**Extreme Magnification and Laser Dentistry: Seeing the Light.**

By Dr. Glenn A. van As

*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 His primitive microscope required that the clinician work standing upright, and this combined with only a single level of magnification made routine usage impossible. 8

In the late 1980’s, San Diego endodontist Dr. Gary Carr, 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 for the improvement in outcomes of endodontic apical surgeries. 9-10 During the early 1990’s, other endodontists including Ruddle, Buchanan, Arens, Stropko, Kim and others began to promote the D.O.M. for its value in both standard endodontic therapy, and for the improvements in outcome of both non surgical retreatments and for surgical cases. 11-24

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, utilizing micro-surgical armamentarium including smaller blades and 7-0 to 10-0 sutures. These delicate surgical procedures allowed for improvements in postoperative pain and quicker healing. 25-33

The usage of lower power telescopic loupes became more of the norm for all of dentistry during the mid to late 1990s. 34,35 As dentists began to understand the role and value that magnification could provide for all disciplines of dentistry, many purchased a 2nd or 3rd set of loupes that were higher in power, and often 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 the **Magnification Continuum** to describe this development of ever increasing magnifications being used in dentistry. 36 The usage of the operating microscope for both diagnosis (new patient exams, earlier visualization of decay and cracks 37) as well as for treatment including standard operative, prosthodontic, cosmetic, and laser dentistry has become more accepted as general practitioners interested in...
creating a microscope centered practice have recognized the value that high levels of magnification provide for all disciplines of dentistry (Fig. 1). 38-55

**Benefits of Microscope Centered Practices.**

The microscope when used routinely for all aspects of dentistry has four basic advantages including:

1) Improved precision of treatment.
2) Enhanced Ergonomics (Figure 2)
3) Ease of Digital Documentation. (Figure 3)
4) Increased Ability to Communicate through integrated Video.

This article will look primarily at the ability of the microscope to provide improvement in visual acuity and in addition the affect that high levels of enhanced magnification and illumination can have on improving the quality of laser dentistry that is provided.
1) 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 horizontal X vertical number of pixels.

Therefore, the clinician using the commonly purchased 2x magnification of entry level loupes sees approximately 4X the visual information of a dentist not using any magnification at all (naked eye).

A set of 3X loupes provides 9 times the visual information of the unmagnified view and over double what is seen with the typical 2x entry level set of loupes.

A microscope at 10X magnification (typical magnification used by the author for routine laser dentistry, single tooth prosthodontics preparations, and finishing of prosthodontics margins) provides 100X the amount of visual information compared to the naked eye view. It provides 25X the information as that of the entry level loupes (2X) and over 10X that of a 3X power of loupes. (Table 1).

<table>
<thead>
<tr>
<th>Magnification</th>
<th>Visual information (VI)</th>
<th>VI Compared to 2X loupes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naked eye</td>
<td>1x</td>
<td>1/4</td>
</tr>
<tr>
<td>2x loupes</td>
<td>4x</td>
<td>Even</td>
</tr>
<tr>
<td>3x loupes</td>
<td>9x</td>
<td>2.25X</td>
</tr>
<tr>
<td>4x loupes</td>
<td>16X</td>
<td>4 X</td>
</tr>
<tr>
<td>6X microscope</td>
<td>36X</td>
<td>9X</td>
</tr>
<tr>
<td>10X microscope</td>
<td>100X</td>
<td>25X</td>
</tr>
<tr>
<td>20X microscope</td>
<td>400X</td>
<td>100X</td>
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There is always a price to be paid for the increased amount of visual information that the microscope provides over low or medium powered loupes. As the magnification increases, the depth and diameter of field of view of the operating field decreases. 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 micro-surgeon chairs. Shanelec and Tibbets reported that the medical literature showed that the clinician not using magnification made movements that were 1-2 mm at a time. At microscope levels of 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 any magnification, has the inherent ability to resolve or distinguish two separate lines or entities that are at least 200 microns or .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 gets beyond 6X power that 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

<table>
<thead>
<tr>
<th>Magnification System</th>
<th>Magnification</th>
<th>Resolution (um)</th>
<th>Resolution (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naked eye</td>
<td>zero</td>
<td>200</td>
<td>0.2</td>
</tr>
<tr>
<td>Low power loupes</td>
<td>2x</td>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td>Med power loupes</td>
<td>4x</td>
<td>50</td>
<td>0.05</td>
</tr>
<tr>
<td>Sharp Explorer</td>
<td>zero</td>
<td>36</td>
<td>0.036</td>
</tr>
<tr>
<td>Microscope low mag</td>
<td>6X</td>
<td>36</td>
<td>0.036</td>
</tr>
<tr>
<td>Microscope med mag</td>
<td>10X</td>
<td>20</td>
<td>0.02</td>
</tr>
<tr>
<td>Microscope high mag</td>
<td>20X</td>
<td>10</td>
<td>0.0100</td>
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Impact of Improved Visual Acuity in Laser Dentistry.

The ability to carefully evaluate at high magnification the laser-tissue interaction is important in many areas of laser dentistry. The microscope offers improved visual acuity through its enhancements in magnification (Fig. 4) and co-axial shadow free illumination and these can be of tremendous benefit in both soft tissue and hard tissue ablation.
In recent years there has been a growing increase in soft tissue diode lasers being purchased by dentists who see their small size, reliability, portability and lower price tag as an attractive alternative to electrosurgery units. As with any new technology there is an expected learning curve to be encountered and this is no different with soft tissue lasers. Clinicians must learn to use an end-cutting device that relies upon slower movements to accomplish the ablation of soft tissue with light. The conversion of the light into thermal energy (photo-thermal) requires the clinician to slow down their movements to give time for the effect to occur.

The primary focus for many clinicians entering into the soft tissue market is to utilize the diode for soft tissue management. The attractiveness of using a laser to trough around crown preps can be met initially with frustration over the relative “slowness of cutting” compared to electrosurge. The natural reaction is to speed up the ablation and this creates bleeding as the quartz glass fiber drags through inflamed tissue. Increasing power results in more charring, with greater postoperative sensitivity and greater risk of recession. The clinician must accurately place the 300 micron fiber, which is close to the resolution of the human eye, in the sulcus 0.5-1.0 mm to avoid vertically changing the gingival sulcus and only laterally distend the sulcus without deepening it. Power settings of 0.4-0.6 watts continuous wave are all that is needed to ablate tissue. (See Figs 5a-f) When combining the diode wavelength with the operating microscope at high power the clinician will ablate soft tissue without charring, and the higher magnifications possible with the microscope allow for the ability to trough around endodontically treated teeth with only strong topical anesthetics such as TAC 20, EMLA or Tricaine Blue at these lower settings.
Fig 5a demonstrates preop view of maxillary incisors prior to veneer preps.

Fig 5b Veneer preps done.                  Fig 5c Diode to trough around margin.  Fig 5d High mag of trough done.

Fig 5e Veneer impression.                  Fig 5f tissue health at 2 weeks.                  Fig 5g Postoperative result.

Other diode contact soft tissue procedures on non pigmented fibrous tissue such as fibroma removal, frenectomies, lingual tongue tie releases, require the clinician to ablate through a photo-thermal effect where the primary chromophore of pigmentation and/or hemoglobin is not as present as in some other procedures where the tissue may be inflamed. The careful analysis at higher magnification of the laser tissue interaction can allow for less charring during these procedures and less postoperative discomfort. With diode frenectomies, the clinician has the ability to visualize with the microscope exactly when all fibers have been ablated, reducing the need for retreatment due to relapse. (Figs. 6a-6c)

Fig 6a Preop frenum pull.                     Fig. 6b. Frenectomy completed.        Fig 6c Postoperative result - high mag.

Fig 6a Preop frenum pull.                     Fig. 6b. Frenectomy completed.        Fig 6c Postoperative result - high mag.

In non contact soft tissue ablation, such as is seen with CO2 wavelengths, the ability to accurately visualize the laser tissue interaction precisely at higher magnifications eliminates the risk for accidental interaction with the wavelength on tooth structure or
bone. The ability to magnify the surgical site gives the clinician working in non contact a
tremendous opportunity to keep the power settings lower and to avoid iatrogenic to
adjacent tissues not requiring ablation.

Diodes and NdYAG lasers can also be used in non contact mode for the treatment of
aphthous ulcers, for hemostasis of extraction sites, for the treatment of hemangiomas and
to aid in hemostasis of direct pulp caps during restorative procedures. Again, as is the
case with CO2 wavelengths, the opportunity to improve the visual acuity allows for
careful and precise use of these wavelengths in non contact treatments.(See Fig 7a-f)

![Fig 7a Preop lower 2nd molar.](image1)
![Fig 7b. Sinus Tract on buccal](image2)
![Fig 7c Extraction complete](image3)

![Fig 7d Diode hemostasis.](image4)
![Fig. 7e. Hemostatic laser clot low mag.](image5)
![Fig 7f Diode clot at high mag.](image6)

The Erbium wavelengths (ErYAG , Er,Cr:YSGG) have been termed as All-Tissue
wavelengths because they are able to ablate any tissue that has water in it. Their affinity
for water and hydroxyapatite as chromophores allows them to cut enamel, dentin, caries,
cementum, bone and soft tissue in a non selective fashion. Many clinicians have taken to
using this wavelength for soft tissue ablation in both a contact and non contact fashion.
The ability to use a contact chisel tip at high magnifications (5-12X mag) in a non contact
fashion allows for the clinician to limit the inherent weakness of this wavelength to
coagulate. The maxillary frenectomies are quick and the typical difficulty in hemostasis
with this wavelength occurs mainly when entering the periosteum in most instances when
ablating soft tissue in non contact. The non contact “plasty” or shaving down of tissue
that is possible with the chisel or large footprint Er:YAG tips using the microscopes at
high magnification is wonderful technique for epulis and tissue tags, as well as in the
creation of ovate pontics for fixed bridges where the tissue can be “melted” away almost
magically. (Fig 8a-d captured stills from video.)
In looking at the precision of treatment in restorative dentistry, studies by Leknius and Geissberger\textsuperscript{59} as well as by Zaugg\textsuperscript{60} et al have demonstrated that as magnification is incorporated, that procedural errors decreased significantly. In the last study, the inclusion of a microscope resulted in less errors than those using loupes.

During regular restorative dentistry, the clinician can rely upon tactile means during the procedure to differentiate when decay is fully removed or when amalgam restorations have been completely been removed. The physical touching of the tooth with the burs be it with a slow speed or even a high speed handpiece, provides the clinician with a great deal of information about the status of the procedure.

The reliance on tactile methods of detection of decay become extremely difficult in hard tissue laser dentistry where so much of the evaluation of the laser-tissue interface is based not on tactile but visual cues. Caries detection dyes are not clean or easy to use with hard tissue laser preparations, as there is a great deal of false positives of the dyes on the ablated enamel. Therefore reliance on high magnification to determine complete decay removal is essential. (Figs 9a-f) Erbium lasers both with contact tips (where the actual distance for effective ablation is 0.5 -1.5 mm in non contact) and in non contact (window and not contact tip) delivery systems there is a tremendous need to actually see the interaction of ablation as it is difficult to “feel” the cutting taking place.
Visual inspection of the laser-hard tissue interaction is obscured by the fact that there is a large amount of water needed for effective and safe ablation. The tips are close to the 200 micron resolution of the naked eye, and the tips are clear in color and must be in pristine non-chipped condition. In addition, most hard tissue lasers work at their optimum level of ablation when the tips are held in a non-contact manner, with the tip held at around 0.5 - 1.5 mm away from the tissue surface. When the distance increases beyond this optimum, then ablation efficiency significantly decreases as the tip gets further out of contact. Often clinicians are forced to increase power to counter the drop in efficiency as they hold the tip away from the hard tissue. When the tip is brought closer to the surface and gets into direct contact with the surface the cutting efficiency decreases as water flow is not able to rehydrate, wash away ablation byproducts, and cool the tissue. Charring, sensitivity and a slowing in ablation will occur. In addition, there will be a decrease in the lifespan of the tip for the laser, as more time is spent in contact mode. It is therefore crucial that magnification is used for many aspects of hard tissue laser dentistry. The higher the level of magnification used, the greater the ability of the dentist to directly view the laser-tissue interaction. The author has seen this countless times in his clinical teaching of new erbium hard tissue lasers where satisfaction with the hard tissue laser improved dramatically once the dentist started using higher levels of magnification.

In addition for laser dentistry, the ability to ideally view the interaction between the laser and hard tissue allows for the dentist to use less energy to accomplish the task at hand. Not only does this meet with the guidelines of the Academy of Laser Dentistry to use the lowest energy possible to complete the procedure, but it allows for settings that are more likely to allow for the patient to be less sensitive during the laser. Often enamel ablation
can be completed at levels of around 1.5 watts. (50 Hz and 30 millijoules). Even at these low settings enamel bevels for Class 3, 4 and 5 restorations require the clinician to “scrape” or alter the ablated enamel prior to acid etching. High magnification with the operating microscope shows that enamel bevels have many loose rods which if not altered with an instrument (hatchet or spoon), air abrasion or a diamond bur will yield significantly lower bond strength compared to bur cut enamel. The fragments of enamel that are scraped off are easily visible under high magnification. (Fig 10a-e).

Fig 10a Preop Left Central incisor.  Fig 10b Enamel Bevel (30Hz 60 mj)  Fig. 10c. Spoon used to “scrape”.

Fig 10d Note loose enamel rods on surface after scrape.  Fig 10e Restoration finished.

The operating microscope again is an instrumental piece of the armamentarium for not only restorative laser dentistry but for the ablation of bone. Numerous studies have shown the safety of erbium lasers on bone in both the medical and dental literature. The microscope and its high level of magnification is very important in properly evaluating the laser-tissue interaction. As with ablation of tooth structure, water is necessary to prevent the photo-thermal effect of ablation from causing charring and bone necrosis. The level of air spray should be limited to prevent iatrogenic risk of air emphysema.

Osseous bone has a thin layer of cortical plate and once that is removed then the marrow spaces are much easier to ablate. To prevent plucking or iatrogenic notching, it is best to use lower settings (1.5-3 watts for example) to remove bone with a high water flow, while keeping the tip as best as possible in non contact. The amount of water and slight bleeding can obscure visibility so the ability to increase the magnification to evaluate the
bone ablation is imperative to success. The interesting item is that with a high speed turbine and its high rate of revolutions, there is far more splatter and more debris with cutting than with lasers. In addition in instances such as for the removal of root tips, the longer contact laser tips that are 400 microns in diameter can be used within the socket without raising a flap to remove roots by troughing around the socket. In these instances where the laser is used for extractions, the power settings may be turned up a little for efficiency of ablation. (Figs 11a -11e).

Recently, a growing interest in closed and open flap osseous recontouring has occurred for those who own hard tissue lasers. In instances where small amounts of bone can be removed for clinicians to be able to gain more ferrule for biologic width infringement, many are using a closed flap technique for the bone removal. The microscope allows for the clinician to accurately place the contact tip within the sulcus and carefully remove small amounts of attached tissue and bone to improve the restorative or cosmetic aspects of the clinical case. (Fig 12 a-l). The microscope is especially useful for closed flap situations in the posterior to avoid iatrogenic troughing of the bone.
Laser Safety

Laser safety is of paramount importance to laser dentists whether they are using no magnification, telescopic loupes or higher levels of magnification. Soft tissue lasers can have their greatest interaction with the retina of the human eye where there is higher levels of hemoglobin present. On the other hand, hard tissue Erbium lasers can have interactions with the cornea and lens of the eye due to its higher level of water content. This is no different when using an operating microscope. For the Global operating microscopes the author has helped design laser filters are built that fit into the microscope and allow for the operator to safely work with the scope without fear of optical damage to the retina (soft tissue wavelengths) or the lens and cornea (hard tissue lasers). The filters are quickly inserted into the microscope depending on the wavelength (one filter exists for the 980 nm diodes, NdYAG, Er:YAG and CO2 wavelengths and a 2nd filter exists for the diode wavelengths that are between 810 - 830 nm). These can be quickly inserted above the beamsplitter but before the oculars so as not to affect the documentation, yet still provide safety for the operator. (Figs. 13a-d).
2) Improved Ergonomics

The operating microscope allows for the dentist to sit in an upright, neutral and balanced posture. This neutral balanced posture obtainable with the D.O.M. has been discussed as being helpful in preventing ergonomic issues that plague so many dentists and seem to be an occupational hazard. 61-62

3) 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. The usage of documentation for medico legal, insurance, patient communication, lecturing purposes or for communication with staff or colleagues is impressive. Even the most seasoned colleagues appreciate the detail that is possible when taking microphotography or videos. Carr 63, Behle 64 and van As 65-66 have all written articles discussing the merits of digital documentation with the D.O.M. and the advantages of doing so.

4) Increased Ability to Communicate through integrated Video

Dentists who have taken to adding video to the microscope have found it useful in providing information to both patients and to auxiliaries as they both now have the ability to observe treatment in real time. 67 Mehrabian has shown that as much as 55% of the understanding that occurs in verbal communication is through visual cues and only 7% of
the comprehension comes from the words we use. Stated differently, patients remember more of what they see and that they see what they hear. Clinicians have found that the images from the operating scopes are a benefit to educating their patients about treatment needs and help in getting patients to accept treatment plans.

The usage of video to different monitors in the operatory has opened up the possibility of working solely from a monitor but particularly for hard tissue laser dentistry where depth perception is so vital to success in determining ablation efficiency, it is difficult if not impossible to work of a 2D screen when 3D is vastly needed in order to tell how far away the tip is from the tissue surface. Still some systems that allow the clinician to work of a monitor do exist out there and more will come with eventual 3D systems becoming available. 67

In closing, the usage of the operating microscope for laser 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. As the new millennium dawned and the integration of lasers into offices occurred, dentists using the combination of the D.O.M. and lasers have found that the two technologies work well in tandem and improve not only the treatment outcome but the enjoyment of providing it.

*Dr. Glenn A. van As was the recipient of the Leon Goldman award for 2006 from the ALD which is for clinical excellence in the field of laser dentistry.*
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