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Original Article

In vitro visualization of human endodontic structures using different endoscope systems

Wilfried Engelke[1], Carolina Leiva[2], Gunar Wagner[3], Víctor Beltrán[1,2]

[1]*Department of Oral and Maxillofacial Surgery, Medical Faculty, Georg August University, Göttingen, Germany;* [2]*CIMOFIR Research Center, Dental School, Universidad de La Frontera, Temuco, Chile;* [3]*Department of Prosthodontics, Georg August University, Göttingen, Germany*

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Abstract: Different endoscope optics for the visualization of interradicular structures were evaluated as a diagnostic tool. A sample of 20 extracted human lower molar teeth was used. Only teeth with fully formed apices were included. All samples were evaluated with three different endoscopic procedures: pulp endoscopy (PE), canal entrance endoscopy (CEE) and root canal endoscopy (RCE). All pulp chambers could be observed using PE (100%), however, only 41 of 60 (68.3%) canals were observed. With CEE, all entrances could be observed, and the middle third of the canals could be visualized in 85% of the canals. The semiflexible endoscope for RCE allowed successful observation of 91.6% of the middle third of the canals. The application of the endoscope may be useful in the identification of root canals even under difficult visual work field conditions. The combined use of a set of various optics might enable the operator to enhance the quality of non-surgical endodontic procedures.

Keywords: Endodontic visualization, endoscopy, root canal

Introduction

A successful outcome of endodontic treatment depends on a high degree of accurate diagnostic and intraoperative visualization. Conventional methods of endodontic diagnosis are based on periapical radiographs, which are used as an initial guide in the formation of a mental image of the canal anatomy. Radiographs are limited in that they reveal only two dimensions of the three dimensional area represented by the image. There also may be geometric distortion of the anatomical structures being imaged [1].

Additionally, some evidence has been found that the use of a magnification device in any endodontic procedure is related to a better clinical outcome compared with the same procedures performed without magnifiers [2]. The integration of optical magnification instruments such as loupes, microscopes and endoscopes into the endodontic working tools enable the magnification of a specified treatment field beyond that possible with the naked eye [3]. Loupes are magnification devices that are widely used in dental procedures that allow easy focus on the surgical field and that have been used to enhance visualization of tissues and to facilitate optimal instrument placement [4]. However, dental loupes have limitations, such as a fixed magnification, which may not allow for proper visualization in all surgical steps. Loupes with integrated light sources could be clinically useful; however, it has been reported that they do not provide any measurable acuity inside the root canal and are dependent on the operator's experience [5].

Forgie et al. [6] reported the use of an intraoral camera in general dental practice and reported an improvement in the detection of occlusal caries. An intraoral camera an intraoral camera helped observers to assess the absence, presence and extension of caries more accurately compared with conventional methods [7].

Intraoral cameras also have been considered as useful tools for orthodontic documentation and have proved to be advantageous for clinical dentistry, research and caries detection. A further possibility for image-analysis-based diag-

Figure 1. Sample teeth mounted in colorless acrylic autopolymer model.

nosis that uses digital intraoral cameras as a support system is the detection of root canal orifices for computer-assisted education [8]. Currently, some intraoral cameras provide reliable assistance to visual color assessment compared to conventional visual methods [9].

Several authors have shown that the surgical microscope is a device that provides visual access to microsurgical techniques with a high degree of reliability and accuracy [10, 11]. The surgical microscope has been used in different areas of medicine such as neurosurgery, ophthalmology and vascular surgery. It also has been used in dentistry, particularly in endodontics, and provides several advantages that include enhancement of visual procedures during endodontic therapy. It has also been used as a diagnostic tool [12] in the detection of small orifices, in vertical root fractures and as a complementary tool in procedures such as repair of perforations [13] and removal of obstacles inside the root canal. However, the bulk of the microscope makes its application more complicated. For example, there is interference of the handle and the handpiece with the visualization of the surgical field, which makes observation of the endodontic instruments more difficult during the procedure [14].

The endoscope has been used in medicine as a complementary tool in oral and pharyngeal diagnosis. The use of the endoscope in endodontics was first described in 1979 as an aid in the diagnosis of root fracture of a maxillary central incisor [15]. In 1996, other authors reported the use of endoscopes in surgical and conventional endodontic applications [16, 17].

Support Endoscopy (SE) is a technique that involves a short distance between the lens and the object being visualized and that uses an endoscopic optic with a support sheath. It is a tool for visualization during minimally invasive procedures. The pollution of the optical system as a result of short distance to the site could be solved by an intermittent or a continuous internal irrigation system [18].

The aim of the present article is to show the in vitro visualization of experimental endodontic structures using a variety of endoscopic tools to demonstrate their utility as complementary or alternative methods to the dental microscope and to other visual aids.

Materials and methods

Sample

Samples of 20 human extracted lower molar teeth (60 canals) were used. Only teeth with fully formed apices were included. Exclusion criteria included endodontic therapy; larger restorations; severely damaged crowns, which made clinical examination impossible; vertical and or horizontal fractures; and the presence of anatomical aberrations.

Root canal preparation

All root canal lengths were determined by introducing a # 10 K-file (VDW, Germany) until its tip was visible at the apical foramen. Working length was established by subtracting 1 mm from the total length. All teeth then were processed and mounted in colorless acrylic autopolymer models (Paladaur, Heraeus Kulzer # 64707948) (**Figure 1**). The root canals were instrumented according to the manufacturer's instructions using the Mtwo System (VDW, Munich, Germany) at a speed of 280 rpm, as recommended by the manufacturer (Endomate TC2 NSK, USA). A crown-down technique was used with continuous irrigation of isotonic saline solution. The preparation sequences of each distal molar root canal were performed until 40/04. The preparation sequence of each mesial root canal was performed until 30/05. All pulp chambers and root canals were examined using various endoscopic optics. Pulp chambers were examined using rigid endoscopes only, and the root canals were examined using rigid and semiflexible endoscopes.

Endoscopic equipment

The rigid endoscopic system equipment consisted of endoscopes of 2.7 mm and 1.9-mm diameter with support and irrigation sheaths

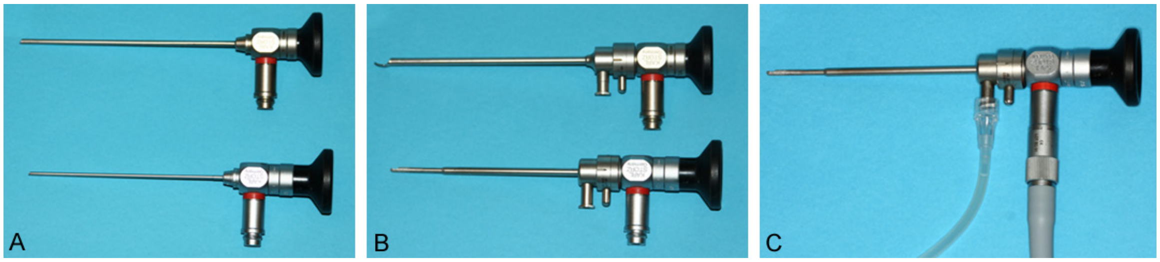

Figure 2. Rigid endoscopic systems: A. Optics (Rigid) 2.7 mm and 1.9 mm. 30 degree view angle. B. Optic assembled with its support. C. Connection to the light source and irrigation.

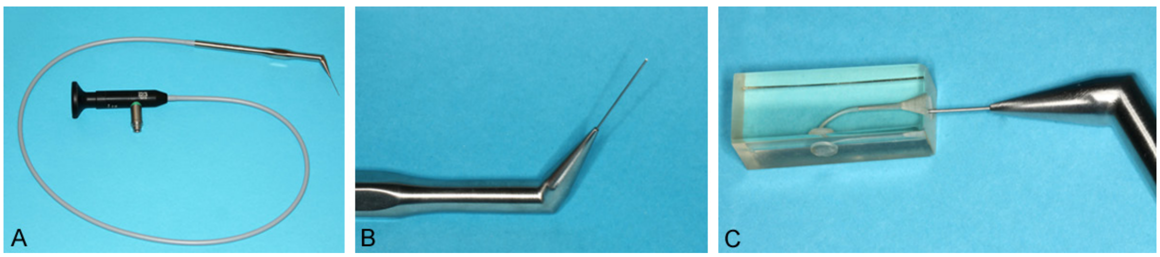

Figure 3. Semiflexible Endoscope: A. Semiflexible Endoscope, outer diameter 0.5 mm and 0 degree views angle. B. Angled handpiece with incorporated fibre optic and light transmission. C. Endoscope inserted into the root canal of a phantom.

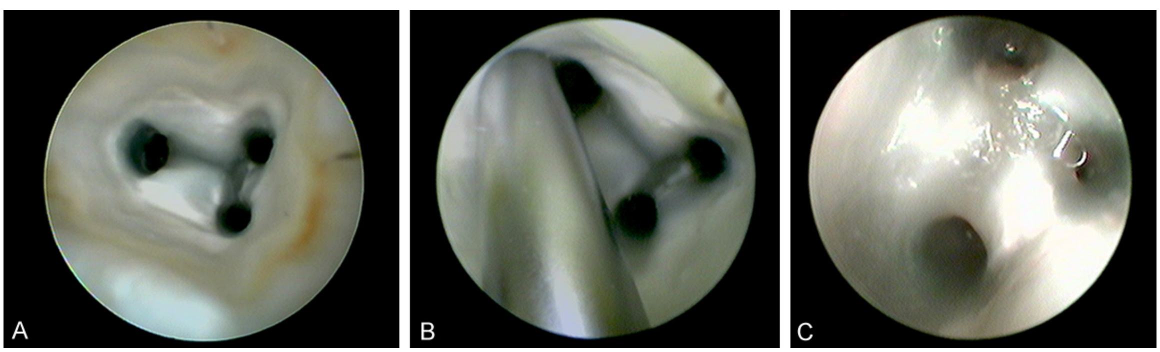

Figure 4. Pulp endoscopy (PE) of first right lower molar (2.7 mm endoscope): (A) General view of the pulp Chamber. (B) 1.9 mm endoscope viewed from a pulp perspective. (C) Image obtained by the optic shown in (B).

(Karl Storz, Tuttlingen, Germany). The endoscopes were linked to a Storz 487-B examination unit and a Xenon 300-W light fountain with a 6,000-K capacity (Karl Storz) (**Figure 2**). The semiflexible endoscopic equipment consisted of a miniature straight forward telescope of 0°, an angled hand piece, an outer diameter of 0.5 mm, a working length of 2 cm and a remote eyepiece with incorporated fiberoptic light transmission (Karl Storz, Tuttlingen, Germany) (**Figure 3**).

Evaluation

All samples were evaluated using the three different endoscopic procedures: pulp endoscopy (PE), canal entrance endoscopy (CEE) and root canal endoscopy (RCE).

For PE, a 2.7 or 1.9 mm optic was placed at the trepanation orifice to provide inspection of the pulp chamber and, in particular, the location of the canal entrances. CEE was performed by placing a 1.9 mm endoscope at the canal entrance to visualize the proximal third of the root canal. RCE was performed using a semiflexible endoscope, which was introduced into the root canal down to the diameter provided by the previous preparation.

Figure 4 shows a pulp endoscopy of a first lower molar. The view allowed an overview of the pulp

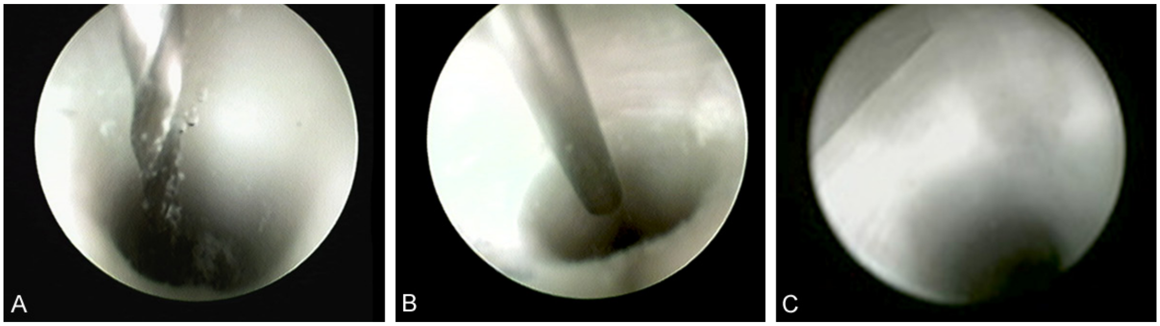

Figure 5. Canal entrance endoscopy using 1.9 mm endoscope: A. Endoscopic view with a file inside of the root canal. B. View of the root canal entrance with the semiflexible endoscope introduced into the canal. C. View of Fissure near the pulp chamber.

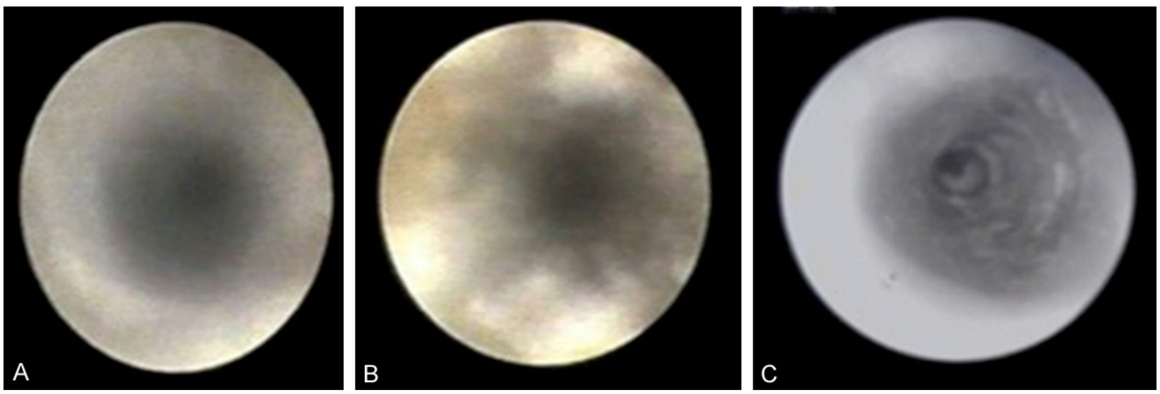

Figure 6. Root canal endoscopy with semiflexible endoscope: A. Endoscopic view of the cervical section of the root canal. B. Endoscopic view of the middle section of the root canal. C. Endoscopic view of the apical section of the root canal.

Table 1. Visibility of different anatomical structures with endoscopic techniques for clinical application

n = 60	PE	%	CEE	%	RCE	%
Pulp Chamber (20 teeth)	20	100	20	100	Not Applied	
Canal entrance (60 canals)	60	100	60	100	Not Applied	
Middle third (60 canals)	41	68.3	51	85	55	91.6
Apical third (60 canals)	10	16.6	20	33.3	28	46.6

chamber from the trepanation orifice to be obtained and allowed visualization of the root canal entrances.

In CEE, the rigid endoscope was introduced into the entrance of the canal following canal preparation. This allowed a low distance to the entrances and the observation of the proximal lumen of the root canals. It was also possible to introduce a file inside the root canal while the observation was performed (**Figure 5**).

For RCE, the semiflexible endoscope was inserted into the lumen of the canal like a rotating dental instrument (**Figure 3C**).

Figure 6 shows a representative image of the apical third of distal root canal of a lower molar.

Results

The visibility results of different anatomical structures with different endoscope techniques are reported in **Table 1**.

In terms of the definition of success, all pulp chambers could be observed using PE. However, only 41 of 60 (68.3%) canals were observed with this method.

With CEE, all entrances could be observed, and 85% of the middle third of the canals could be

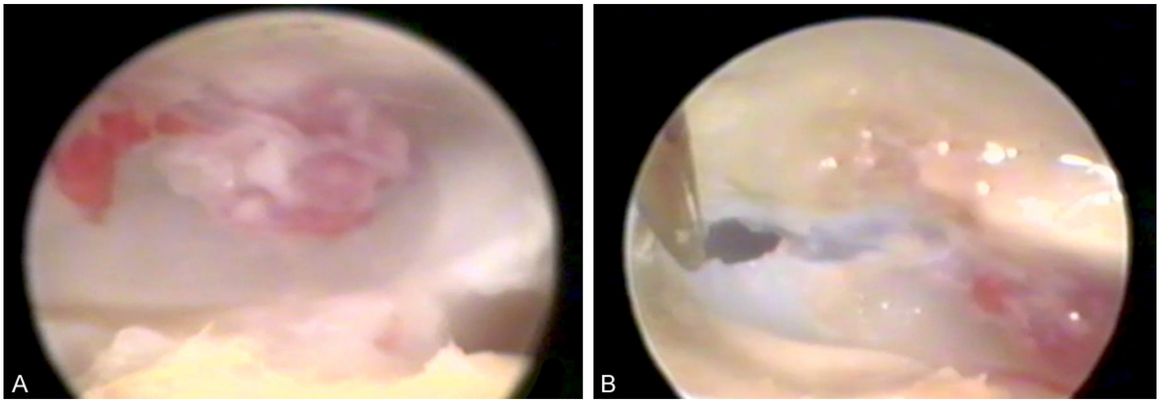

Figure 7. A Clinical Example of endoscopic visualization under Immersion technique using 1.9 mm endoscope: A. Pulp chamber perforation with granuloma tissue, B. Short distance observation of the pulpal floor perforation.

visualized, but in only 20 of 60 (33.3%) were the apical third of the canals observed.

Using the semiflexible endoscope for RCE, 55 of 60 of the middle third of the canals were observed successfully. This resulted in a success rate of 91.6%, but only 28 of 60 (46.6%) of the apical third of the canals were visible.

A clinical example of endoscopic visualization can be seen in **Figure 7**. A lower molar with an iatrogenic perforation on the floor of the pulp chamber is observed using a 1.9 mm optic with immersion. The endoscopic view allows the in vivo visualization of the perforation and of a granuloma of the root canal.

Discussion

Experience has shown that the use of conventional microscopes, intraoral cameras or loupes frequently requires interruption of an on-going surgical procedure because of a time-consuming cleaning process [11]. The endoscope provides the dentist with excellent vision without the use of additional mirrors. Additionally, because of its non-fixed field of vision, the endoscope allows observation of the surgical field at various angles and distances without losing depth of field and focus [19]. The easy cleaning of the work field through intermittent, continuous or simultaneous irrigation is an important advantage for clinical application. This allows the operator to visualize and work at the same time while cleaning the system, without the need for intermittent removal of the device [14].

The main use of intraoral cameras has been described for caries detection. Emerging technologies have been able to develop intraoral cameras combined with a computer software to be applied as diagnostic tools for root canal orifices [8]. Although this was very useful for real time detection of root canal orifices, there are no reports about the effectiveness of visualization inside of the root canal.

The superiority and high sensitivity of endoscopy versus other visualization techniques has been demonstrated in an in vitro study involving the correct identification of dentinal cracks in resected root ends [20].

Similar outcomes have been observed by Von Arx et al., who evaluated the accuracy of endoscopy as a visual aid for the identification of the detection of dentinal cracks after root-end resection [21].

Previous studies have used the orascope as a magnification tool for assessing dentine cracks. The accuracy of correct identification with an endoscope was significantly better than with other magnification devices.

The results of the current study show that the application of PE was very useful in the identification of pulp chambers and the entrances of the root canals. The perspective of the direct view with the 2.7 mm optic is similar to the main occlusal perspective during microscopic examination of the pulp. Pulposcopy is performed under dry conditions if there is no major pollution by bleeding. In case of bleeding or other forms of pollution, the inspection may be performed with intermittent cleaning of the lens by water stream injection or performed under continuous irrigation (immersion endoscopy). The application of the rigid endoscope (2.7 mm and 1.9 mm) appears to be useful in endoscopically assisted visualization and allows simultaneous shaping of the root canal walls. It also appears to be very useful in the identification of root canals. The use of simultaneous irrigation has allowed the identification of root canals, even under difficult visual work field conditions.

For large trepanations, a 2.7 mm optic with a support sheath is the instrument of choice; small trepanation orifices required the use of the 1.9 mm optics, which may be guided directly or with a support sheath.

In general, the application of the semiflexible endoscope with a diameter of 0.5 mm allows the visualization of the morphology of the apical third and the middle section of root canals and permits the determination of how well the canal is prepared after mechanical shaping. Nevertheless it has drawbacks, such as the low optical resolution and the limited access to curved root canals due to the fragile design of the optical fiber. Some narrow canals could not be observed because the flexible endoscope could enter only a few millimeters into the lumen.

The majority of the root canals had a very narrow canal diameter that did not allow the complete introduction of the endoscope that was needed to obtain visual access of the apical zone. Other canals had curvatures that interfered with the visualization of the apical third. Generally, the semiflexible endoscope provides imaging of the apical third of the root canal without actually having to be placed in this area of canal [3]. We agree that it is a very delicate device, and some wedging into the canal may damage fiber optic bundles within the scope. Additionally, the canal should be dry because the fiber optic probe will not properly visualize a canal filled with liquid or dentin particles.

Additionally, the use of sodium hypochlorite may be critical because this solution has a high light refractory index, such that the light is reflected which makes correct observation inside the canals difficult.

In our work, the semiflexible endoscope requires a minimum file size of # 35 file to reach the middle third. In contrast, the Bahcall orascope has a 0.8-mm diameter tip, and the canal requires a minimum file size of # 90 for the root canal [3].

We believe that use of the semiflexible endoscope allows a more conservative preparation of the root canal, although in some cases, it would be convenient to enlarge the canal for a better directly visualized treatment of the root canal using CEE or RCE.

Our work has revealed some critical visualization problems that could be solved by a combined approach. The guidance of the 1.9 mm endoscope is best supported using the 2.7 mm endoscope. It is possible to obtain quality images of the root canals and, in some cases, even including the apical third. The combination of the 1.9 mm endoscope with the 0.5 mm flexible endoscope does not allow the possibility of simultaneous mechanical instrumentation; however, this combination could allow good vision of the inside of the root canal to the apical third.

The difference between the quality of images obtained by the rigid and semiflexible endoscopes depends on the resolution capacity of the flexible endoscope and is determined by the number of fibers contained in the image transmission system. In contrast, the resolution capacity of a rigid endoscope is limited only by the wavelength and therefore has a resolution that is considerably higher than that of the flexible endoscope in achieving high quality images [22].

It is important to mention that the flexible endoscope is easier to handle compared with the rigid endoscopes. For the semiflexible endoscope a pencil-like manner can be used to place the device. On the other hand, the rigid endoscope usually requires additional assistance, especially during the mechanical preparation procedures of the root canal walls.

Further development of endoscopy might include the combination of magnification, light, irrigation/suction and surgical micro-instruments in one device. This combination could lead to more advanced root canal treatment techniques [14].

The endoscope may be considered for use in preoperative observation and diagnosis and could be useful for endodontic treatment. Generally, an endoscope appears to be the best tool to use for diagnostics of the pulp chamber and canal entrances of root canal. It is also very useful in shaping of root canals and in keeping the work field clean. The endoscope allows visualization of the apical and middle section of root canals but has limited access to curved or narrow root canals.

The application of the endoscope appears to be useful in endoscopic-assisted visualization and very useful in the identification of root canals. Simultaneous irrigation can assist in the identification of root canals, even under difficult work field visual conditions. The combined use of a set of various optics might enable the operator to enhance the quality of non-surgical endodontic procedures.

Disclosure of conflict of interest

None.

Address correspondence to: Carolina Leiva, Dental School, Universidad de La Frontera, Temuco 478-1176, Chile. Tel: 56-45-2325775; E-mail: Carolina.leiva@ufrontera.cl

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