Recognition of Root Canal Orifices in Video Sequences as a Future Support System During Endodontic Treatment

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Abstract

Introduction: The objective of this study was to show the practical application of computer-aided techniques for detecting root canal orifices through the access cavity using a video camera mounted on a microscope. **Methods:** A minimum distance classification image recognition algorithm was tested in an *in vitro* study to assess the possibilities of computer-aided recognition of root canal orifices. A Motic DM143 digital stereo microscope (Motic Germany GmbH, Wetzlar, Germany) was used because it includes a video camera that can be connected via USB1.1 to any computer. **Results:** The newly developed software is capable of communicating with a video camera and can automatically detect the root canal orifices in all teeth used in this study. A total of 165 extracted human teeth (molars and premolars) were used as test data to collect 8,250 images via screenshots for the evaluation of the detection quality. The software provided a detection sensitivity of 90.1%, with only 11.9% of the images as false-positive detections. **Conclusion:** The study shows that computer-aided recognition of root canal orifices with video cameras is possible. *(J Endod 2009;35:1400–1403)*

Key Words

Automatic detection, computer vision, root canal orifices, video

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Since microscopes were introduced into endodontics in 1977, a number of optical devices have been developed and improved to support operators during endodontic treatment (1–3). Except for the increasing spread of operation microscopes, a large number of practitioners use loupes in conjunction with headlamps as well as the recently introduced endoscope for apical surgery. Endoscopes have been investigated in endodontics since Detsch et al (4) first used the endoscope to diagnose dental fractures in 1979, and Held et al (5) reported the first employment of the endoscope in surgical and nonsurgical endodontics in 1996. The first unique intraoral camera documented in the dental literature was reported by Chanda (6). The increasing spread of intraoral cameras opens new possibilities for magnification purposes, allows simultaneous documentation of findings, and opens the possibility of augmented reality applications. The additional information displayed in the visible video stream should support both operators and patients in real time during therapy. An example of such an application for endodontics is introduced in this article as a software program that can be used with standard intraoral or microscope cameras connected via a USB to any computer operating under Microsoft Windows 98, 2000, or XP (Microsoft, Redmond, WA). Clinical studies (7–9) have found the ability of clinicians to identify and negotiate canals in maxillary molars to be significantly improved by the use of the operating microscope. Intraoral cameras and the application of microscopes in endodontics are increasingly becoming standard techniques in dental medicine. The application of intraoral cameras opens new options to support the operator with augmented reality that cannot only improve the treatment procedure but also render the treatment strategy more apparent and thus more comprehensible. The system introduced here is a conceptually new development that advances imaging in endodontics into the realm of computer vision and augmented reality. The video image of the accessed tooth can be scanned automatically for the coronal contours of the root canal orifices with this software program. Although at its current state of development, our system only approaches experienced operators with respect to detection of root canal orifices, it nonetheless can certainly serve as a tool to visualize the canal orifices and treatment strategy for the patient via a video screen.

Methods

A total of 165 extracted human teeth from second dentition (patient age varied between 40 and 70 years) with fully intact root and enamel surfaces and without endodontic treatments recently extracted for periodontal reasons were selected for this study. Only molars and premolars and no wisdom teeth were used in this study. The teeth were immersed in 1% chloramine solution for 3 days to disinfect them and subsequently kept for 24 hours in 3% hydrogen peroxide (H_2O_2) before cleaning their external surfaces from residual connective tissue. Only completely intact teeth were selected to ensure that the hydrogen peroxide only bleached the outer surfaces and did not penetrate as far as the root canal orifices. After thorough cleaning, the lower third of the tooth roots were fixed in a plaster block. In this position, the teeth were then accessed according to the applicable rules (10–12); this involved removing the entire top of the pulp chamber to provide a view of the entire floor of the pulp chamber from a certain angle. Pulp tissue was removed using 3% natriumhypochlorid and a hand excavator (E1 Excavator; Hu-Fiedy, Chicago, IL) and extirpation needles. Teeth where two canals emanated from a single orifice (so-called 1-2 configuration) were excluded from this study. Furthermore, artificial gingival scalloping was added by applying impression material (Panasil Putty; Kettenbach, Eschenburg, Germany) up to the

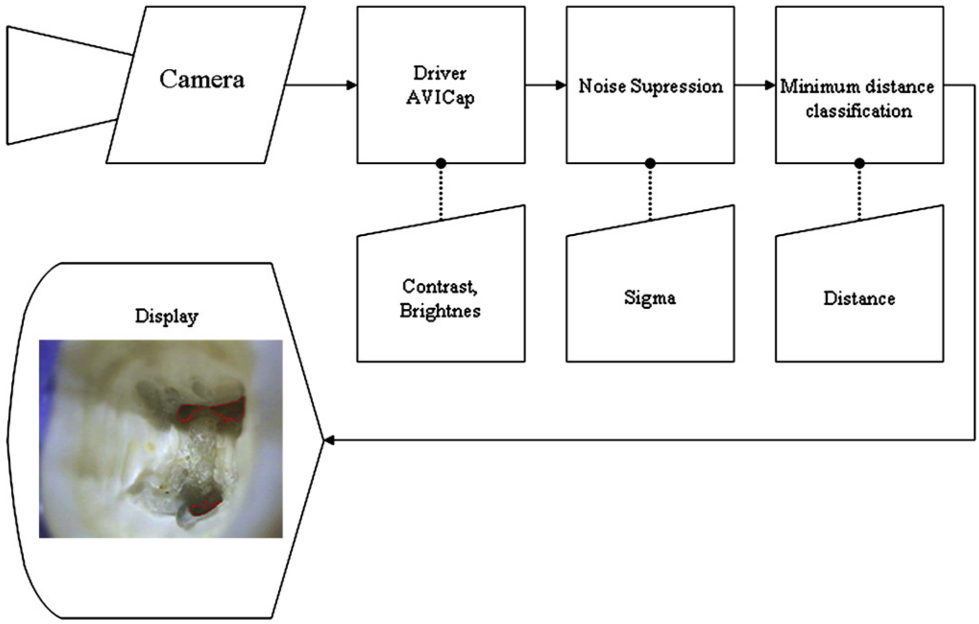

Figure 1. A schematic flowchart of the detection algorithm.

enamel/cementum junction to avoid light shining through from beneath the crown because this incident light is not present with natural teeth. A DM143 digital stereo microscope (Motic Deutschland GmbH, Wetzlar, Germany) was used to obtain the video sequences. The microscope communicated via USB 1 with a 2-GHz Intel Pentium 4 Dell Optiplex 240 (Dell, Round Rock, TX) equipped with 256-MB Ram. The Windows AVICap(Audio Video Capture) functions of Microsoft® Video for Windows® (VFW, Microsoft, Redmond, CA) were used to communicate with the video driver. The interface described is capable of communicating with any Windows video driver. Borland Developer Studio 6 (Borland GmbH, Langen, Germany) was used to write a software program that can run on any Windows computer higher than Windows 98. To obtain reproducible and comparable results, the contrast, brightness, and noise suppression levels were adjusted on the camera at maximum incident light with the light source integrated in the microscope. A KL1500 cold light source (Schott, Mainz, Germany) was used.

The detection algorithm applied here exploits the optical properties of the root canal orifices (Fig. 1). First, being the deepest regions in the pulp chamber floor, the canal orifices are always the darkest regions of the image within the cavity boundary on the video image (shadow), and, second, their contours always appear solid as well as largely round, elliptical, or oval. A three times three pixel sized Gaussian convolution kernel was used for preprocessing (with a standard deviation of 0.8) to reduce the noise in the video images. Because the root canal orifices represent themselves as the deepest canyons in the pulp chamber and therefore darkest image regions under incident light caused by the cast shadows, an initial pixel p_i can be taken to detect the root canal

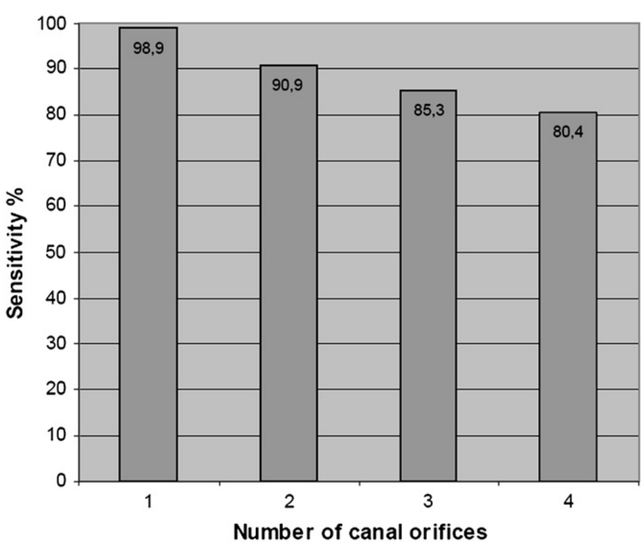

Figure 2. Sensitivity of the computed detection for the four groups shown as percentage of the canal orifices found by an experienced operator.

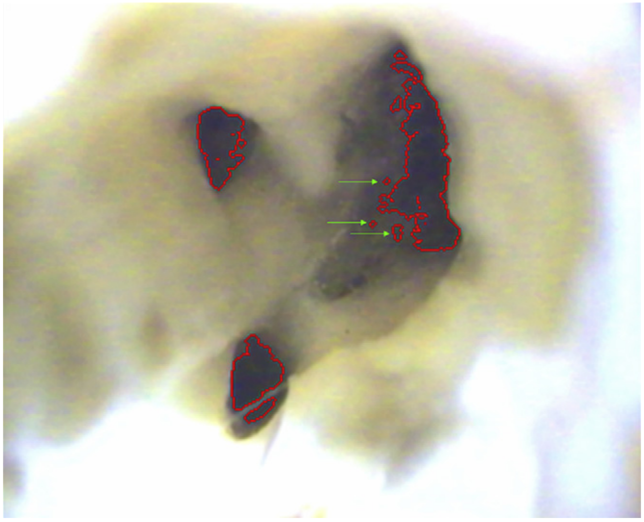

Figure 3. An illustration of the false-positive display indicated by the green arrows.

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