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Extreme Magnification: Seeing the Light

A Peer-Reviewed Publication
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Educational Objectives

1. Understand the evolution of the use of microscopes in dentistry.
2. Know the improvements in treatment precision obtainable using a microscope.
3. Understand how the integration of microscopes into the dental office can improve ergonomics and documentation, as well as aid communication.

Introduction

In 1981, Apotheker brought the concept of extreme magnification, in the form of an operating microscope, into dentistry. The virtue of high levels of magnification in the medical field had been understood for many decades.¹⁻⁷ Dr. Apotheker postulated that the tremendous improvements in visual acuity, made possible through the use of the operating microscope, would be beneficial to the discipline of endodontics. His primitive microscope required the clinician to work while standing upright and this, combined with only a single level of magnification, made routine usage impossible.⁸

In the late 1980s, San Diego endodontist Dr. Gary Carr, working on TMJ dissections with Dr. Terry Tanaka in the anatomy lab, discovered how vital the operating microscope was in these dissections. Dr. Carr concluded that the incredible magnification and illumination made possible with the microscope could be of benefit to the discipline of endodontics. He continued on with Apotheker's preliminary concepts, and started promoting the usage of the Dental Operating Microscope (D.O.M.) as a crucial piece of the armamentarium used in the improvement of outcomes of endodontic apical surgeries.^{9,10} During the early 1990s, other endodontists, including Ruddle, Buchanan, Arens, Stropko, Kim, and others, began to promote the D.O.M. for its value both in standard endodontic therapy and for the improvements in outcomes of both non-surgical retreatments as well as surgical cases.¹¹⁻¹⁴

In 1998, the American Academy of Endodontics decided to institute the requirement that all post-graduate endodontic students from accredited programs become proficient in the usage of the D.O.M. in order to graduate from their post-doctoral program. The literature was beginning to cite the advantages of using the microscope, compared to no magnification or entry-level loupes, in root canal therapy.¹⁵⁻²⁴ These advantages included the ability to use a more conservative access preparation and a higher incidence of locating extra canals, such as the second mesial-buccal (MB2) canals in maxillary molars, and mid-mesial (MM) canals in mandibular molars. (Figure 1)

Figure 1
FPO – awaiting image

Other advantages included a greater ability to detect additional canal anatomy, such as including fins and isthmuses, as well as deep bifurcations before the canal curved in the apical third. The improvement in visual acuity was

also beneficial for the detection and removal of pulp stones. Additionally, it became apparent that the ability to diagnose cuspal and vertical fractures was greatly improved. Finally, D.O.M. use made it easier to use ultrasonics in the refinements of access preparations to provide for straight-line access into all canals. Surgical endodontics and the success rate for apicoectomies were also shown to improve with routine usage of the operating dental microscope.

After the introduction of the microscope to endodontics, there was a spike of interest in the D.O.M. for periodontics, and it was found by Shanelec, Belcher, and others that routine usage of the D.O.M. could provide for more delicate surgical procedures requiring microsurgical armamentarium, including smaller blades and 7-0 to 10-0 sutures. These delicate surgical procedures allowed for reductions in postoperative pain and quicker healing.²⁵⁻³³

During the 1990s, a small group of restorative dentists, many with an active interest in endodontics, started to incorporate the microscope as an important part of the armamentarium in general practice. For these restorative dentists, the microscope became an integral part of all dental procedures, as they discovered that the dramatic improvement in visual information provided by the D.O.M. allowed for a level of precision in both diagnosis and treatment outcomes that was not previously possible. It was in 1997 that this author first became intrigued with the possibilities of creating a Microscope-Centered practice.

The growth of the usage of surgical telescopes from a rarity to the norm in general practice increased dramatically from 1980 to 2001. In the author's home province of British Columbia, the percentage of clinicians using any form of magnification rose from 20 percent in 1986 to 75 percent in 2000.^{34,35} In the 20 years following 1986, there was an initial increase in the number of clinicians using entry-level powers of magnification (2.0–3.0x), and a subsequent growth in those practitioners purchasing medium-powered loupes (3.0–6.0x power). As clinicians began to understand the role and value that magnification could provide for all disciplines of dentistry, many purchased a second or third set of loupes that were higher in power and often used a headlight to improve the illumination of the surgical field. As this decade has progressed, the greatest increase in new users of the D.O.M. has been from those clinicians familiar with using medium-powered loupes routinely. The author started to notice this trend in the early part of this decade, and coined the term Magnification Continuum to describe the development of ever-increasing magnifications being used in dentistry.³⁶

Figure 2
FPO – awaiting image

Figure 3
FPO – awaiting image

During the early part of this decade, and progressing to the present, evidence of the usefulness of the D.O.M. in restorative dentistry began to accumulate. The microscope offered merit in the early diagnosis of decay, especially in the area of occlusal fissures, where traditionally, the usage of an explorer and radiographs had been shown to be particularly weak. The earlier visualization of dentinal cracks both prior to and after the removal of restorative materials was again documented by Dr. Clark in his landmark study in 2003.³⁷ (Figures 2,3) In addition, the value of the microscope in the provision of restorative dentistry, prosthodontics, and cosmetic dentistry has been documented numerous times.³⁸⁻⁵⁵

Benefits of Microscope-Centered Practices

The author has been using the microscope routinely for almost 100 percent of his clinical dentistry since 1997, and has identified four basic advantages in using the operating microscope and accompanying documentation systems (digital microphotography and videography) for private practice. These benefits include:

- 1) Improved precision of treatment
- 2) Enhanced ergonomics
- 3) Ease of digital documentation
- 4) Increased ability to communicate through integrated video

These four common advantages are witnessed in all aspects of a microscope-centered practice, regardless of the discipline involved or procedure being completed.

Improved Precision of Treatment

The visual information provided by the operating microscope is, in fact, not indicative of the magnification that is being employed. The actual amount of visual information is the area under the scope and is therefore the number of horizontal pixels multiplied by the number of vertical pixels.

Therefore, the clinician using the commonly purchased 2x magnification of entry-level loupes sees approximately four times the visual information of a dentist not using any magnification at all (i.e., with the naked eye). A set of 3x loupes provides nine times the visual information of the unmagnified view and more than doubles what is seen with the typical 2x entry-level set of loupes.

Figure 4
FPO – awaiting image

Figure 5
FPO – awaiting image

A microscope at 10x magnification (typical magnification used by the author for routine, single-tooth prosthodontic preparations and finishing of prosthodontic margins) provides 100 times the amount of visual information compared to the naked-eye view. It provides twenty-five times the information compared to that obtained through the use of entry-level loupes (2x) and over ten times that of 3x power loupes. (Table 1)

Table 1

Magnification	Visual information (VI)	VI Compared to 2x loupes
Naked eye	1x	1/4
2x loupes	4x	Even
3x loupes	9x	2.25
4x loupes	16x	4x
6x microscope	36x	9x
10x microscope	100x	25x
20x microscope	400x	100x

There is always a price to be paid for the increased amount of visual information that the microscope provides when compared to low- or medium-powered loupes. As magnification increases, the depth and diameter of the field-of-view of the operating field decrease. There is an increased demand at higher magnification for improved control of the micromotor muscles and joints (fingers and wrists) that can require stabilization of the gross motor joints (elbow and shoulder) with microsurgical chairs. Shanelec and Tibbets reported that the medical literature showed that the clinician, working without magnification, made movements that were 1–2 mm at a time. At 20x magnification, the refinement in movements can be as little as 10–20 microns (10–20/1000 of a mm) at a time. It is useful therefore to note that the limitation to precision of treatment is not in the hands but in the eyes.⁵⁶

Carr reported that the human eye, when unaided by magnification, has the inherent ability to resolve or distinguish two separate lines or entities that are at least 200 microns, or 0.2 mm, apart.⁵⁷ If the lines are closer together, then even 20/20 unmagnified vision will not allow for the clinician to resolve them as two separate entities and the objects will appear as one. As you bring magnification into the equation, the resolution of the human eye improves dramatically. (Table 2)

Baldissara et al.⁵⁸ showed that the experienced clinician with a sharp, new explorer can determine marginal gaps with a tactile sense, when the gaps were of a distance of around 36 microns. Thus, it can be assumed that when magnification is greater than 6x power, the reliance on an explorer and tactile means of inspection significantly decreases. This reliance on visual means of discovery, as opposed to tactile means, is something that the author and many other microscope-centered clinicians have discovered as their motor skills improve during the learning curve.

Table 2

Magnification System	Magnification	Resolution (μm)	Resolution (mm)
Naked eye	zero	200	0.2
Low- power loupes	2x	100	0.1
Med- power loupes	4x	50	0.05
Sharp Explorer	zero	36	0.036
Microscope, low mag	6x	36	0.036
Microscope, med mag	10x	20	0.02
Microscope, high mag	20x	10	0.01

The precision of treatment studies by Leknius and Geissberger,⁵⁹ as well as by Zaugg et al.,⁶⁰ demonstrated that as magnification is incorporated, procedural errors decrease significantly. In the latter study, the inclusion of a microscope resulted in fewer errors than when a set of loupes was used.

Improved Ergonomics

The operating microscope allows the dentist to sit in an upright, neutral, and balanced posture. While using the microscope, the clinician is able to practice while looking straight ahead without having to either bend forward in an effort to see better (causing lower-back pain), or raise the patient horizontally in order to bring the oral cavity closer to the clinician (causing neck pain). This neutral balanced posture, obtainable with the D.O.M., has been discussed as being helpful in preventing ergonomic issues that plague so many clinicians and which seem to be an occupational hazard.⁶¹⁻⁶² The clinician is able to sit upright while using the microscope without fatigue, tension, or stress in the neck or lower back muscles, which allows one to focus completely on the task at hand. The microscope allows for 100 percent of the retina to be focused on the site.

Ease of Digital Documentation

The D.O.M. can be a tremendous addition to a general practice when it comes to documenting a clinical case. With the addition of a beamsplitter that splits the light and image to two ports (sides), a dentist can use an adapter to connect a digital camera (point and shoot, or an SLR version) on one side of the microscope, and on the other side, connect a video camera. The addition of these accessories allows for tremendous ease in documentation of procedures. The procedures can be quickly captured at multiple magnifications, and it is routine to shoot as many as sixty to eighty digital photos during a 1.5 hour procedure. Real-time video can be captured on hard drives, and mini DV tapes when used with Sony Handycams, or directly to DVD. The usage of documentation for medico-legal, insurance, patient communication, and lecturing purposes, as well as for communication with staff or colleagues, is impressive. Even the most seasoned clinician appreciates the detail that is possible when taking microphotography or videos. Carr,⁶³ Behle,⁶⁴ and the present author⁶⁵ have all written

articles discussing the merits of digital documentation with the D.O.M. and the advantages of doing so.

Figure 6
FPO – awaiting image

Many digital cameras have been released during the last 6 years; the number of mega pixels, the quality in the color of the images, the sharpness of the images, and the number of options available in these cameras, have improved or increased, whereas the cost and weight of the cameras have dramatically decreased. Early adaptors placed lightweight point-and-shoot cameras on the microscope with immediate results that staggered the operator with their instant gratification. Recently, many users of D.O.M.s have opted to place Single Lens Reflex (SLR) cameras on their bodies, or alone on the microscope. The immediacy of the output of the photos, achieved by connecting the camera to a monitor in the operator, has changed the means of documentation for the author. The storage of these images on cards, to be transferred to computers for permanent storage on hard drives or DVDs, has revolutionized the way that cases are archived. The ability to capture and quickly edit these images, as well as the ability to present them in a professional fashion without waiting for slides or photos to be developed, has truly changed the ability of the clinician to determine the quality of the documentation as it is occurring. There is no longer disappointment when the slides or film are returned, to see that a vital step in the slides was missed. The Internet has improved the ability of clinicians to share their cases, getting feedback, helpful hints, or constructive criticism essentially within minutes of the case being completed.

Videos may allow even greater ability to show multiple steps during the procedure, and perhaps the future for documentation lies in video, and the ability to quickly edit video files and integrate them into programs, such as Windows Movie Maker and PowerPoint, for patient education, lectures, and discussions on techniques and cases. Recently, the Internet has sprouted several sites for individuals to post their homemade videos, and the future of the Internet does seem to be moving in the direction of streaming live video. This ability will open up the possibility of watching live procedures, documented through the microscope, on the Internet, and a whole new level of continuing education (CE) will emerge, as lectures and procedures become viewable via computer from the comfort of one's own home.

Increased Ability to Communicate through Integrated Video

Clinicians who have taken to adding video to the microscope have found it useful in providing information both to patients and to auxiliaries, as they both now have the ability to observe treatment in real time. The microscope, like an intraoral camera, allows for co-observation, but it also allows patients and staff members to observe treatment and become involved in a particular portion of the procedure. Patients are educated on the conditions that exist in their mouths from the video, and this is very useful during

new-patient exams and second opinions for consultations. The ability both to show patients pre-existing work, and also to allow them to witness new dental restorations, helps create trust in the doctor-patient relationship. If a picture is worth a thousand words, then how much is a magnified, live stream video worth?

Mehrabian has shown that as much as 55 percent of the understanding that occurs in verbal communication is through visual cues, and only 7 percent of the comprehension comes from the words we use. Stated differently, patients remember more of what they see, and what they see is what they hear. Clinicians have found that the images from operating scopes are of benefit in educating their patients about treatment needs and in helping to get patients to accept treatment plans.

Finally, the live video stream opens up tremendous abilities to share information with colleagues, either in a lecture format, where live video can be transferred from the scope to an LCD projector and transmitted onto a screen for the audience to see, or be captured on tape or hard drive and shared with colleagues. In over-the-shoulder workshops held in my office, colleagues have the ability to watch the procedure comfortably and at high magnification, which allows for a greater learning experience.

Summary

The use of the operating microscope in dentistry provides for tremendous benefits for any clinician. The advantages of improved precision and ergonomics, ease of documentation, and the ability to communicate with patients, staff, and colleagues are clear. As the new millennium dawned, dentists using the D.O.M. have found that the technology not only improves treatment outcomes, but also increases the enjoyment of providing the treatment.

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