It plays an
important role in estimating and confirming the lengths of root canals before and during
instrumentation.

Cleaning, shaping and filling of the root canal system cannot be accomplished accurately unless the working length is
correctly measured [1,2]. Working length is always measured in relation to the position of
root apex because its precise location is a problem which causes countless endodontic
failures [3].

There are several methods for determining the working length, but traditionally, the root
length is determined by direct measurement on conventional periapical radiographs. This
method can be challenging for excessively curved or with peculiar spatial orientation
roots due to the subjectivity of the examiner [4-6].

Therefore, the aim of this study is to evaluate a digital method for radiographic working length determination in endodontic
treated teeth with varied degrees of root curvature and without an initial marker.

MATERIAL AND METHODS
300 scanned radiographs for 240 clinical cases with undergoing endodontic treatment
were used to make digital measurements of the working length on the computers monitor
with a program for distance measurement.
The radiographs were taken in the Radiology Department of University Hospital “Prof. Dr. Dan Theodorescu” using a periapical semistandardized technique. Radiographs (with optimal degree of radiographic coverage and processing level) for anterior and posterior, upper and lower teeth, from adult patients and both genders were accepted.

The digital measurement tool was provided by Xray Vision 3.7 (Apteryx Inc., Akron, OH, USA, 2010). The initial radiographs were not digitally enhanced and they were standardized scanned on a flatbed scanner.

A mathematical algorithm of calculus based on proportionality ratio between clinical and radiological dimensions of dental crown and root was used for each tooth.

The data regarding the pair of determinations (before and after treatment) obtained for each analyzed case from 10 observers (with different radiologic and clinical background) were used to evaluate the diagnostic accuracy of the method for each group of teeth.

The quality of the odontometric determinations for each case was evaluated by a double initial (I) and final (II) analysis.

I. INITIAL ANALYSIS

Individual comparative etalonation was made on each initial image for the graphic measurement tool by establishing some general landmarks:

→ the coronal part of the investigated tooth was clinically measured with a caliper and the obtained value was marked as DC (k), were D = dimension, C = clinical, k = case number;

→ the coronal part of the investigated tooth was radiographic measured with the digital program and the obtained value was marked as DRx (k), were D = dimension, Rx = radiographic, k = case number.

The ratio between DC.k and DRxk generated a correction factor that was used to determine the real length of the root canal (RL.k) by multiplication with the initial radiographically digitally measured length (RxL.k = WL).

For each case the mathematical algorithm of calculus was:

$$DC_{RL} = \frac{\text{DRx}}{\text{RxL}}$$

II. FINAL ANALYSIS

New digital determinations of the working length Rx.L. was used during the endodontic treatment and after its completion the determinations accuracy was radiographic evaluated in the final analysis.
length were made on the posttreatment radiographic images with the already described individual comparative etalonation method and the final values obtained (FD) were compared with the initial determinations (ID) (fig.2).

![Figure 2. Final determination](image)

The observers used the zoom function and the isodensity determination program for identifying the apical landmark.

All the determination were made for initial and final analysis, in a random selection in order to avoid observers subjectivity.

The digital determinations were made automatically using the measurement program for points and segments and the clinical determinations for the coronal parts were made with a calliper with a precision of 0,1 mm.

**RESULTS**

The data obtained for initial and final determinations (for each case) were compared and after that, the information were statistically processed using an algebraic ratio to give a mean value (with a standard deviation of 0,5 mm) for each dental group anterior and posterior, upper and lower.

Initial and final working length determinations (mm) are presented in table I and II.

<table>
<thead>
<tr>
<th>Mandible</th>
<th>Central I</th>
<th>Lateral I</th>
<th>Canin</th>
<th>1PM</th>
<th>2 PM</th>
<th>1Molar M/D</th>
<th>2Molar M/D</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>12,6±0,5</td>
<td>12,4±0,5</td>
<td>16,1±0,5</td>
<td>14,1±0,5</td>
<td>14,3±0,5</td>
<td>D14,2±0,5</td>
<td>M13,4±0,5</td>
</tr>
<tr>
<td></td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
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<tr>
<td>FD</td>
<td>12,5±0,5</td>
<td>12,3±0,5</td>
<td>16±0,5</td>
<td>14±0,5</td>
<td>14,2±0,5</td>
<td>14±0,5</td>
<td>13,9±0,5</td>
</tr>
<tr>
<td></td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
</tr>
<tr>
<td>ΔD</td>
<td>0,992</td>
<td>0,991</td>
<td>0,993</td>
<td>0,992</td>
<td>0,993</td>
<td>0,985-0,992</td>
<td>0,984-0,992</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maxilla</th>
<th>Central I</th>
<th>Lateral I</th>
<th>Canin</th>
<th>1PM</th>
<th>2PM</th>
<th>1Molar</th>
<th>2 Molar</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>13,5±0,5</td>
<td>12,6±0,5</td>
<td>17±0,5</td>
<td>13,7±0,5</td>
<td>13,8±0,5</td>
<td>P 14,5±0,5</td>
<td>V11,3/11±0,5</td>
</tr>
<tr>
<td></td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
<td>±0,5</td>
</tr>
<tr>
<td>FD</td>
<td>13,4±0,5</td>
<td>12,4±0,5</td>
<td>16,9±0,5</td>
<td>13,5±0,5</td>
<td>13,7±0,5</td>
<td>P14,3±0,5</td>
<td>V11,2/10,8±0,5</td>
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</tr>
<tr>
<td>ΔD</td>
<td>0,996</td>
<td>0,984</td>
<td>0,994</td>
<td>0,985</td>
<td>0,992</td>
<td>0,981-0,990</td>
<td>0,981-0,985</td>
</tr>
</tbody>
</table>

The meanings of the abbreviations are as follows:
- **ID** - initial determination;
- **FD** - final determination (mm);
- **ΔD** - variation of determination

$\Delta D = \frac{FD}{ID}$.

The degree of acceptance as a equivalent determination was at a maxim variation of 0.01 which corresponds to a precision of determination of 10µ.

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The variation of determination $\Delta D$ varied for all dental groups in a range of 0.981 to 0.996 (for maxilla 0.981-0.996 and for mandible 0.985-0.993). Initial working length determinations (ID) are slightly oversized in comparison with the posttreatment measurements (FD) but all results agree with the statistic data regarding the root length.

Some specific observations can be made regarding the dental groups digitally measured.

For the incisors group the digitally determined working length had the highest accuracy (up to 0.996) for the central upper (fig. 3) followed by the central lower and lateral lower due to their particular endodontic morphology with straight roots and well defined apex.

The exception was the lateral maxilar incisors group with the lowest degree of accuracy $\Delta D = 0.984$ because of the disto-oral root curvature in the apical third and the variety of apex location. In this case the digital odontometric method used a dot by dot measurement technique, the segmental method having no applicability (fig. 4).

The upper molars presented the widest endodontic variety and so, the digital measurements presents a wide range $\Delta D = 0.984-0.992$ for the lower molars and $\Delta D = 0.981-0.990$ for the upper molars (fig. 5, 6).

For the lower molars the segmental measurement tool was used on the straight part of the root and the dot by dot addition measurement tool was used for the curved part until the detected radiographic apex was reached.
The different determinations can be explained by the misinterpretation of the mesial canals position and length due to the eccentrical projection.

At the upper molars group the determinations were rather consistent for the oral and distobucal roots, major radiometric differences occurred for the mesiobucal root with extreme curvature and a high degree of overlapping with the oral root.

At the opposite side, the curved canals final determinations may be shorten with up to 1mm comparative to initial determinations as the canal is straightened out by instrumentation.

CONCLUSIONS
1. Radiographic digital techniques have a superior precision in identifying the radiologic apex in comparison with the classic film based visual method when they are used in combination with the selective image amplification and the histogram based on optical isodensity.
2. Digital odontometry obtained with distances measuring programs has values comparable with the statistic determined root lengths and it eliminates the observers subjectivity based on different radiologic and clinical background.
3. The radiographic digital working length determination has a quick learning curve and can be used in most cases regardless morphologic complexity and spatial particularities of the endodontic system.
4. Digital odontometric technique has some limitations regarding the ortoradiality (especially for multiple root canals), but an individual digital approach for each root can easily overcome this problem.
5. This digital method provides better results for narrow roots with a limited radiographic aspect on classic radiographs after an initial digital enhancement in order to get the correct working length.

REFERENCES