The Use of the Operating Microscope in Endodontics

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KEYWORDS

• Operating microscope • Magnification • Endodontics

Endodontists have frequently boasted that they can do much of their work blindfolded simply because there is "nothing to see." The truth is that there is a great deal to see with the right tools.[1]

In the last 15 years, for nonsurgical and surgical endodontics, there has been an explosion in the development of new technologies, instruments, and materials. These developments have improved the precision with which endodontics is performed. These advances have enabled clinicians to complete procedures that were once considered impossible or that could be performed only by talented or lucky clinicians. The most important revolution has been the introduction and widespread adoption of the operating microscope (OM).

OMs have been used for decades in other medical disciplines: ophthalmology, neurosurgery, reconstructive surgery, otorhinolaryngology, and vascular surgery. Its introduction into dentistry in the last 15 years, particularly in endodontics, has revolutionized how endodontics is practiced worldwide.

Until recently, endodontic therapy was performed using tactile sensitivity, and the only way to see inside the root canal system was to take a radiograph. Performing

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endodontic therapy entailed "working blind," that is, most of the effort was taken using only tactile skills with minimum visual information available. Before the OM, the presence of a problem (a ledge, a perforation, a blockage, a broken instrument) was only "felt," and the clinical management of the problem was never predictable and depended on happenstance. Most endodontic procedures occurred in a visual void, which placed a premium on the doctor's tactile dexterity, mental imaging, and perseverance.

The OM has changed both nonsurgical and surgical endodontics. In nonsurgical endodontics, every challenge existing in the straight portion of the root canal system, even if located in the most apical part, can be easily seen and competently managed under the OM. In surgical endodontics, it is possible to carefully examine the apical segment of the root end and perform an apical resection of the root without an exaggerated bevel, thereby making class I cavity preparations along the longitudinal axis of the root easy to perform.

This article provides basic information on how an OM is used in clinical endodontic practice and an overview of its clinical and surgical applications.

ON THE RELATIVE SIZE OF THINGS

It is difficult, even for a scientist, to have an intuitive understanding of size. Specifically, a dentist must have an accurate understanding of the relationship between the gross dimensions involved in restorative procedures and the dimensions of deleterious elements that cause restoration failure, such as bacteria, open margins, and imperfection in restorative materials. A filling or a crown may appear well placed, but if bacteria can leak through the junction between the tooth and the restorative material, then treatment is compromised.

A brief review of relative size may be helpful. Cell size is measured in microns (millionths of a meter, μm), and a single bacterial cell is about 1 μm in diameter. One cubic inch of bacteria can hold about a billion cells. A typical human (eukaryotic) cell is 25 μm in diameter, so an average cell can hold more than 10,000 bacteria. By comparison, viruses are so small that thousands can fit within a single bacterial cell. Simple calculations show that 1 in^3 can contain millions of billions of viruses.These calculations do not end there. For example, the size of macromolecules (eg, bacterial toxins) is measured in nanometers, or one-billionth of a meter (**Fig. 1**).

Some of these bacterial toxins are so potent that even nanogram quantities can cause serious complications and even death. Clearly, dentists are at a severe disadvantage in their attempts to replace natural tooth structure with artificial materials that do not leak, in view of the virtually invisible microbiologic threats to restoration integrity.[2]

THE LIMITS OF HUMAN VISION

Webster defines resolution as the ability of an optical system to make clear and distinguishable 2 separate entities. Although clinicians have routinely strived to create bacteria-free seals, the resolving power of the unaided human eye is only 0.2 mm. Most people who view 2 points closer than 0.2 mm will see only 1 point. For example, **Fig. 2** shows an image of a dollar bill. The lines making up George Washington's face are 0.2mm apart. If the bill is held close enough, one can probably just barely make out the separation between these lines. If they were any closer together, you would not be able to discern that they were separate lines. The square boxes behind Washington's head are 0.1 mm apart and not discernible as separate boxes by most people. The

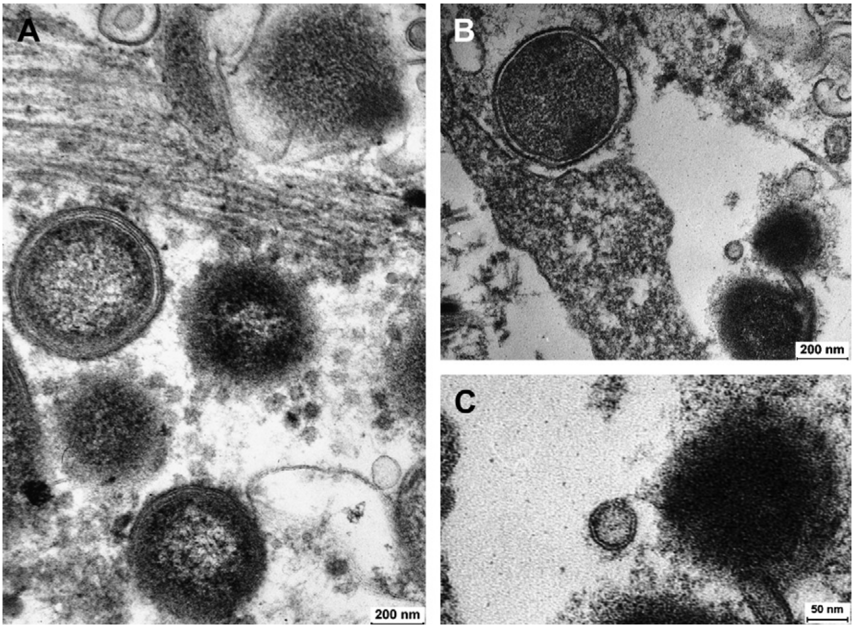

Fig. 1. (*A*) Bacterial blebbing from gram-negative biofilm bacteria. (*B*) Membrane-enclosed bleb. (*C*) Higher magnification of bleb. (*From* Carr GB, Schwartz RS, Schaudinn C, et al. Ultrastructural examination of failed molar retreatment with secondary apical periodontitis: an examination of endodontic biofilms in an endodontic retreatment failure. J Endod 2009;35(9):1303–9; with permission.) (Pacific Endodontic Research Foundation.)

boxes are beyond the resolving power of the unaided human eye. For the sake of comparison, it would take about 100 bacteria to span that square. Clinically, most dental practitioners will not be able to see an open margin smaller than 0.2 mm. The film thickness of most crown and bridge cements is 25 μm (0.025 mm), well beyond the resolving power of the naked eye.

Fig. 2. A dollar bill without magnification. Note that the lines that make George Washington's face cannot be seen in detail.

Optical aids (eg, loupes, OMs, surgical headlamps, fiberoptic handpiece lights) can improve resolution by many orders of magnitude. For example, a common OM can raise the resolving limit from 0.2 mm to 0.006 mm (6 μm), a dramatic improvement. **Fig. 3** shows the improvement in resolution obtained by the standard OM used in dentistry today. A clinical example is that at the highest power a restoration margin opening of only 0.006 mm is essentially sealed and this is beyond the common cement thickness film used in restorative dentistry.

WHY ENHANCED VISION IS NECESSARY IN DENTISTRY

Any device that enhances or improves a clinician's resolving power is extremely beneficial in producing precision dentistry. Restorative dentists, periodontists, and endodontists routinely perform procedures requiring resolution well beyond the 0.2-mm limit of human sight. Crown margins, scaling procedures, incisions, root canal location, caries removal, furcation and perforation repair, postplacement or removal, and bone- and soft-tissue grafting procedures are only a few of the procedures that demand tolerances well beyond the 0.2-mm limit.

OPTICAL PRINCIPLES

Because all clinicians must construct 3-dimensional structures in a patient's mouth, stereopsis, or 3-dimensional perception, is critical to achieving precision dentistry. Dentists appreciate that the human mouth is a small space to operate in, especially considering the size of the available instruments (eg, burs, handpieces) and the comparatively large size of the operator's hands. Attempts have been made to use the magnifying endoscopes used in artroscopic procedures, but these devices require viewing on a 2-dimensional (2D) monitor, and the limitations of working in 2D space are too restrictive to be useful.

Several elements are important for consideration in improving clinical visualization. Included are factors such as

- Stereopsis
- Magnification range
- Depth of field
- Resolving power
- Working distance
- Spherical and chromatic distortion (ie, aberration)
- Ergonomics
- Eyestrain
- Head and neck fatigue
- Cost.

Dentists can increase their resolving ability without using any supplemental device by simply moving closer to the object of observation. This movement is accomplished in dentistry by raising the patient up in the dental chair to be closer to the operator or by the operator bending down to be closer to the patient.[2] This method is limited, however, by the eye's ability to refocus at the diminished distance.

Most people cannot refocus at distances closer than 10 to 12 cm. Furthermore, as the eye-subject distance (ie, focal length) decreases, the eyes must converge, creating eyestrain. As one ages, the ability to focus at closer distances is compromised. This phenomenon is called presbyopia and is caused by the lens of the eye losing flexibility with age. The eye (lens) becomes unable to accommodate and

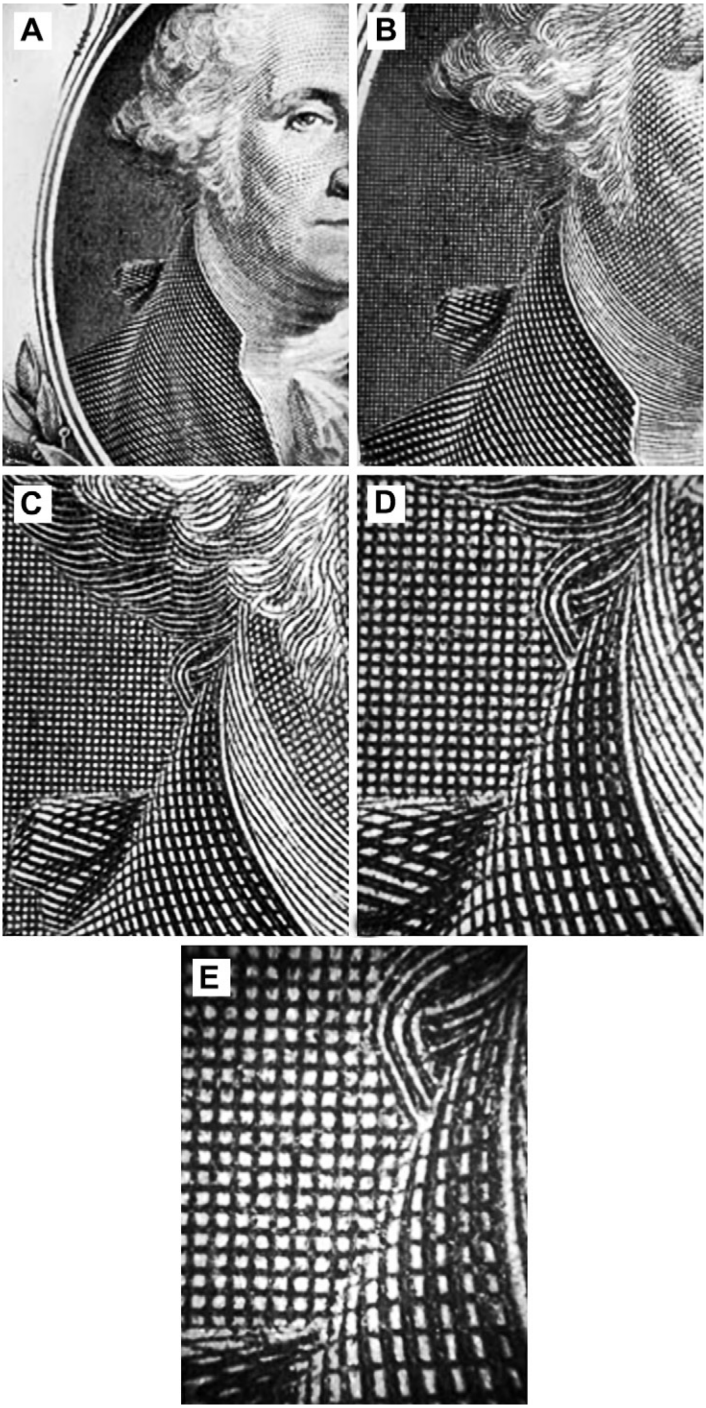

Fig. 3. Different magnifications of a dollar bill as seen through an OM. (*A*) Magnification ×3. (*B*) Magnification ×5. (*C*) Magnification ×8. (*D*) Magnification ×10. (*E*) Magnification ×18.

produce clear images of near objects. The nearest point that the eye can accurately focus on exceeds ideal working distance.[3]

As the focal distance decreases, depth of field decreases. Considering the problem of the uncomfortable proximity of the practitioner's face to the patient, moving closer to the patient is not a satisfactory solution for increasing a clinician's resolution. Alternatively, image size and resolving power can be increased by using lenses for magnification, with no need for the position of the object or the operator to change.

LOUPES

Magnifying loupes were developed to address the problem of proximity, decreased depth of field, and eyestrain occasioned by moving closer to the subject. (Depth of field is the ability of the lens system to focus on objects that are near or far without having to change the loupe position. As magnification increases, depth of field decreases. Also, the smaller the field of view, the shallower the depth of field. For a loupe of magnification ×2, the depth of field is approximately 5 in [12.5 cm]; for a loupe of magnification ×3.25, it is 2 in [6 cm]; and for a loupe of magnification ×4.5, it is 1 in [2.5 cm].)

Loupes are classified by the optical method by which they produce magnification. There are 3 types of binocular magnifying loupes: (1) a diopter, flat-plane, single-lens loupe, (2) a surgical telescope with a Galilean system configuration (2-lens system), and (3) a surgical telescope with a Keplerian system configuration (prism-roof design that folds the path of light).

The diopter system relies on a simple magnifying lens. The degree of magnification is usually measured in diopters. One diopter (D) means that a ray of light that would be focused at infinity would now be focused at 1 meter (100 cm or 40 in). A lens with 2 D designation would focus light at 50 cm (19 in); a 5 D lens would focus light at 20 cm (8 in). Confusion occurs when a diopter single-lens magnifying system is described as 5 D. This designation does not mean ×5 power (ie, 5 times the image size). Rather, it signifies that the focusing distance between the eye and the object is 20 cm (<8 in), with an increased image size of approximate magnification ×2 (2 times actual size). The only advantage of the diopter system is that it is the most inexpensive system. But it is less desirable because the plastic lenses that it uses are not always optically correct. Furthermore, the increased image size depends on being closer to the viewed object, which can compromise posture and create stresses and abnormalities in the musculoskeletal system.[3]

The surgical telescope of either the Galilean or the Keplerian design produces an enlarged viewing image with a multiple-lens system that is positioned at a working distance between 11 and 20 in (28–51 cm). The most used and suggested working distance is between 11 and 15 in (28–38 cm).

The Galilean system provides a magnification range from ×2 to ×4.5 and is a small, light, and compact system (**Fig. 4**).

The prism loupes (Keplarian system) use refractive prisms and are actually telescopes with complicated light paths, which provide magnifications up to ×6 (**Fig. 5**).

Both systems produce superior magnification and correct spherical and chromatic aberrations, have excellent depth of field, and are capable of increased focal length (30–45 cm), thereby reducing eyestrain and head and neck fatigue. These loupes offer significant advantages over simple magnification eyeglasses.

The disadvantage of loupes is that the practical maximum magnification is only about ×4.5. Loupes with higher magnification are available, but they are heavy and unwieldy,

Fig. 4. An example of a Galilean system. (*Courtesy of* Designs for Visions, Inc, Ronkonkoma, NY, USA.)

with a limited field of view. Using computerized techniques, some manufacturers can provide magnifications from ×2.5 to ×6 with an expanded field. Nevertheless, such loupes require a constrained physical posture and cannot be worn for long periods of time without producing significant head, neck, and back strain.

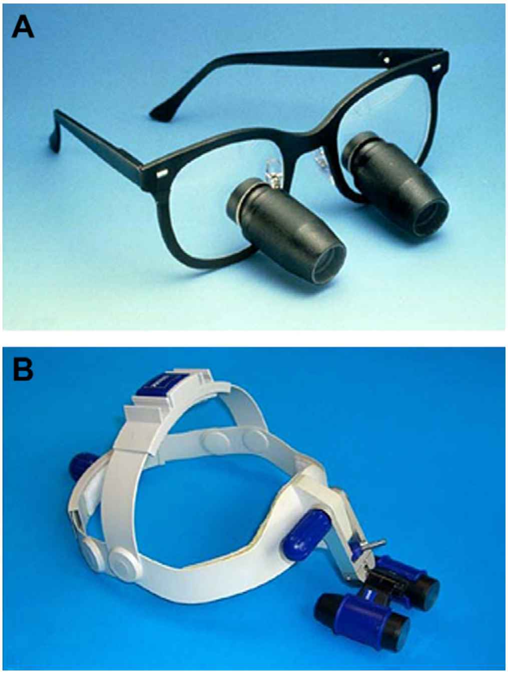

Fig. 5. An example of a Galilean system. (*A*) Prism loupes. These loupes have sophisticated optics, which rely on internal prisms to bend the light. (*Courtesy of* Designs for Visions, Inc, Ronkonkoma, NY, USA.) (*B*) Headset and prism loupes. (*Courtesy of* Carl Zeiss, Inc, Germany.)

THE PROBLEM OF LIGHT

By increasing light levels, one can increase apparent resolution (the ability to distinguish 2 objects close to each other as separate and distinct). Light intensity is determined by the inverse square law, which states that the amount of light received from a source is inversely proportional to the square of the distance. For example, if the distance between the source of light and the subject is decreased by half, the amount of light at the subject increases 4 times. Based on the law, therefore, most standard dental operatory lights are too far away to provide the adequate light levels required for many dental procedures.

Surgical headlamps have a much shorter working distance (13 in or 35 cm) and use fiberoptic cables to transmit light, thereby reducing heat to minimal levels. Another advantage is that the fiberoptic cable is attached to the doctor's headband so that any head movement moves the light accordingly. Surgical headlamps can increase light levels up to 4 times that of conventional dental lights (**Fig. 6**).

THE OM IN ENDODONTICS

Apotheker introduced the dental OM in 1981.[1] The first OM was poorly configured and ergonomically difficult to use. It was capable of only 1 magnification (×8), was positioned on a floor stand and poorly balanced, had only straight binoculars, and had a fixed focal length of 250 mm. This OM used angled illumination instead of confocal illumination. It did not gain wide acceptance, and the manufacturer ceased

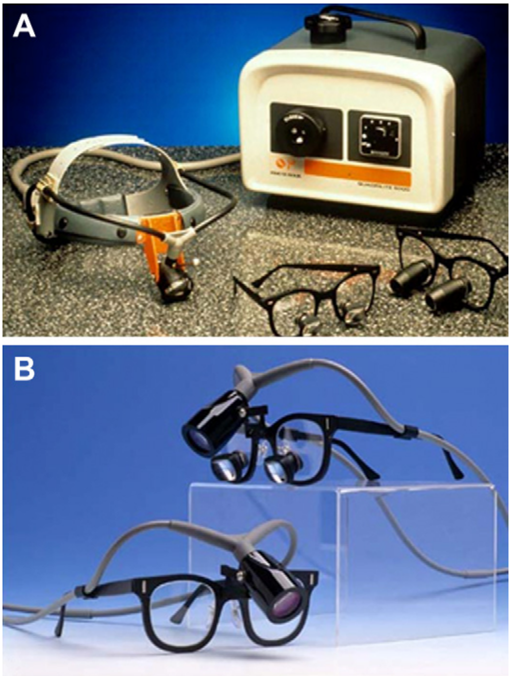

Fig. 6. Surgical headlight and loupes. Together, these devices can greatly increase a clinician's resolution. (*Courtesy of* Designs for Visions, Inc, Ronkonkoma, NY, USA.)

manufacturing it shortly after its introduction.[4] Its market failure was more a function of its poor ergonomic design than its optical properties, which were actually good.

Howard Selden[5] was the first endodontist to publish an article on the use of the OM in endodontics. He discussed its use in the conventional treatment of a tooth, not in surgical endodontics.

In 1999, Gary Carr[6,7] introduced an OM that had Galilean optics and that was ergonomically configured for dentistry, with several advantages that allowed for easy use of the scope for nearly all endodontic and restorative procedures. This OM had a magnification changer that allowed for 5 discrete magnifications (magnification $\times$3.5–$\times$30), had a stable mounting on either the wall or ceiling, had angled binoculars allowing for sit-down dentistry, and was configured with adapters for an assistant's scope and video or 35-mm cameras (**Fig. 7**).

It used a confocal illumination module so that the light path was in the same optical path as the visual path, and this arrangement gave far superior illumination than the angled light path of the earlier scope. This OM gained rapid acceptance within the endodontic community, and is now the instrument of choice not only for endodontics but for periodontics and restorative dentistry as well. The optical principles of the dental OM are seen in **Fig. 8**.

The efficient use of the OM requires advanced training. Many endodontic procedures are performed at magnification $\times$10 to $\times$15, and some require a magnification as high as $\times$30. Operating comfortably at these magnifications requires accommodation to new skills that were not taught until recently in dental schools. Among other things, working at these higher-power magnifications brings the clinician into the realm where even slight hand movements are disruptive, and physiologic hand tremor is a problem.

In 1995, the American Association of Endodontists formally recommended to the Commission on Dental Accreditation of the American Dental Association that microscopy training be included in the new Accreditation Standards for Advanced Specialty Education Programs in Endodontics. At the commission's meeting in January 1996, the proposal was agreed on, and in January 1997, the new standards, making microscopy training mandatory, became effective.[8]

EFFICIENT USE OF AN OM IN ENDODONTICS

Although the OM is now recognized as a powerful adjunct in endodontics, it has not been adopted universally by all endodontists. It is seen by many endodontists as simply another tool and not as a way of practice that defines how an endodontist works. Although cost is frequently cited as the major impediment, in truth, it is not

Fig. 7. Today's OM allows the doctor and the assistant to ergonomically view the same field. This OM is fitted with a 3CCD (charge coupled device) video camera and an assistant scope.

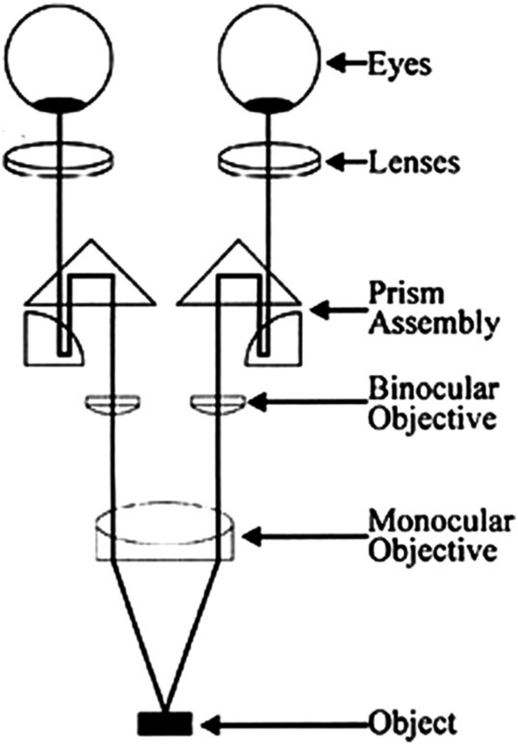

Fig. 8. Galilean optics. Parallel optics enables the observer to focus at infinity, relieving eyestrain.

cost but a failure to understand and implement the positional and ergonomic skills necessary to effectively use an OM. This failure has restricted its universal use in all endodontic cases.

The occasional or intermittent use of an OM on a patient results in the inefficient use of a clinician's time. It represents a disruption in the flow of treatment of the patient, which can only negatively affect the final result. Clinicians who practice this way seldom realize the full advantage of a microscopic approach and never develop the visual and ergonomic skills necessary to operate at the highest level.

The skillful use of an OM entails its use for the entire procedure from start to finish. Working in such a way depends on refinement of ergonomic and visual skills to a high level.

THE LAWS OF ERGONOMICS

An understanding of efficient workflow using an OM entails knowledge of the basics of ergonomic motion. Ergonomic motion is divided into 5 classes of motion:

Class I motion: moving only the fingers (**Fig. 9**)
Class II motion: moving only the fingers and wrists (**Fig. 10**)
Class III motion: movement originating from the elbow (**Fig. 11**)
Class IV motion: movement originating from the shoulder (**Fig. 12**)
Class V motion: movement that involves twisting or bending at the waist.

Fig. 9. (*A*) Fingers waiting for the file. (*B*) File placed in between fingers. (*C*) Fingers capturing file.

Fig. 10. (*A*) Hand waiting for the instrument. (*B*) Fingers and wrist movement receiving the instrument. (*C*) Fingers movement receiving the instrument.

Fig. 11. (*A*) Elbow rested at the stool support. (*B*) Supported elbow rotation and instrument apprehension. (*C*) Supported elbow rotation to working position.

Fig. 12. (*A*) Professional at the neutral position. (*B*) Shoulders, arms, elbows, and hands moving to reach the OM. (*C*) OM moved to the ideal position without rotational movement of the waist.

No clinical example of the Class V motion movement is shown because this movement is the most prejudicial of all (unfortunately, this is the most common movement used by dentists and dental assistants with or without the OM).

POSITIONING THE OM

The introduction of the OM in a dental office requires significant forethought, planning, and an understanding of the required ergonomic skills necessary to use the OM efficiently. Proper positioning for the clinician, patient, and assistant is absolutely necessary. Most problems in using an OM in a clinical setting are related to either positioning errors or lack of ergonomic skills in the clinician. If proper ergonomic guidelines are followed, it is possible to work with the OM in complete comfort with little or no muscle tension.

In chronologic order, the preparation of the OM involves the following maneuvers:

Operator positioning
Rough positioning of the patient
Positioning of the OM and focusing
Adjustment of the interpupillary distance
Fine positioning of the patient
Parfocal adjustment
Fine focus adjustment
Assistant scope adjustment.

OPERATOR POSITIONING

The correct operator position for nearly all endodontic procedures is directly behind the patient, at the 11- or 12-o'clock position. Positions other than the 11- or 12-o'clock position (eg, 9-o'clock position) may seem more comfortable when first learning to use an OM, but as greater skills are acquired, changing to other positions rarely serves any purpose. Clinicians who constantly change their positions around the scope are extremely inefficient in their procedures.

The operator should adjust the seating position so that the hips are 90° to the floor, the knees are 90° to the hips, and the forearms are 90° to the upper arms.[9] The operator's forearms should lie comfortably on the armrest of the operator's chair, and feet should be placed flat on the floor. The back should be in a neutral position, erect and perpendicular to the floor, with the natural lordosis of the back being supported by the lumbar support of the chair. The eyepiece is inclined so that the head and neck are held at an angle that can be comfortably sustained. This position is maintained regardless of the arch or quadrant being worked on. The patient is moved to accommodate this position. After the patient has been positioned correctly, the armrests of the doctor's and assistant's chairs are adjusted so that the hands can be comfortably placed at the level of the patient's mouth. The trapezius, sternocleidomastoid, and erector spinae muscles of the neck and back are completely at rest in this position.

Once the ideal position is established, the operator places the OM on one of the lower magnifications to locate the working area in its proper angle of orientation. The image is focused and stepped up to higher magnifications if desired.[10]

Fig. 13. Examples of traditional operatory designs with large side cabinets, sinks, and so forth. A design such as this makes efficient OM use problematic.

OPERATORY DESIGN PRINCIPLES FOR USING OM

The OM was originally introduced into standard dental operatories that have been designed in the conventional way, with outdated ergonomic concepts using the traditional operatory side cabinets, dual sinks, over-the-patient delivery systems, and so forth. This historical design turned out to be extremely inefficient because of the ergonomic constraints imposed by the way the OM is actually used in endodontic procedures. There is an ergonomic flow to using an OM efficiently, and careful operatory design is critical in enabling this flow. One of the main reasons clinicians struggle with using the OM for all procedures is that the ergonomic design of the operatory prohibits it. Clinicians who attempt to use the OM for all procedures but do not have appropriate ergonomic designs to their operatories experience significant frustrations (**Fig. 13**).

The organizing design principle using the OM in the dental operatory should revolve around an ergonomic principle called circle of influence (**Fig. 14**). The principle posits that all instruments and equipment needed for a procedure are within reach of either the clinician or the assistant, requiring no more than a class IV motion, and that most endodontic procedures are performed with class I or class II motions only (**Fig. 15**). The principle assumes that the most ergonomic way to work is to perform all procedures under the OM, including the diagnostic examination, oral cancer screening, anesthesia, and rubber dam placement.

Therefore, the circle of influence design principle places the OM at the center of the operatory design, and all the ergonomic movements necessary to work with this technology are centered within those circles. Simplicity and efficiency are the guiding principles of this innovative design. This innovative concept allows for the constant evolution of the operatory design while maintaining its ergonomic parameters and permitting the incorporation of new technologies as they become available.

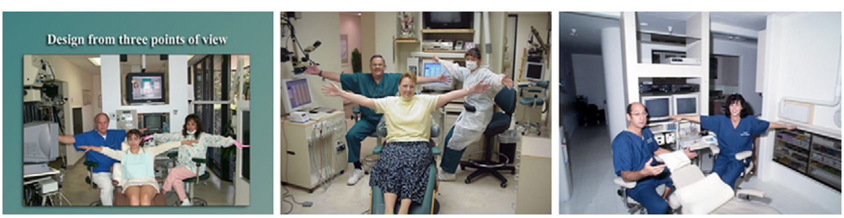

Fig. 14. The circle of influence design takes into consideration the 3 participants of the dental team: doctor, assistant, and patient. Maximum ergonomics, efficiency, and comfort for all members are achieved with this office design.

Fig. 15. The circle of influence principle can be implemented into private practice (*A*) and in the academic environment (*B*) (Einstein Medical Center, Philadelphia, PA, USA).

The design has been improved to make it even simpler to implement and less expensive by adopting off-shelf solutions from IKEA (PA, USA). This design is extremely valuable, especially because of its availability and ease of setup. In a few hours, one can construct an ideal OM operatory back wall using all the circle of influence design principles for a fraction of the cost of a traditional operatory with custom cabinets (**Fig. 16**).

Fig. 16. (*A*) The circle of influence design concept using different IKEA cabinets. Note how spacious and clean this design is, in contrast to traditional ones. The key elements here are rear-mounted or ceiling mounted OM, cart, back wall, assistant table, stool with arm support, computer integration, and rotational chair. (*B*) Ease of construction using modular design principles. (*C*) Efficient IKEA delivery cabinets.

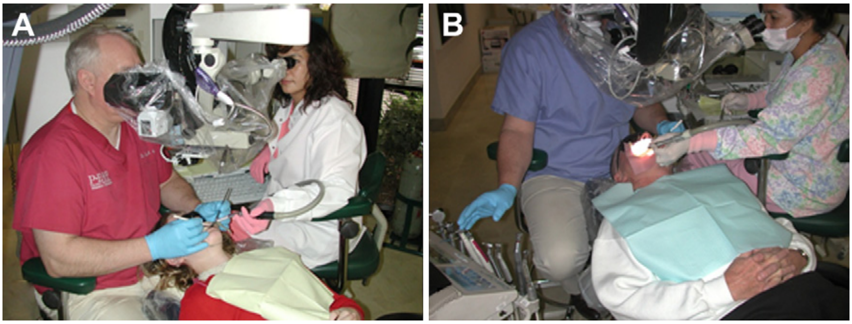

Fig. 17. (*A*) Team work development: doctor and assistant working erect and muscularly relaxed. (*B*) Adjustable cart allowing access to all instruments, using only a class III motion.

KEY ELEMENTS OF THE NEW DESIGN

This new design assumes a teamwork approach to the delivery of endodontic care. The doctor and assistant are placed at the scope in upright and comfortable positions (**Fig. 17**A). The scope is positioned so that the doctor and the assistant are muscularly at rest through all treatment phases (see **Fig. 17**A). This configuration places some constraints on the design of the back wall and on the cart systems used. Computers, scanners, digital radiographs, and monitors are ergonomically placed according to the circle of influence principle and are easily reached by either the doctor or the assistant with only class III motions (**Fig. 17**B). The cart must be easily movable and adjustable and at the correct height to be ergonomically positioned (see **Fig. 17**B).

The dental chair is freely rotatable with the doctor's legs, so that the patient, not the OM, is moved when a field of view needs to be changed. Patient movement, and not OM movement, is a paradigm shift in understanding how to use an OM efficiently. The small rotational movement of the dental chair should be done using the practitioner's legs and not hands (**Fig. 18**). This simple principle can change the way one practices. In this position, the patient faces the ceiling, and the practitioner works around at the 11-o'clock position for nearly every procedure. Doctor and assistant stools with arm support are critical (**Fig. 19**). Because fine motor skills are necessary to work under

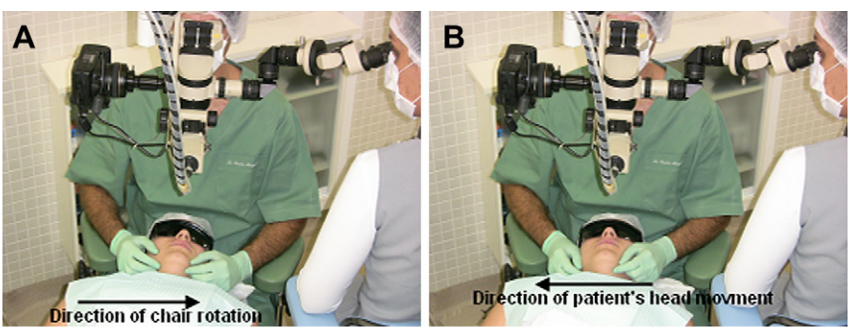

Fig. 18. (*A*) Small movement of the chair to the left (note that patient's head is tilted a little to the left). (*B*) If necessary, the patient's head is moved slightly to the right to compensate chair movement (note that the OM was not touched at any time).

Fig. 19. Elbow support for doctor and assistant is mandatory to allow the necessary fine motor skills under constant magnification and muscular comfort throughout the day.

constant magnification, it is mandatory that both members have adequate elbow and arm support. Without either support, fine motor skills with either hand become more problematic for the practitioner and for the dental assistant (**Fig. 20**).

THE OM AND CLINICAL PROCEDURES

The efficient use of an OM for all clinical procedures requires not only ergonomic sophistication but also special clinical skills that are not required in nonmicroscopic endodontics. When one tries to use conventional concepts with magnification, frustration and inefficiency are the usual results (**Fig. 21**). Specifically, in microendodontics, the use of specialized micromirrors vastly improves efficiency and capability (**Fig. 22**). The skills needed to manipulate much smaller mirrors at higher magnification are easily acquired by dentists, but not without some effort. The use of smaller mirrors results in the mirror being placed further away from its usual location, and even minor hand movements can make such use frustrating for the novice (**Fig. 23**). Proper ergonomic form and a well-trained assistant can mitigate some of this frustration, but it takes practice and repetition to master the skills required (**Fig. 24**).

Removing canal or pulp chamber obstructions is also greatly facilitated by the use of an OM. Even obstructions such as separated instruments deep within canals can be addressed, given the proper training and level of persistence. Examining fractures,

Fig. 20. A simple exchange of instruments demands fine motor skills once the doctor and assistant are going to ideally use class I, II, and III movements (note how the doctor's hands does not leave the reference point at patient's cheek).

Fig. 21. Image with intermediate magnification (×6) of access on tooth No.15. Nothing is seen besides the high-speed head and parts of the tooth. Such image when using the OM, causes frustration and introduces inefficiency and significant clinical impairment.

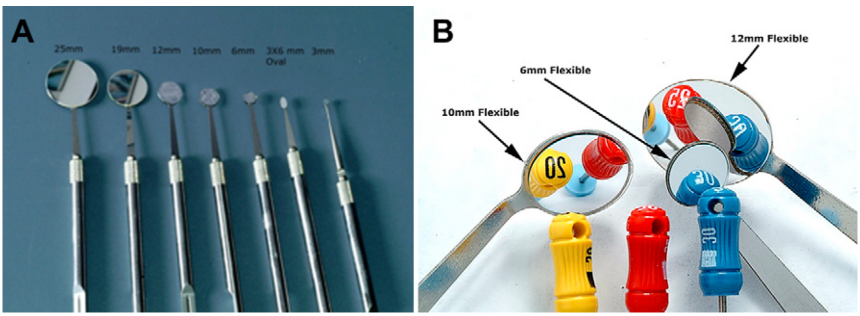

Fig. 22. (*A*) A selection of flexible mirrors in different sizes and shapes. (*B*) Detail of highly reflective mirrors with flexible and flat shafts. (*Courtesy of* EIE2, San Diego, USA.)

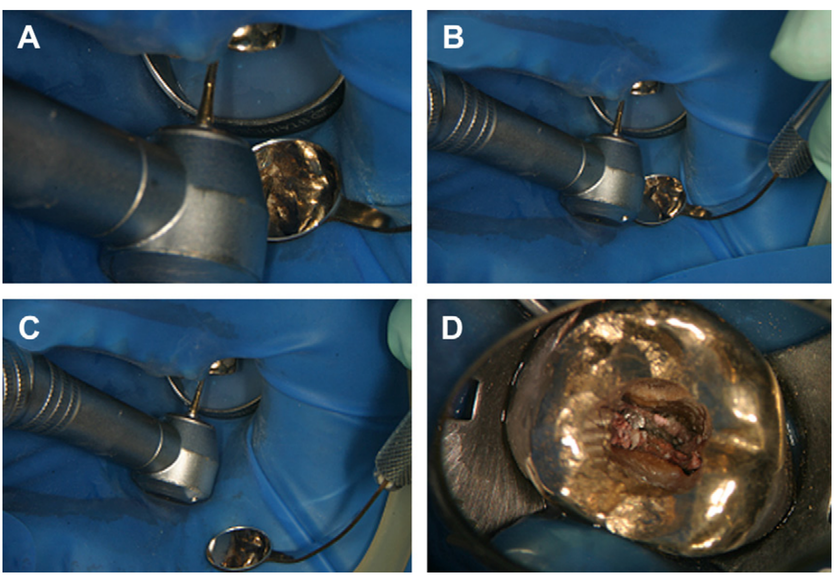

Fig. 23. (*A*) Inadequate level of magnification and mirror position. (*B*) Adequate magnification to position mirror. (*C*) Adequate mirror position. Notice the flex of the mirror staff. (*D*) Adequate magnification level with clear view of the operatory field.

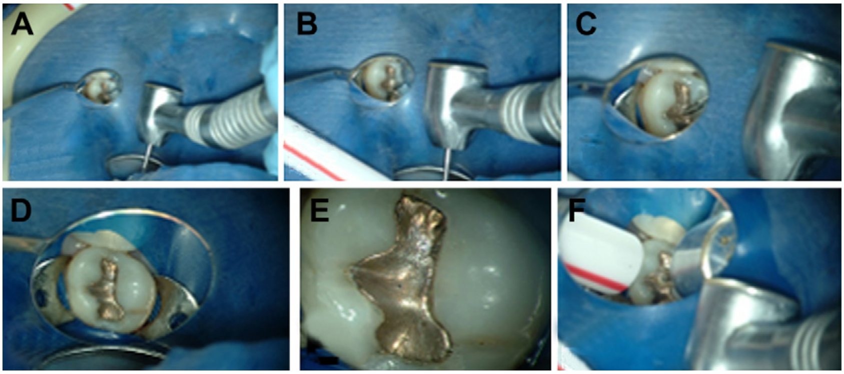

Fig. 24. (*A*) The use of smaller mirrors positioned further away. Adequate level of magnification and mirror position. (*B–E*) Higher magnifications of occlusal surface. (*F*) Clear view of occlusal surface ready to initiate clinical work with high speed and suction well position.

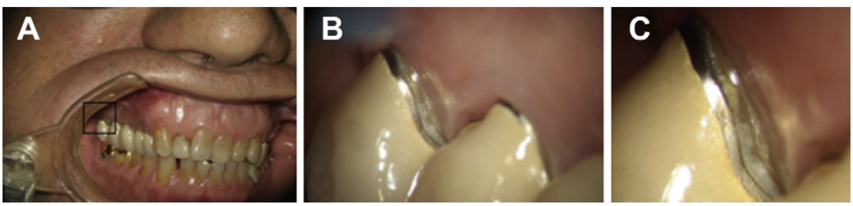

Fig. 25. Clinical diagnosis of prosthetic margins. (*A*) Low magnification of crown on tooth No. 2. (*B*) Intermediary magnification of crown margin. (*C*) High magnification of crown margin.

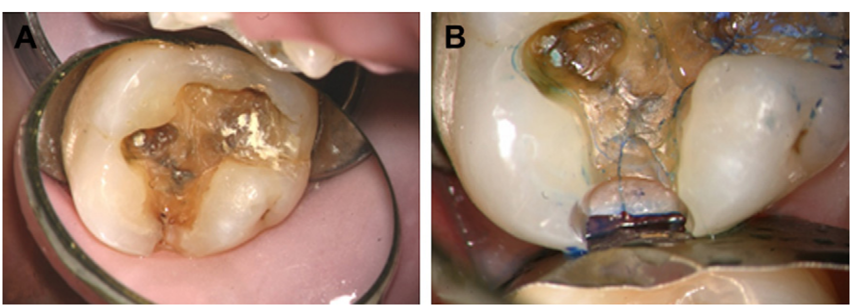

Fig. 26. Clinical diagnosis of cracks. (*A*) Intermediary magnification of occlusal surface of tooth No. 2. (*B*) Higher magnification showing cracks on distal area.

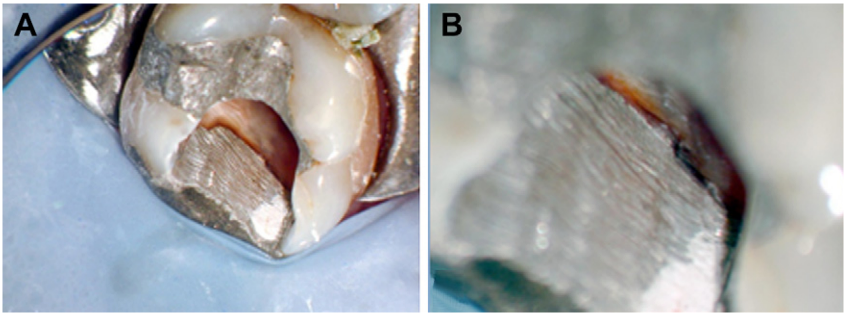

Fig. 27. Clinical diagnosis of caries. (*A*) Intermediary magnification of occlusal surface on tooth No. 14. (*B*) Higher magnification showing gross microleakage and an open margin on cervical area.

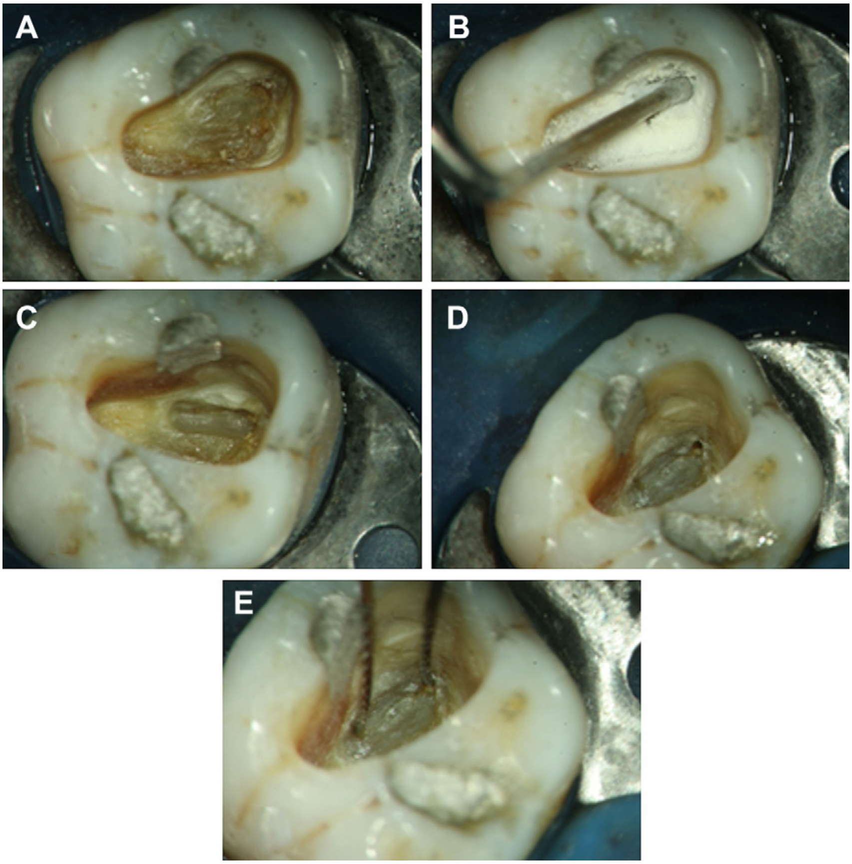

Fig. 28. (*A*) Intermediary magnification of endodontic access on tooth No. 15 (note there is no sign of canals). (*B*) Dentin smear resulted from ultrasonic instrumentation (Pearl diamond, EIE2 Excellence in Endodontics, GBC Innovations, Inc, San Diego, CA, USA) of pulp floor. (*C*) Groove produced after ultrasonic usage. (*D*) Mesiobuccal (MB) and second MB (MB2) canals located after ultrasonic usage. (*E*) Files inserted on MB and MB2 canals.

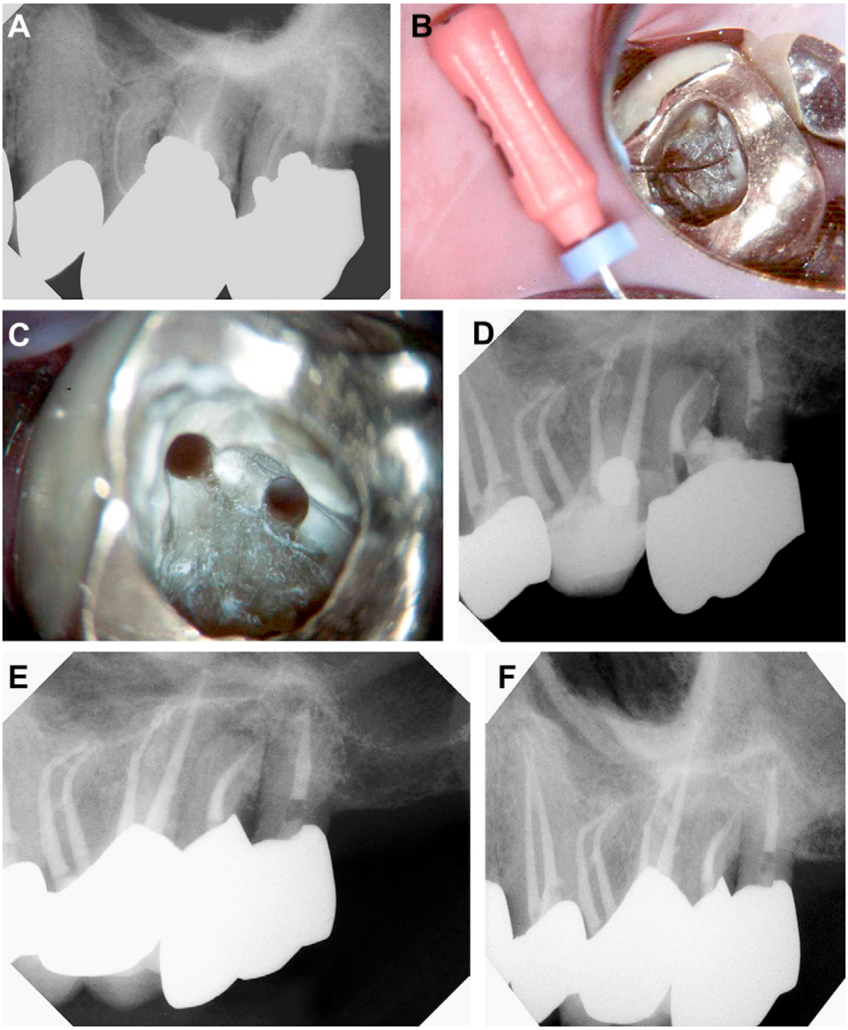

Fig. 29. (*A*) Preoperative radiograph of teeth Nos. 13, 14 and 15 showing inadequate previous root canal treatment (teeth 14 and 15) with incomplete shaping and obturation of the root canal system. (*B*) Intermediary magnification of 06 file at MB2. (*C*) Higher magnification showing MB and MB2, cleaned and shaped. (*D*) Immediately postoperation. (*E, F*) Long-term recall.

crown margins, cement layers, subgingival defects, and caries extension are all enhanced by a microscopic approach.

To discuss the uses of the OM in endodontics is beyond the scope of this article, but several examples of its use serve to illustrate its permanent place in endodontics.

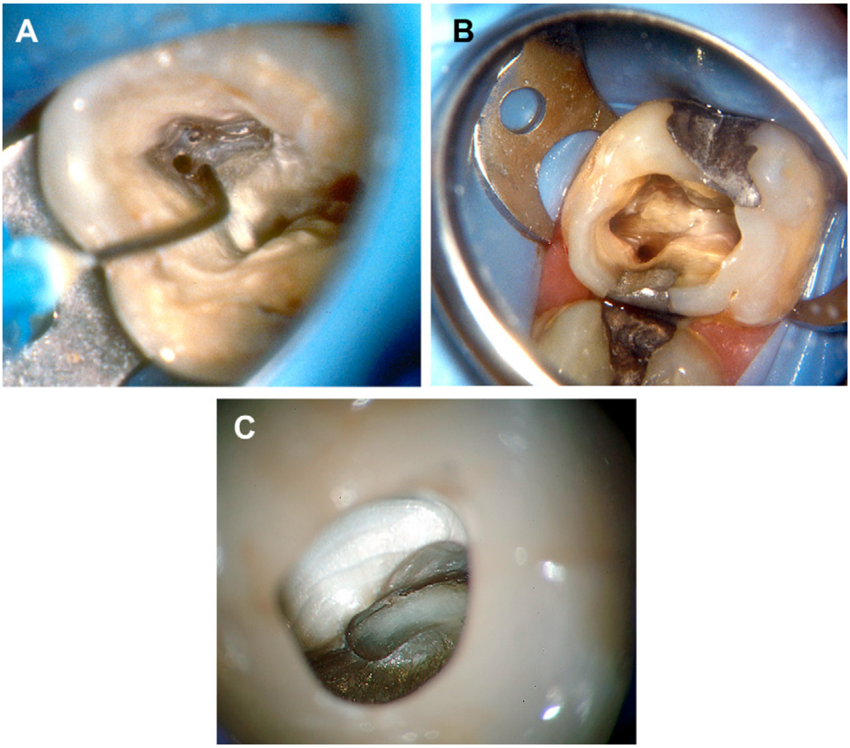

Fig. 30. Intermediate magnification of tooth No. 2 with an extra distal lingual canal (white spot dehydrated with air).

Fig. 31. Intermediate magnification of tooth No. 3 with an MB2 canal way under the mesial ridge.

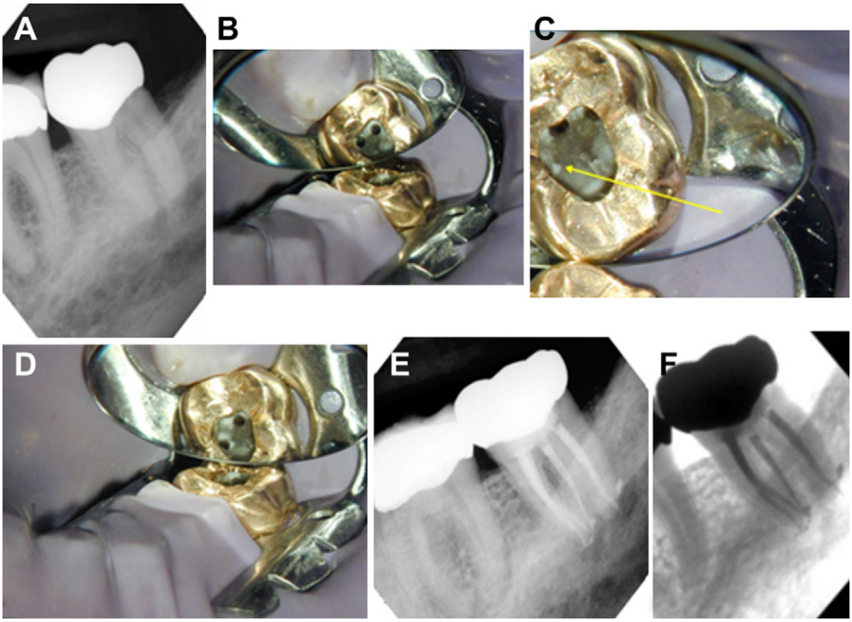

Fig. 32. (*A*) Preoperative radiograph of tooth No. 18 showing the presence of chronic apical periodontitis, but no sign of aberrant anatomy. (*B*) Low magnification of mesial canals, cleaned and shaped. (*C*) Higher magnification showing extra mesial lingual canal (*arrow*). (*D*) Low magnification of mesial lingual canal, cleaned and shaped. (*E*) Immediate postoperative radiograph, (*F*) Immediate postoperative inverted radiograph.

Clinical Diagnosis

In endodontics, clinical diagnosis has a greater need for enhanced vision. With the advent of implant dentistry, a more accurate diagnosis is necessary to select only viable and long-lasting teeth that will withstand the test of time (**Figs. 25–27**).

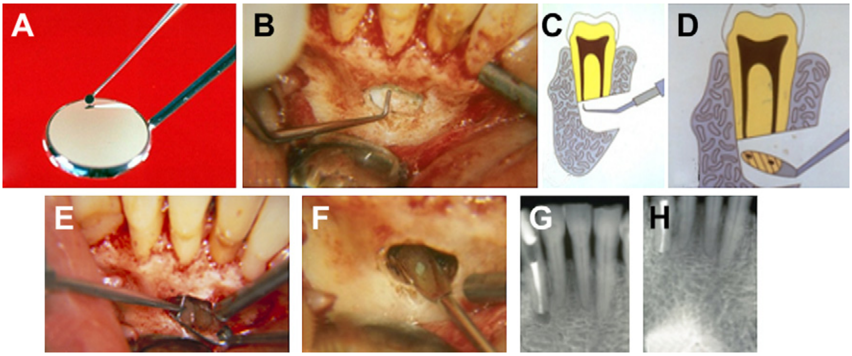

Fig. 33. (*A*) Regular and retro mirror comparison. (*B*) Apical exploration after root resection. (*C, D*) Microsurgery technique. (*E*) Ultrasonic retro preparation. (*F*) Retro preparation filled. (*G*) Immediately postoperation. (*H*) Long-term recall.

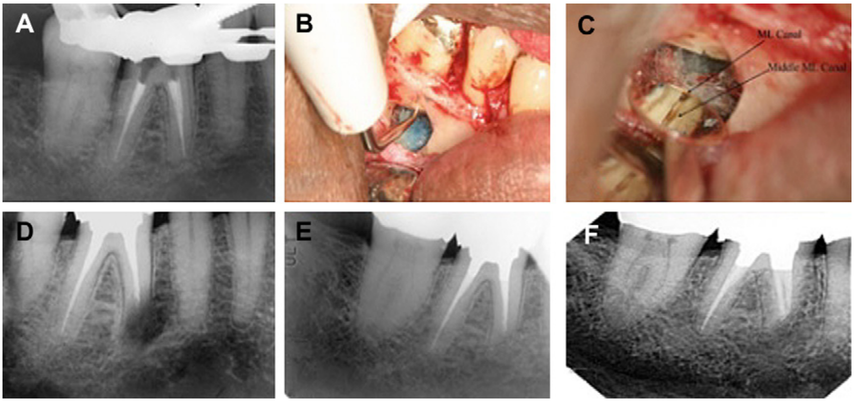

Fig. 34. (*A*) Before operation. (*B*) Ultrasonic root preparation with moderated bevel, (*C*) Micromirror view of retropreparation, (*D*) Immediately postoperation. (*E*) 5-year recall. (*F*) 10-year recall.

Locating Canals

Locating canals is perhaps the most obvious use of the OM in endodontics. Calcified canals (**Fig. 28**), missed canals (**Fig. 29**), aberrant canals (**Figs. 30–32**), dilacerated canals, and canals blocked by restorative materials are all addressed easily by the skillful use of an OM.

Operators quickly learn the visual skills necessary to distinguish dentin from calcified pulp, relying on changes in color, translucency, and refractive indexes to identify remnants of pulpal tissues. Such searches have historically resulted in perforations or gross destruction of tooth structure, but with the advent of the OM, such misadventures are uncommon.

Surgical Endodontics

Modern endodontic surgical procedures demand a microscopic approach. Use of the smaller retro mirrors allow for a more moderated bevel of the root resection and permit a coaxial ultrasonic preparation into the root (**Figs. 33** and **34**).[6]

Surgical soft-tissue management is also greatly enhanced by a microscopic approach, leading to faster healing, less traumatic soft-tissue management, and the advent of microsurgical suturing techniques that minimize trauma and lead to rapid, primary intention wound healing (**Fig. 35**).

These are only a few of the endodontic applications of a microscopic approach, but there are others such as lateral root repairs, perforation repairs, external cervical

Fig. 35. (*A*) Immediately postoperation. (*B*) 48 hours postoperation. (C) 21 days postoperation. Incision scar barely visible.

invasive resorption repairs, and other resorptive repairs that also benefit from a microscopic approach. In reality, all clinical endodontic procedures should be done under constant illumination, magnification, and ergonomics. This requirement applies even for implant dentistry, which needs special attention to fine details to achieve excellence.[10]

As the OM gains widespread acceptance in endodontics, the advantages of its use in providing precision care will carry over into restorative dentistry, and it will eventually become a universal approach for all phases of dentistry.[4,10–15]

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