# The Correlation between Electronic and Radiographic Working Length Determination in Resin Model: a Laboratory Study

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Original Article

# The Correlation between Electronic and Radiographic Working Length Determination in Resin Model: a Laboratory Study

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## Abstract

The aim of the study was to evaluate the correlation between the electronic and the radiographic working length determination in a simulated resin jaw model. Fifty-one extracted human upper central incisors of 3rd year dental students' exercises were used in this experiment. After the access opening, students practiced to use the electronic apex locator (EAL) on teeth embedded in resin jaws and fixed in the phantom heads under the supervision of instructors. The working length (WL) determined by EAL was statistically compared with that obtained from a radiograph of the same tooth. The acceptable criteria for WL determination by EAL was for the file which is short and beyond the radiographic apex ± 0.50 mm. Intraclass correlation coefficient between EAL and radiograph according to the acceptable criteria revealed 0.710 (95% CI = 0.538, 0.825). The reliability coefficient equaled 0.7090. There was a good correlation between EAL and radiograph regarding the working length determination in the simulated resin jaw model. The use of electronic working length determination in the resin jaw model not only obtains suitable teaching purpose but also reduces the number of radiographs required for WL estimation.

**Key words:** Electronic apex locator, Radiograph, Resin jaw model

## Introduction

In dental schools in Thailand, endodontics is one of the subjects taught during the 3rd and 4th year of undergraduate dental curriculum before students begin to practice in the clinics. Students acquire both theoretical knowledge and competencies to conduct the technical procedures of root canal treatment in patients. Upon completion of this course, students have an understanding of endodontics and recognize that endodontics is the science of treating pulpal and periradicular diseases.

One of the most important aims of endodontics is to eliminate or reduce bacterial infection in the canal to a degree that it no longer irritates periapical tissue. The clinically acceptable working length (WL) in canal instrumentation is the distance between a reference point occlusally or incisally of the tooth to the apical cemento-dentinal junction (apical constriction). Root canal instrumentation and root canal filling termination should extend to this point. Students regularly rely on radiographs to determine the end point of the canal instrumentation while working in the endodontic laboratory. The apical constriction area of the canal instrumentation end point is adjusted 0.5 - 1.0 mm. from the radiographic apex.[1] In contrast, contemporary clinical endodontics routinely uses electronic apex locators (EALs) to determine the working length.[2,3]

The accuracy of the modern EAL in determining the apical constriction has been shown to be clinically acceptable.[3-5] EAL was first introduced into endodontics as a response to concerns over the effects of radiation exposure, utility of radiographs and superimposition of anatomical landmarks on radiographic apices. Raypex 5 (VDW GmbH, Munich, Germany) claims to be a fourth generation device and two separate frequencies 400 Hz and 8 KHz are used similarly to a third generation such as Root ZX (J.Morita Corp, Tokyo, Japan).[5] Root ZX and Raypex 5 determine the WL via an impedance ratio. The main differences between two devices are their displays and the fact that Root ZX passes the two currents simultaneously whereas Raypex 5 passes only one frequency at a time. According to the user manual Raypex 5 is controlled by a microchip; no further adjustments and calibration are required and the size of the endodontic file should fit into the canal to ensure the precise measurement.[6]

A simulation model that can be used with EAL presents a great advantage to the endodontic education. Dental students at Rangsit University's Faculty of Dental Medicine have the opportunity to use EALs on teeth that are embedded in simulated resin jaws and fixed in phantom heads. They are taught that root canal preparation and root canal filling regularly end at the apical constriction providing optimal conditions for biological healing of the periradicular tissue. This area can not accurately be obtained from the periapical radiograph. As mentioned, EAL is a device of choice for clinically determining the apical constriction. It is essential for students to undertake the exercise of using EAL in the endodontic education before the clinical practice. This exercise will improve their technical abilities in endodontic study and familiarize them with procedures that they will face in their clinical work.

The objective of this study was to evaluate the correlation between electronic and radiographic working length determination in a simulated resin jaw model.

## Materials and Methods

Fifty-one extracted human upper central incisors of the 3rd year dental students' endodontic exercise were used in this experiment. The teeth were embedded in simulated resin jaw models before endodontic treatment practice.

### Simulated resin jaw preparations (Fig.1)

A mixture of the clear resin and hardening agent (024A and M60 Rungart, Bangkok, Thailand) a ratio of 100:1 was poured into a silicone mold shaped like an upper jaw. After thirty minutes, the resin jaw was taken out of the mold.

The oasis (flower sponge, Smithers-oasis, Kedah, Malaysia) was inserted into the bottom anterior socket of the resin jaw model. Then, the upper central incisor was fixed into the oasis and the self-curing acrylic resin was poured into the upper half of the socket. The cervical area of the tooth was kept above the self-curing acrylic resin in order to allow for the insertion of the rubber dam clamp. Two holes were drilled through the resin jaw

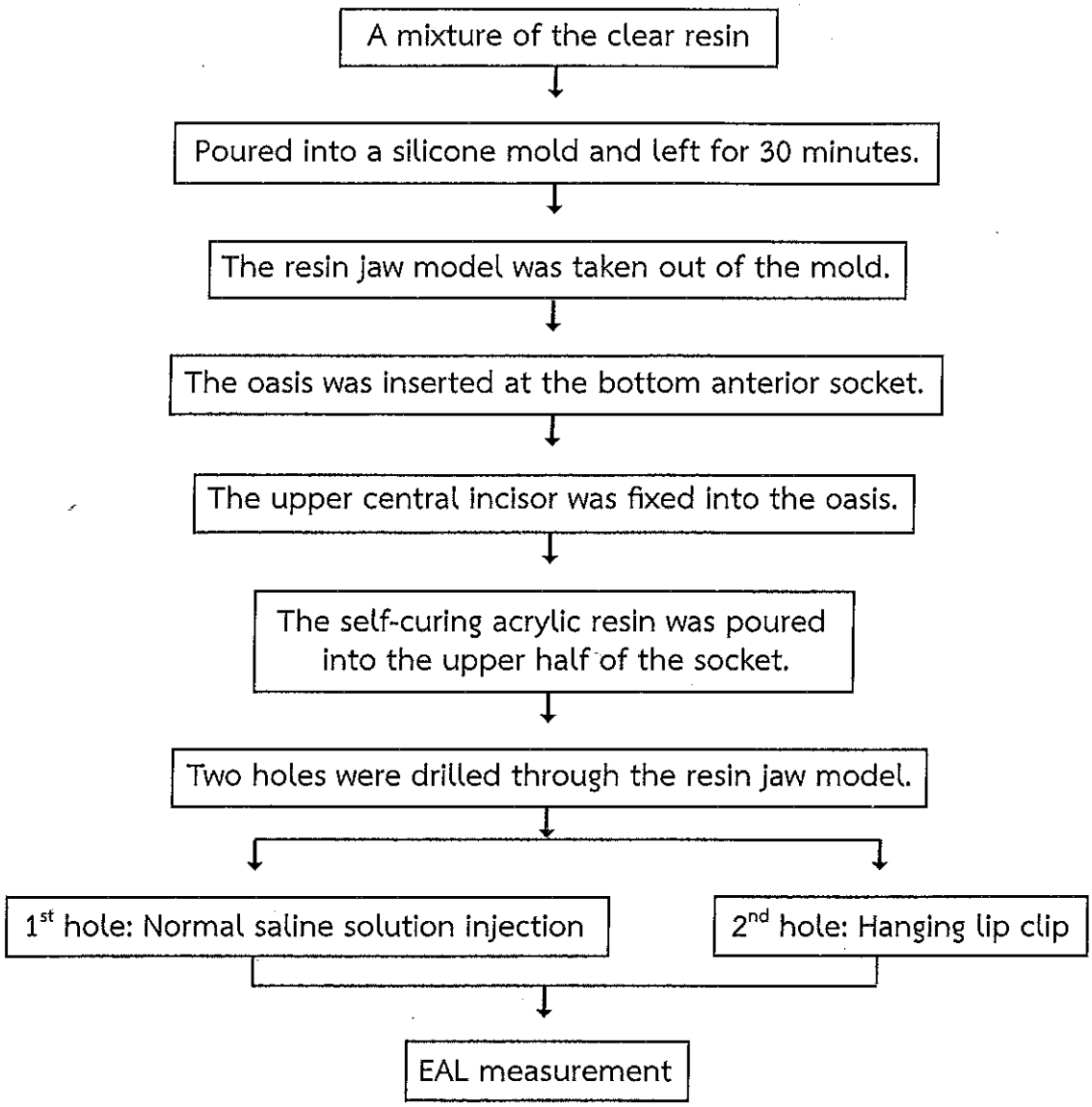


*Figure 1 Diagram of the simulated resin jaw model preparation procedure*

model until the socket was perforated. A wire was secured into one of the holes and a hanging lip clip was attached to it. A normal saline solution was injected into the other hole to obtain a closed circuit system while measuring the working length with EAL. X-ray film (ANSI1.2, Kodak (Thailand) Co. Ltd, Bangkok, Thailand) was placed in the palatal groove behind the palatal socket.

## Working Length Determination using EAL

The Raypex 5, an electronic apex locator, was used in this experiment. Students practiced using EAL in working length determination under the supervision of a group instructor.

The rubber dam was inserted before the access cavity was prepared and the canal orifice had been negotiated. Dentine in the pulp chamber, which interfered with passing of the file into the canal orifice, was eliminated. The canal was irrigated with normal saline solution. Excess normal saline solution in the pulp chamber was removed by using a cotton pellet and no attempt was made to dry the canal. Working length determination was performed under the rubber dam with the Raypex 5 device and the file inserted. The file size was selected according to the size of the individual canal. A lip clip and a file clip were in place as shown in Fig. 2. Then, a K-file (Dentsply Maillefer, Ballaigues, Switzerland) was

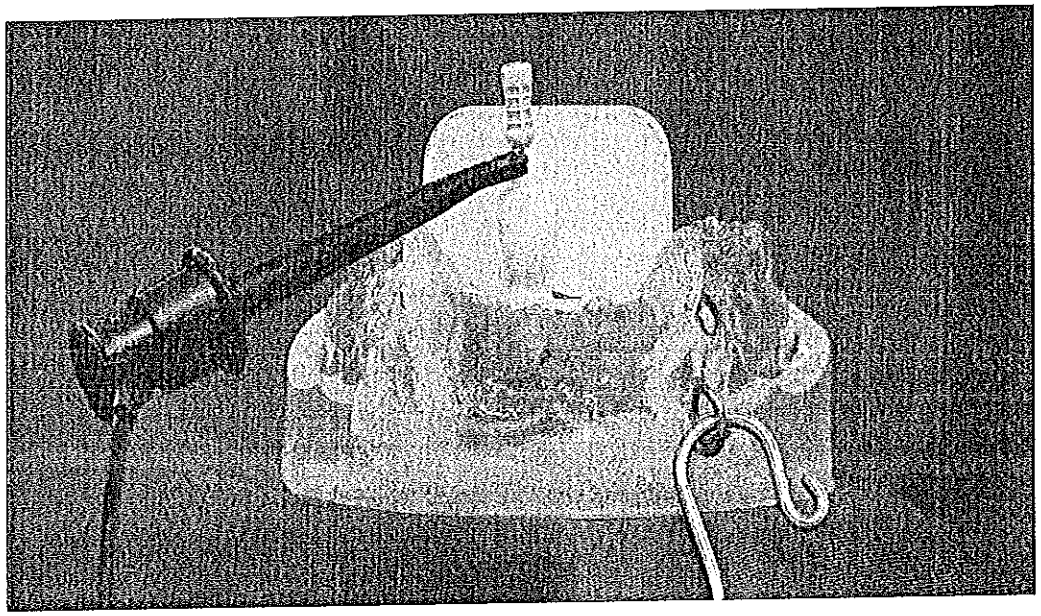

*Figure 2 Position of a file clip, lip clip and film on the simulated resin jaw model*

slowly inserted into the canal until the last green light (apical constriction area recommended by the company) appeared on the display. Next, the cotton pellet was placed into the pulp chamber to prevent the file from moving out of place. A rubber stop was gently moved towards the reference point (incisor edge). The file clip and lip clip were removed and the radiograph was taken (model Intra, Planmeca, Helsinki, Finland, 63 kV, 8 mA, 5 seconds) to determine the working length, as shown in Fig. 3. Film processing was done by soaking the film first in developer solution (Kodak, Coburg, Australia) for 10 seconds, then, in fixer solution (Kodak, Coburg, Australia) for another 10 minutes and finally, leaving it to dry.

The file was removed from the tooth and the length between the tip of the file and the lower part of the rubber stop was measured by using finger ruler (VDW, Munich, Germany) as well as recorded.

## Data Analysis

The length of the file on the radiograph was measured. The acceptable criterion for radiographic working

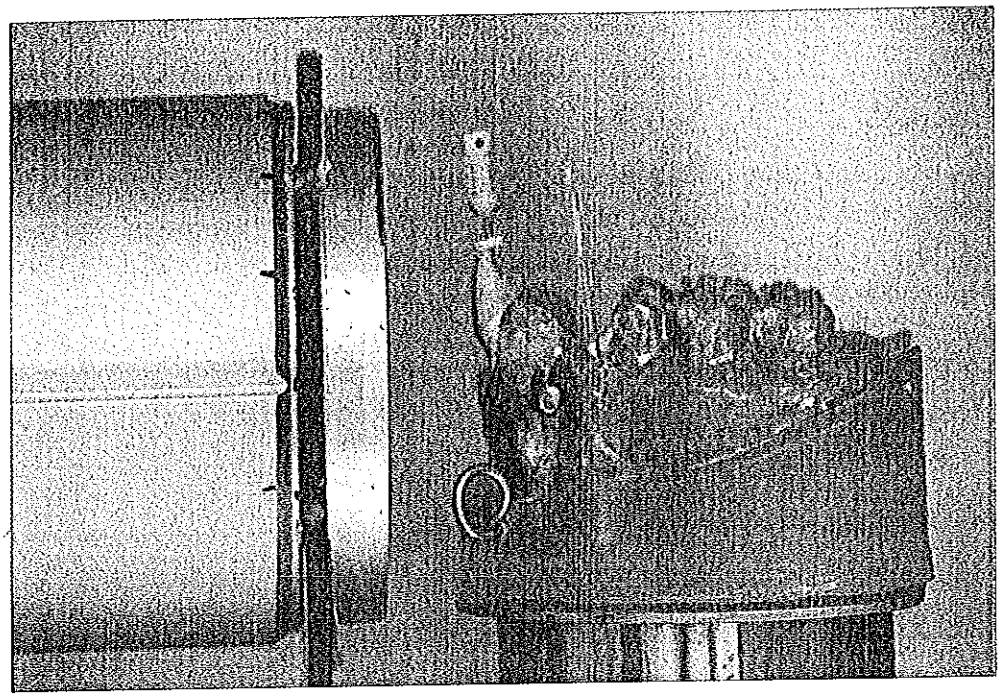

*Figure 3 The position of the radiograph taken in the laboratory*

length determination by EAL was if the file was short and beyond the radiographic apex ± 0.5 mm.

The length of the file determined by EAL and radiograph of the same tooth were statistically analyzed. Intraclass correlation coefficient was performed with a *p*-value ($p = 0.05$). All measurements and radiograph interpretation were performed by one operator.

## Result

Working length determination of the teeth in simulated resin jaw model using EAL revealed that the instruments are 0.5 mm. short and 0.5 mm. beyond the radiographic apices in 3 and 18 canals respectively. The instruments were found to be at the radiographic apex in 12 canals, while in 18 canals they were at a distance of 1 mm. from the radiographic apex, as shown in Table 1.

*Table 1 Distance between the file tip and radiographic apex after WL measurement using Raypex 5 of 51 canals*

| Distance from radiographic apex (mm.) | No. of canals |
|---|---|
| + 1.0 | 18 |
| + 0.5 | 18 |
| 0.0 | 12 |
| - 0.5 | 3 |

+ ⟶ outside of the radiographic apex

- ⟶ inside the radiographic apex

Data obtained from EAL measurements and radiograph interpretations were statistically analyzed (Table 2). The acceptable range of distance of the instrument was short and beyond radiographic apex ± 0.5 mm. The results showed an intraclass correlation coefficient of 0.710 (95 % CI = 0.538, 0.825). The reliability coefficient equaled to 0.7090. There was a good correlation between EAL and radiograph in the resin jaw model with regards to working length determination.[7]

*Table 2 Descriptive statistics of the length measured by Raypex 5 and the periapical radiograph*

| Root length | Mean ± SD | Min, Max | ICC | 95 % CI | *p* |
|---|---|---|---|---|---|
| The electronic apex locator | 22.30 ± 1.25 | 19.0, 25.5 | | | |
| The radiograph | 21.80 ± 1.24 | 18.5, 25.0 | | | |
| Difference (the electronic apex locator - the radiograph) | 0.50 ± 0.45 | - 0.5, 1.0 | 0.710 | 0.538 - 0.825 | 0.000* |

* significant $p < 0.001$, ICC = Intraclass Correlation Coefficient

## Discussion

The current study shows that there is a correlation when comparing working length determination methods using EAL to methods using radiographs (0.710). However, the correlation is less than previously shown in a study by Vajrabhaya *et al.* (0.972).[8] There are two possible reasons for the discrepancy. Firstly, their study was conducted by one operator while our study involved several dental students who utilized EALs by themselves under the supervision of an individual group instructor. Then all measurements and radiograph interpretation were conducted by one operator. Secondly, in the previous study only one EAL was used for the whole experiment, while the individual groups in our study utilized a total of eight EALs. The results of this study indicated the reinforcement of well-trained EAL using by instructors to improve the accuracy of EAL in resin jaw models.

Previously, Huang[9] conducted an experiment simulating electronic root canal measurements *in vitro*. The results demonstrated that electronic root canal measurements could also be explained by principles of electricity and not only by biological characteristics. This study also showed that the accuracy was influenced by two factors: the moisture content of the root canal and the diameter of the apical foramen. Hülsman and Pieper[10] reported that the distance measured from the foramen increases if the size of the foramen is over 0.2 mm. Therefore, as the major foramen diameter increases, the distance measured from the foramen also increases. In the current study, a normal saline solution was used as an irrigant to induce and to create a closed circuit system. In addition, the teeth used in this experiment are the routine exercise of endodontic course so all had mature apices. The accuracy of EAL has been shown to be comparable when used in the presence of a normal saline solution or a sodium hypochlorite solution.[11] The *ex vivo* study of Chen *et al.*[12] revealed that Raypex 5 exhibited a higher percentage of canals accurate to ± 0.5 mm. of visually determined working length more than Dentaport ZX. Under the condition of *in vivo* study Raypex 5 and the third generation device (Mini Apex Locator, SybronEndo, CA, USA and RootZX) performed equally well with the ± 0.5 mm. short of the major foramen[5] and the ± 0.5 mm. short of minor foramen.[13]

Clinical simulation in the laboratory is an important teaching tool in endodontic education and allows students to become familiar with real-life conditions. Rubber dam application on the resin jaw model made

students aware of the irritation that may occur to a patient if the irrigant or the file instrument drops into the patient's throat. The model can be reused by simply burning out old teeth with a dental torch. The wire that is fixed within the hole of the resin jaw model should be placed mesially or distally beyond the root apex, even if it will superimpose on the apex of the root on the radiograph, thus making it impossible to differentiate between the file instrument and the wire.

Two basic methods are used to evaluate the accuracy of EAL. The first method uses the real distance of the file tip to the apical foramen. This distance is measured after extraction of the tooth. The second method uses a radiographic technique to verify the electronic length. If extraction of the tooth has not been possible, radiograph will be used to verify the canal length. In this study, we used the latter method for evaluation, because the radiographic technique is routinely used in the laboratory and students have to practice those teeth in the resin jaw models until final step. The students estimated the working length of each tooth from the pre-operative radiograph. Normally, two or three radiographs may be taken before obtaining a proper working length. Therefore, EALs were included in the laboratory practice at Rangsit University's Faculty of Dental Medicine to reduce the number of the radiographs taken.

The present study reveals that there is a good correlation between EALs and radiographs. A teaching model which allows the use of EAL for working length determination is advocated for endodontic education in this study. The results of this study revealed that 18/51 canals, the instruments out of the radiographic apex 1 mm. The working length of these teeth was determined by minus 1.5 mm. from the EAL length. Our findings are similar to those obtained by the *in vivo* studies of Wrbas *et al.*[13] and Stöber *et al.*[5] that the file tip extended beyond major foramen 20 % and 25 % respectively. However, the reduction in the number of radiographs taken and students' understanding of the concept and technique of utilizing EALs are important advantages. Radiographs are still necessary for students in endodontic teaching. They provide information regarding canal anatomy, root morphology and the termination of the file tip.

The location of the apical constriction is highly irregular and can be up to 3 mm. on one wall of the root compared with the opposite wall[14-16] and also cannot be identified clinically. The development of EALs makes the assessment of working length more accurate and predictable. A radiograph provides a two-dimensional image of a three-dimensional structure. Therefore, radiographs do not provide precise localization of apical constriction. Root canal instrumentation beyond the apical foramen and flare-ups may not be avoided after canal disinfection. Files were out of the apical foramen 56 % and 33 % of premolars and molars respectively if only radiographic working length calculations were used.[17]

The European Society of Endodontology supported and reinforced the undergraduate curriculum in Endodontics to include the competency training in preclinical labrolatory classes.[18] The resin jaw model in this study simulates the clinical situation case for teaching purpose both in the process of treatment and the essential clinical device training such as EAL. The knowledge that students acquire in the laboratory will be applied to their clinical work and results in more effective clinical performances regarding working length determination.

## Conclusion

The study demonstrates that the use of EAL with a resin jaw model supports endodontic studies in determining the working length of root canal. This is highly useful to improve the efficiency of the students during their future clinical practice and the use of the EAL is therefore encouraged in the laboratory study.

## References


1. Kutter Y. Microscopic investigation of root apexes. *J Am Dent Assoc* 1955;50:544-52.
2. Vajrabhaya L, Tepmongkol P. Accuracy of Apex locator. *Endod Dent Traumatol* 1997;13:180-2.
3. Gordon MP, Chandler NP. Electronic apex locators. *Int Endod J* 2004;37:425-37.
4. Welk AR, Baumgartmer JC, Marshall JG. An in vivo comparison of two frequency-based electronic apex locators. *J Endod* 2003;29:497-500.
5. Stöber EK, de Ribot J, Mercade M, Vera J, Bueno R,

Roig M, *et al.* Evaluation of the Raypex 5 and the Mini Apex Locator: an *in vivo* study. *J Endod* 2011;37: 1349-52.

6. VDW GmbH. *Apex locator Raypex 5 User Manual.* Endodontic Synergy VDW, Endo Easy Efficient. Munich, Germany. p. 17-32.
7. Altman D. **Practical statistics for medical research.** 1st ed. Chapman and Hall, London; 1991. p. 277-99.
8. Vajrabhaya L, Thongsuphan S, Runghirunskul S, Korsuwannawong S. Development of simulated resin jaw in endodontic laboratory. *J Dent Assoc Thai* 2010;60:258-64.
9. Huang L. An experimental study of the principle of electonic root canal measurement. *J Endod* 1987;13: 60-4.
10. Hülsmann M, Pieper K. Use of an electronic apex locator in the treatment of teeth with incomplete root formation. *Endod Dent Traumatol* 1989;5: 238-41.
11. Jenkins JA, Walker WA, Schindler WG, Flores CM. An *in vitro* evaluation of the accuracy of the RootZX in the presence of various irrigants. *J Endod* 2001;27:209-11.
12. Chen E, Kaing S, Moban H, Ting SY, Wu J, Parashos P. An *ex vivo* comparison of electronic apex locator teaching model. *J Endod* 2011;37:1147-51.
13. Wrbas KT, Ziegler AA. *In vivo* comparison of working length determination with two electronic apex locator. *Int Endod J* 2007;40:133-8.
14. Gutierrez JH, Aguayo P. Apical foraminal openings in human teeth. Number and location. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1995;79: 769-77.
15. Pineda F, Kuttler Y. Mesiodistal and buccolingual roentgenographic investigation of 7,275 root canals. *Oral Surg Oral Med Oral Pathol* 1972;33:101-10.
16. Dummer PM, McGinn JH, Rees DG. The position and topography of the apical cannal constriction and apical foramen. *Int Endod J* 1984;17:192-8.
17. ElAyouti A, Weiger R, Löst C. Frequency of overinstrumention with an acceptable radiographic working length. *J Endod* 2001;27:49-52.
18. European Society of Endodontology. Undergraduate curriculum guideline for endodontology. *Int Endod J* 2001;34:574-80.