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## The Use of Extreme Magnification in Fixed Prosthodontics

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The surgical operating microscope was introduced in the early 1920s, but it was largely ignored until 1950, when it was reintroduced by Richard A. Perritt for use in microsurgical operations in ophthalmology.<sup>1</sup> The magnification and illumination provided by the microscope has resulted in its acceptance as an essential part of the surgical armamentarium. Microsurgical techniques gained widespread acceptance, primarily in otolaryngology, ophthalmology, neurology, and urology, and they play a critical role in surgery to reattach severed extremities.<sup>2-8</sup>

The application of the operating microscope in clinical dentistry can be traced to Apotheker in 1981.<sup>9</sup> He converted a medical operating microscope for use in endodontics. Reports by Carr, Arens, Buchanan, Kim, Ruddle, and others<sup>10-15</sup> led to the routine use of the microscope in the 1990s for both surgical and standard endodontic therapy. During that time, specifically designed dental operating microscopes became an accepted part of endodontic therapy. Since 1998, competency in the use of a surgical microscope is required of all postdoctoral students in endodontics who complete an accredited training program.

During the mid-1990s, a number of periodontists began to advocate the use of the surgical microscope for certain periodontal procedures. Shanelc, Belcher, and Nordland<sup>16-22</sup> developed new suturing techniques with ultrafine (7-0 to 10-0) sutures that relied upon the significantly enhanced vision made possible by the microscope. The microscope provided clinicians with improved precision during delicate surgical procedures and resulted in reduced postoperative discomfort. Until recently, the role of the operating microscope in general dental practice has been very limited, involving practitioners who performed a significant number of endodontic or periodontic procedures.



**Figure 1.** The clinician is in an ergonomically balanced operator position.

Use of the operating microscope has been shown to improve visual acuity, providing increased precision in surgical care as well as in certain other types of treatment. In addition, the operating microscope provides important ergonomic benefits. The clinician sits in a comfortable upright position, relying upon directed patient movements or movements of a mirror to visualize the surgical site (Figure 1). The balanced position of the clinician when using the microscope may help reduce musculoskeletal injuries that are common among members of the dental profession.<sup>23</sup>

In addition to the ergonomic benefits, dentists using the operating microscope have discovered that the video camera attached to the microscope can be useful by providing both patients and the auxiliary staff with the ability to observe treatment in real time. The microscope, like intraoral cameras, allows for co-observation. In addition, this feature makes it possible for patients to observe treatment.

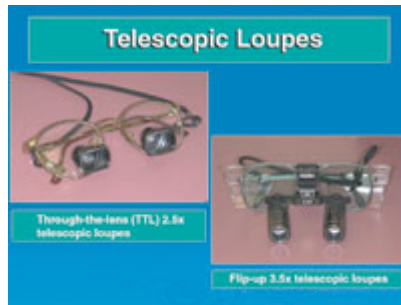
Mehrabian has shown that as much as 55% of the understanding that occurs in verbal communication is through visual cues, and that only 7% of the comprehension in communication comes from the words we use.<sup>24</sup> Stated differently, patients remember more of what they see than what they hear. Clinicians have found that the images from the operating microscope are a benefit in educating patients about their treatment needs. The ability to easily document a procedure using digital microphotography and microvideography with cameras attached to the operating microscope opens up new possibilities for patient education, documentation for professional presentations, and medical/legal documentation.<sup>25</sup>

In addition to the ergonomic benefits and documentation provided by the operating microscope, general dentists have found that it allows for significant enhancement in the precision of restorative and prosthodontic care. Martignoni, in his textbook on prosthodontics published in 1990, was among the first to discuss how the microscope might be useful in operative dentistry.<sup>26</sup> Since that time, several clinicians have suggested that this device can be used to improve tooth preparation and the final restoration in fixed prosthodontics.<sup>27-36</sup>

### Resolution of the Human Eye and Magnification in Clinical Dentistry

Carr<sup>37</sup> reported that the human eye, when unaided by magnification, has the ability to resolve or distinguish 2 discrete lines or objects separated by a space of 200  $\mu\text{m}$  (0.2 mm). If the lines are closer together than 0.2 mm, the eye will see them as a single line. Magnification improves the ability of the eye to resolve these objects, and allows the clinician to see greater detail than is possible with the eye alone. For

example, 2x magnifiers such as telescopic loupes improve resolution to 100  $\mu\text{m}$ , and 4x loupes improve the resolution of the human eye to 50  $\mu\text{m}$ , or 0.05 mm (see Table).



**Figure 2.** TTL (through-the-lens) and flip-up telescopic loupes.

Amsted or single-lens loupes are simple clip-on lenses that helped magnify the operating field. These single-lens systems have been replaced by multiple-lens telescopic loupes that are commonly used today (Figure 2). These magnifiers are available in either a flip-up variety or are directly mounted on the lenses of the glasses. Their magnification range is from 2x to 8x. Typically, loupes with magnification greater than 3.5x require some form of illumination from an accessory headlamp for adequate visualization of the operating field.



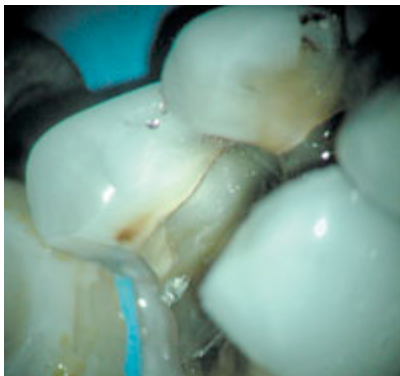
**Figure 3.** The magnification continuum.

Typically, dentists will initially use loupes with a magnification of 2.5x, and employ them for difficult procedures requiring enhanced vision such as endodontic therapy or veneer cementation. After an initial adjustment period, the dentist will begin to use the loupes for all procedures. In British Columbia the routine use of surgical telescopes by dentists has increased from approximately 20% in 1986 to 75% in 2000.<sup>38,39</sup> Dentists may then change to higher-powered loupes used with illumination (Figure 3).

Dentists have realized that many details that are potentially important in the provision of care are beyond the resolution of the human eye. Incipient carious lesions, tooth fractures, preparation of crown margins, and crown margin evaluation during insertion are often determined by tactile means. At magnifications above 4x to 6x, visual enhancement provided by the microscope may lessen the reliance on tactile sense. One study has shown that an experienced clinician with a sharp, new explorer can determine marginal gaps in the range of 35 to 50  $\mu\text{m}$ .<sup>40</sup>

Microscopes, in contrast to telescopic loupes, allow multiple steps of magnification between 2x to 40x. The microscope provides true stereoscopic vision through the binoculars, and the coaxial illumination from halogen, metal halide, or xenon bulbs creates shadow-free lighting.

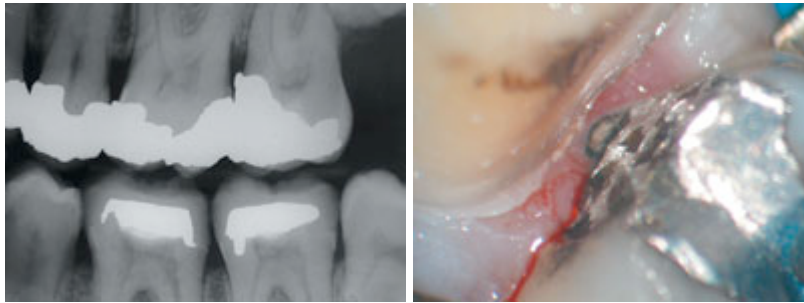
#### The Role of the Operating Microscope in the Preparation Stage of Fixed Prosthetics



**Figure 4.** Fracture of the lingual cusps of teeth requiring full coverage restoration.

The preparation phase of fixed prosthodontic care is technically demanding. Many factors determine the final design of the preparation, including the required reduction of tooth structure, detection of marginal caries, fractures, furcations, and the need for the margins of the restoration to be placed on solid tooth structure (Figure 4).

In addition, the clinician must consider the aesthetic, functional, and biologic principles regarding placement of the margins of the restoration (supragingival, gingival, or subgingival), and the type of margin best suited for the tooth (shoulder, bevel, or chamfer). While the successful provision of inlay, onlay, and crown restorations depends upon a solid understanding of the above, successful treatment is predicated on the ability of the clinician to clearly and distinctly view the operating field (Figure 5a and 5b). Leiknius and Geissberger have shown that magnification (low-magnification telescopic loupes), when used by dental students, helped reduce errors in preparation design and laboratory processing by half when compared to a control group not using magnification.<sup>41</sup>



**Figures 5a and 5b.** Overhang on the mesial surface of the second molar.



**Figures 6a and 6b.** Caries on the margin of a veneer preparation (medium and high magnification).



**Figure 7.** Caries on the distal margin (16x). **Figure 8.** Brush cutting margins with a 12-bladed carbide finishing bur.



**Figure 9.** Pulpal blush on maxillary central incisor crown preparation. (This tooth required endodontic therapy.)



**Figure 10.** Silk black cord being placed with periodontal probe. Note the clarity and visibility of margin.

The dental operating microscope can be used for the entire preparation of a tooth, but some dentists will use loupes for gross reduction of tooth structure before using the microscope to finish the preparation. Alternatively, the lower range of magnification of the microscope (2.5x to 4x) can be used for delivery of anesthesia and rubber dam placement. An entire quadrant of teeth can generally be seen at this level of magnification. Gross reduction of tooth structure is accomplished using medium magnification (6.4x to 10x), and margins are completed using 16x magnification. After finishing the margins, the preparation is examined at a lower magnification to ensure that no undercuts have been created.

Clinically, the use of higher magnification for preparation of margins appears to reduce the degree of taper of the preparations. Close attention must be given to the line of draw and parallelism when preparing multiple abutments for a fixed bridge. Otherwise, it is easy to create tooth preparations with divergent tapers, which can affect the path of insertion. The transition from low magnification (for gross tooth reduction) to high magnification (for final placement of the margin), and then back to low magnification (for the final evaluation), ensures that the clinician does not become so focused on the placement of the margin that unwanted undercuts are created.

An important benefit of higher magnification is the ideal placement of the crown or veneer margin. Finishing a margin at higher magnification can be accomplished with an electric handpiece. Finer control when finishing crown preparations is possible with an electric handpiece, where the rpm can be precisely lowered by using the dial on the front of the unit, not by a foot control as is employed with a high-speed air turbine. Or, an air turbine handpiece may be used without water spray, using a delicate "brushing" motion with a finishing bur and a gentle stream of air to avoid excessive heat generation. This brush cutting at high magnification polishes the margin, resulting in a smooth and discernable finish line.



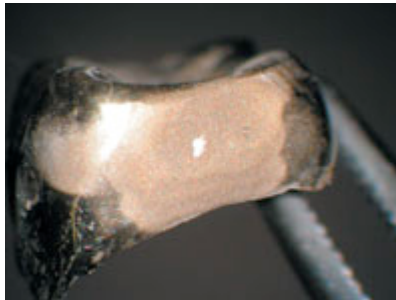
**Figure 11.** Use of extreme magnification for laboratory fabrication of prosthetic restorations.



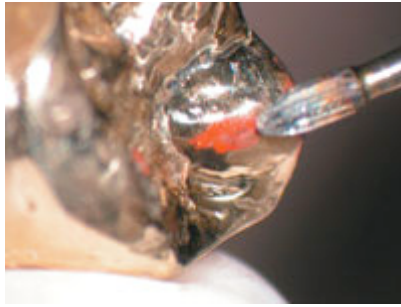
**Figure 12.** Explorer and premolar crown during try-in. (Crown is not seated on the palatal surface.)



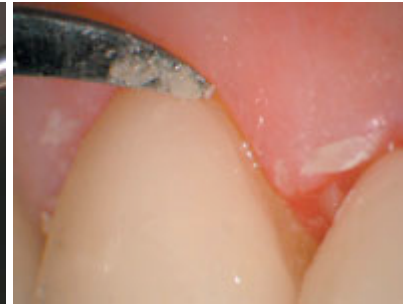
**Figure 13.** Crown seated visually after interproximal contacts are adjusted.



**Figure 14.** Crown with a tight contact detected on a sandblasted surface as small shiny spot.



**Figure 15.** Precise adjustment of a small occlusal contact detected during try-in.



**Figure 16.** Gold knife removing resin cement from a veneer (16x).



**Figure 17.** Interproximal resin carefully removed with small metal sawblade.



**Figure 18.** Evaluation of the margin of a gold onlay (16x).

In contrast to high magnification, at medium magnification (6.4x to 10x power), the entire visual field is occupied by one tooth. At the higher magnification, only part of the tooth (2 to 3 surfaces) is visible at a time. The advantage of using higher magnification is the reduction of peripheral "visual noise." At 16x magnification, 100% of the image is the operating field, and the clinician's concentration is not affected by peripheral distractions. While the clinician is focused on the operating task, it is important that the assistant monitor the patient for signs of distress or discomfort. A video monitor connected to the microscope (Figure 1) also provides the assistant with a view of what the clinician is seeing. Therefore, properly trained auxiliary personnel are essential. If the chairside assistant is viewing the operative field with binoculars to assist the dentist, a second assistant should be in the operatory.

It is important to remember that in contrast to conventional practice, use of an operating microscope at higher magnification does not allow the clinician to see all 5 sides of the tooth at once. Therefore, a much more regimented approach to crown preparation is needed to eliminate the need for frequent changes in the position of the microscope. The tooth is prepared segmentally, from gross reduction to completion of the margin. This avoids frequent repositioning of the microscope. Often, a full crown preparation can be completed with only 2 or 3 separate viewpoints. Traditionally, when preparing a crown without magnification, the dentist will move his head frequently in order to gain visual access. Often, the patient remains stationary during this process, and the clinician must lean forward or reposition the dental chair in order to obtain the necessary view of the tooth. Over time, this unbalanced operating position can result in the dentist developing upper cervical or lower thoracic musculoskeletal problems.

When using the operating microscope efficiently for crown and bridge preparation, the instrument remains stationary, and changes in the position of the patient, the patient's head, and the dental mirror will allow for optimal viewing. Use of higher magnification provides the clinician with a more detailed view of the margin of the preparation, but there is a corresponding decrease in the width and depth of the operating field. A good general rule is to use 10x magnification for the completion of tooth preparations.

When first using the microscope for crown and bridge procedures, the clinician will find that it takes longer to prepare teeth for crowns as compared to conventional technique. It takes time to develop the motor skills necessary to work at higher magnification. Shanelc has observed that with time, the clinician can learn to make movements in the range of 10 to 20  $\mu\text{m}$  (10 to 20/1000ths of a mm).<sup>42</sup> In addition, higher magnification will reveal rough and irregular margins, which causes the clinician to spend more time trying to finish these margins to the ideal. Once the learning curve for positioning the microscope is mastered, the actual time required for tooth preparation is equal to or less than what it was prior to using the microscope. The microscope helps the clinician see when the margin is satisfactory. There is no need to indirectly assess (with a dental explorer) whether the margin is on solid tooth structure or if caries or restorative material is on the finish line. The margin is visualized at 10x power and above.

After the final margins have been completed, another benefit of the operating microscope is improved tissue management. Whether retraction cord, a laser, or electrosurgery is used, it is easier to determine precisely whether the margin of tooth structure is visible prior to taking the impression. It is of paramount importance to be able to circumferentially view the margin prior to impressioning so a clear impression is obtained. The impression can then be viewed under the microscope and then checked at high magnification for voids, tears, or other discrepancies prior to being sent to the laboratory. The provisional restoration can be trimmed under the microscope, ensuring that the restoration is well adapted and will allow for the healing of the tissues during the provisional stage.

#### **The Role of the Operating Microscope During the Insertion Stage of Fixed Prosthetics**

Once the impression reaches the laboratory, it is ideal if the laboratory uses magnification during the fabrication of the prosthesis. Many forms of high magnification are available for this purpose, allowing the work to proceed under 10x to 40x power. In 1985, Chou and Pameijer<sup>43</sup> described how a laboratory technician can more precisely trim stone dies with the aid of a microscope. There is little doubt that laboratory quality is enhanced with the use of magnification.

Magnification System	Magnification	Resolution ( $\mu\text{m}$ )	Resolution (mm)
Unaided Human Eye	zero	200	0.2
Amsted Loupes	1.5x	133.33	0.133
Low-Magnification loupes	2.5x	80	0.08
Medium Power Loupes	4x	50	0.05
Sharp Explorer*	zero	36	0.036
Microscope-low mag.	6.4x	31	0.031
Microscope-med. mag.	10x	20	0.02
Microscope-high mag.	24x	8.33	0.0083

During the try-in and seating appointment, the microscope is extremely useful. Historically, the prime indicator of a well-fitting crown is judged by the smooth, tactile feel of an explorer moving without interruption over the restoration-tooth interface. In combination with pre-cementation radiographs, the crown is judged for acceptability prior to cementation. There are many subjective variables when using an explorer, including the condition of the explorer tip, the angle of contact between the explorer and the tooth, the force applied, and the specific location of the tip at any point in time. The interpretation of the tactile data by clinicians will vary. A sharp explorer in the hands of a skilled, trained clinician has been shown to be approximately 5 times as effective in determining the marginal fit than the unaided eyes.<sup>44</sup> Visualizing the fit of the crown using 10x magnification further improves the ability to determine if the margin is acceptable (See Table).

One of the primary reasons crowns may be difficult to seat properly is tight interproximal contacts. Patients will remark that a crown feels tight and return to the office complaining of food entrapment. Interproximal contacts involving gold crowns can be sandblasted. The actual contact can then be viewed at high magnification as a shiny spot on the sandblasted surface. For porcelain crowns, waxed floss will often leave a remnant of wax at the contact, which again will be visible under high magnification and easily and specifically adjusted. The specificity of adjustments reduces the risk for an open contact after cementation.

Occlusal contacts can also be difficult to visualize when assessing gold crowns. When using the microscope, these contacts are easy to view and can be adjusted without damaging the occlusal anatomy of the crown. In addition, the use of articulating ribbon can result in the material being seen on the occlusal surface of porcelain crowns even when the occlusion is very close to ideal. Limited and appropriate adjustment of the crown ensures that the final restoration has ideal morphology.

Further, when veneers are cemented, the resin luting agent can be extremely difficult to visualize. It is ideal to remove as much of the cement as possible after tacking the resin to place with a brief polymerization cure (3 seconds). Most of the removal of excess cement should be accomplished at this time to ensure an ideal result. Should excess resin remain, it will often be difficult to see and can lead to persistent inflammation of the marginal tissues. Translucent resins are particularly difficult to see, and in most cases, the microscope facilitates removal of the excess. The cementation of full coverage restorations is also improved when using the microscope, as minute amounts of cement can often be seen and easily removed. This is true even if the excess cement is slightly subgingival.

## Conclusion

The popularity of the operating microscope will likely increase in the future for prosthodontic procedures. Dentists will derive benefits from magnification, primarily during the preparation and insertion stages of fabricating indirect restorations<sup>6-18</sup>. The enhanced visual acuity and illumination simplifies many technically difficult tasks. In addition, the clinician is able to practice in a balanced ergonomic position and can document the procedure with still or video photography.

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*Disclosure: Dr. van As receives an honorarium from Global Surgical (microscopes) and Hoya Con/Bio (lasers) for certain lectures.*