An improved model for teaching use of electronic apex locators

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Abstract

Aim To develop a simple, practical and inexpensive model, which enables the use of electronic apex locators (EALs) during pre-clinical and continuing education.

Methodology Extracted teeth were placed in a mould and embedded in acrylic resin. The resin was applied in two consecutive steps to form a cavity around the root apices. A closable plastic tube serves as a valve, and a steel wire connects to the EAL.

Results With its semi-closed reservoir for conductive fluids surrounding the root apices, the new model enables working length measurements of root canals using EALs.

Conclusions The model simulates the clinical situation for endodontic teaching purposes, as it allows working length determination of root canals as recommended. The measuring results of the EAL can be verified by radiography. At the same time, the roots are not directly visible and accessible to the user, allowing a precise evaluation and grading of the treatment.

Keywords: electronic apex locator, pre-clinical education, teaching model.

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Introduction
The undergraduate curriculum guidelines for Endodontology, published by the European Society of Endodontontology (2001), state that undergraduate training should be at a level that ensures an improved standard in clinical practice. Nonetheless, students show a markedly higher incidence of inadequate root fillings compared with treatments performed by more experienced dentists (Farzaneh et al. 2004, Eleftheriadis & Lambrianidis 2005, Khabbaz et al. 2010). These findings demonstrate the significance of endodontic teaching. Undergraduate students require intensive practical exercises, before performing endodontic procedures in patients for the first time. The major challenge is to simulate a condition that helps students to transfer their knowledge acquired from the pre-clinical setting to the clinic. It can be assumed that the quality and quantity of endodontic education has a possible impact on the treatment outcome (Lynch & Burke 2006, Sonntag et al. 2008). Several teaching approaches have been introduced in this respect, including the use of human skulls (Pitts et al. 1984), bovine mandibles (Bramante et al. 1981) and porcine jaws (Beatty & Vertucci 1984). Nowadays, it is common practice to use extracted human teeth during pre-clinical endodontic education (Nattress et al. 1997). They can be placed into a dental model embedded in a variety of materials and be mounted in a manikin head to simulate a realistic clinical situation. Although these models enable radiographic imaging, they do not provide the conditions for the application of techniques such as electronic apex locators (EALs). The recommendation for working length determination today is a combination of apex...
The aim of this study was to adapt the set-up of previous laboratory studies (Baldi et al. 2007, Stoll et al. 2010) to develop an endodontic teaching model, which enables the use of EALs. A prerequisite was inexpensive fabrication with minimal laboratory effort. Furthermore, the root apices should not be directly accessible, to allow a validated evaluation and grading of the outcome of endodontic procedures during pre-clinical courses. To enable unrestricted use throughout the duration of a pre-clinical course, the model should be durable and storable.

Materials and methods

The fabrication process is illustrated in Fig. 1. First, plaster duplicates of dental study models (0.623.1492; KaVo, Biberach, Germany) were produced. The palatal and lingual sections of the corresponding arch were reduced to facilitate paralleling radiographic imaging. A silicon duplicating mould was fabricated subsequently. Extracted teeth with closed apices were placed into the fabricated form, and impression silicon putty (Eurosil Max; Henry Schein, Melville, NY, USA) was formed around the roots. Spaces between the roots and the occlusal surface were additionally sealed using dental wax (a–c). The silicon putty was cut back, leaving no recessed areas, a levelled surface and a consistent gap towards the mould (d). Afterwards, acrylic resin (Paladur; Heraeus Kulzer, Hanau, Germany) was used in two consecutive steps to build the model. During the first step, the model was filled with resin up to the top of the silicon putty (e). In this process, the putty served as a placeholder and was removed after the resin had set. An orthodontic steel wire was used to build a loop with angled ends reaching into the previously constructed cavity (f). It was attached to the model at a distance away from the roots to prevent radiographic superimposition. In the second step, the model was taken out of the model and placed in reverse in a resin-filled base former (g). The margin edges were trimmed, and an aperture with an approximate diameter of 5 mm was drilled in the distal end of the model (h). In a final step, the tip of a plastic tube (ThermoTube™ PCR Tube 0.2 mL; Peqlab, Erlangen, Germany) was cut-off, and the tube was attached to the opening, serving as a valve for the enclosure (i). Depending on available pre-clinical teaching equipment, any type of base plate can be attached afterwards to enable use in a manikin head.

![Figure 1](figure) Figure 1 Figure illustrating the fabrication of the model step-by-step (a–i).
Results
This set-up results in a semi-closed reservoir that surrounds the root apices and can be filled with a conductive medium such as saline. The teeth are embedded in the model, and the roots are not directly accessible or visible. The incorporated steel wire enables a connection to the apex locator electrode, where the ends reach into the enclosure and close the electric circuit.

Discussion
According to endodontic surveys, the majority of dentists still use radiographs for endodontic working length determination (Bjørndal & Reit 2005, Lee et al. 2009). Qualtrough et al. (1999) revealed in an international comparison that only 21–43% of the dental schools taught the use of EALs. Furthermore, Chandler & Koshy (2002) observed a relation between the year of qualification and EAL usage, allowing the assumption that students who learned the advantages of EALs continue to use them. For this reason, the application of EALs in clinical and continuing education should be promoted to improve their acceptance.

Major disadvantages of radiographs for the determination of working length are variations in root canal anatomy and the consequential high variance of average values that are used to define the distance between anatomical apex and apical constriction (Kuttler 1955, Dummer et al. 1984). The frequency of laterally located foramina can lead to misinterpretation of radiographic working length and result in unintentional overinstrumentation (Pineda & Kuttler 1972, ElAyouti et al. 2001). A further disadvantage of radiographs is their two-dimensionality. Superimposition of anatomical structures can require retakes of endodontic radiographs (Gound et al. 1994). EALs are a useful aid in this regard, and their application is reported to potentially reduce the number of radiographs taken during endodontic treatment (Brunton et al. 2002, Chandler & Koshy 2002). Their accuracy in locating the minor foramen within ±0.5 mm is up to 100% (Vieyra et al. 2010). Although EALs have been used in several laboratory studies, this set-up has not been successfully adopted to pre-clinical endodontic teaching models (Baldi et al. 2007, Stoll et al. 2010, Vieyra et al. 2010). One attempt was made by Tinaz et al. (2002). Their model used alginate as an embedding medium to enable the use of EALs during pre-clinical endodontic teaching. However, they evaluated root canal length measurements and observed increasing values over time. When the diameter of the foramen was greater than 0.45 mm and the alginate was set for more than 28 h, measurements were even beyond the apex. This disadvantage makes the use of EALs in a teaching model difficult. Although alginate showed the highest accuracy comparing different embedding media, considering the duration of a pre-clinical endodontic course, the apical alginate depot would have to be replaced repeatedly (Baldi et al. 2007, Chen et al. 2011). Furthermore, the root apex is accessible without great effort, and a validated evaluation of the competence level is not possible.

In conclusion, a semi-closed system and change of the embedding media to saline seem to be appropriate. The model simulates the clinical situation and enables both the use of EALs for root canal length measurements and radiographic verification (Fig. 2). All the materials of the present model are commonly available in a dental clinic or laboratory. The manufacturing time is kept within limits and takes less than one hour. However, using teeth with open apices and placing the model in the maxillary position of the manikin head can result in reduction in the fluid level over time. In this case, the plastic tube serves as a valve, which can be used to refill or refresh the conductive media. The model can also be drained for storage purposes and be used in the following course for exercising retreatment techniques.

Figure 2 Example of root canal treatment performed using the teaching model (a–c). Working length is determined using electronic apex locator (a), followed by radiographic verification (b).
The teaching model described has been introduced and evaluated successfully in the pre-clinical endodontic course at the Faculty of Dentistry in Freiburg.

**Conclusions**

The model simulates the clinical conditions for endodontic teaching purposes realistically, as it allows working length determination of root canals as recommended. The measuring results of the EAL can be verified by radiography. At the same time, the roots are not directly visible and accessible to the user, allowing a precise evaluation and grading of the treatment.

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**References**


