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 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]

Fig 1 showing the microscope centered operatory.

<u>Benefits of Microscope Centered Practices.</u>

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.

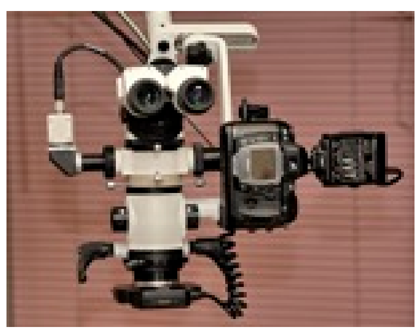

Fig 2 showing neutral and balanced ergonomics of author at the microscope.
Fig 3 video camera on left and digital SLR Nikon D70 on the right of the scope.

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 1

Magnification	Visual information (VI)	VI Compared to 2X loupes
Naked eye	**1x**	**1/4**
2x loupes	**4x**	**Even**
3x loupes	**9x**	**2.25X**
4x loupes	**16X**	**4 X**
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 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 (10-20/1000th 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

Magnification System	Magnification	Resolution (um)	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	0.0100

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.

Fig 4 showing magnification range of the Global G6 microscope.

Soft tissue laser ablation and the Operating Microscope.

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.

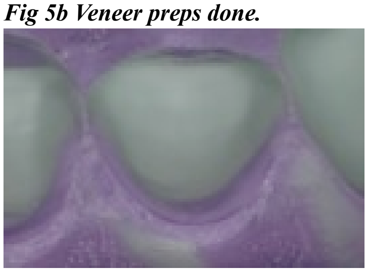

Fig 5e Veneer impression.

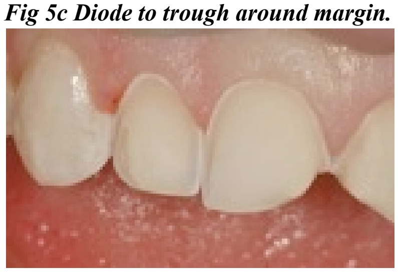

Fig 5f tissue health at 2 weeks.

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.

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 apthous 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.

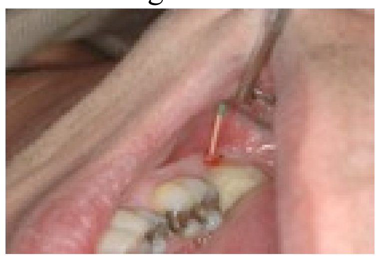

Fig. 7b. Sinus Tract on buccal

Fig 7c Extraction complete

Fig 7d Diode hemostasis.

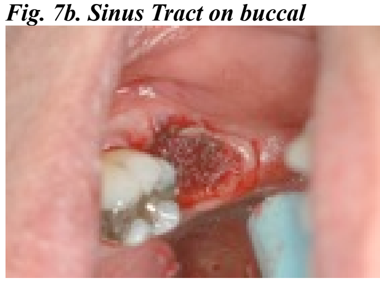

Fig. 7e. Hemostatic laser clot low mag.

Fig 7f Diode clot at high mag.

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.)

Fig 8a Non contact ErYAG frenectomy - note early charring before adjusting power settings.
Fig 8b High mag view of frenectomy- not lack of hemorrhage in non contact mode.

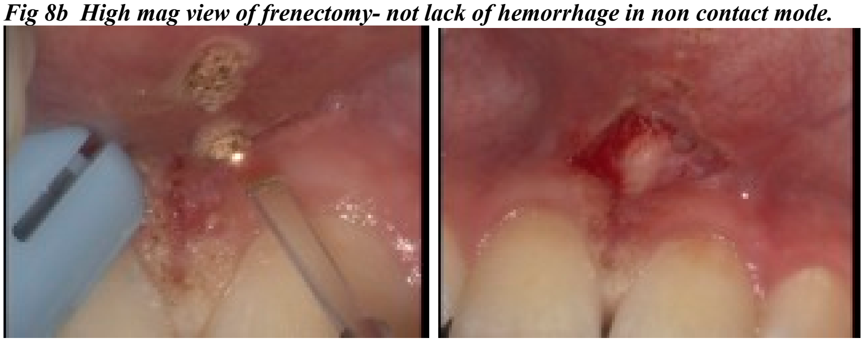

Fig 8c Non contact "plasty" of epulis on maxillary lip. Note "flash" at ablation site.
Fig 8b High mag view of frenectomy after periosteum "scored" with Er:YAG.

Hard tissue laser ablation and the Operating Microscope.

In looking at the precision of treatment in restorative dentistry, studies by Leknius and Geissberger[59] as well as by Zaugg [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.

Fig 9a Preop interproximal decay.
Fig 9b Decay visible on distal of first primary molar.
Fig 9c High mag shows decay still visible on facial wall of box.

Fig 9d Preparations completed. ***Fig 9e Restorations finished.***

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".

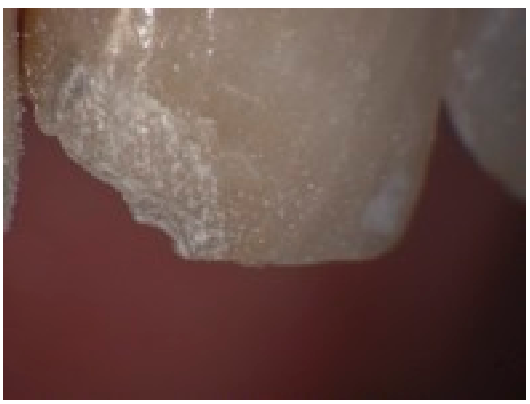

Fig 10d Note loose enamel rods on surface after scrape.

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 then 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).



Fig 11a Er:YAG for extraction of root at 30Hz 50-100 mj.
Fig 11b Trough around root with bone removal complete.
Fig 11c Elevator applying leverage in trough.

Fig 11d Root removed.

Fig 11e Extraction socket, note lack of sutures or flap.

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.

Fig 12a Preop retracted smile.

Fig 12b Smile.

Fig 12c Gingivectomy R side.

Fig 12d ErYAG Frenectomy.

Fig 12e Gingivectomy done #7-10

Fig 12f Non contact papilla "plasty"

Fig 12g ErYAG plasty completed

Fig 12h Closed flap recontouring.

Fig 12i Osseous Completed.

Fig 12j One month postop.

Fig 12k Frenectomy healing.

Fig. 12l Diode touchup on #9

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. and 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).

  

Fig 13a ErYAG microscope laser filter *Fig. 13b Light blue ErYAG filter.* *Fig 13c Filter in scope.*

Fig 13d. Laser filter placed in scope below oculars.

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.

References

[Mark] Nylen O. The Microscope in Aural Surgery: Its First Use and Later Development. Acta Otolaryngol, 116:226, 1921.
[2] Dohlman GF. Carl Olof Nylen and the birth of the Otomicroscope and Microsurgery. Arch Otolaryngology 90: 161-165, Dec 1969.
[3] Klopper P, Muller JH, Van Hattum AH. Microsurgery and Wound Healing. Amsterdam, Excerpta Medica, 1979, p 280.
[4] Jacobsen, JA, and Suarez, EI, Microsurgery in Anastomosis of Small Vessels. Surg Forum, 11:243-245, 1960.
[5] Harms, H, and Mackensen, G, Ocular Surgery under the Microscope, Yearbook Medical Publishers, Inc, Chicago, 1967.
[6] Banowski, LH, A Review of Optical Magnification in Urological Surgery, in Microsurgery, Edited by Silber, SJ; William and Wilkins, Baltimore: 443-462, 1979.
[7] Barraquer, JL, The History of the Microsurgery in Ocular Surgery. J Microsurgery, 1:292, 1980.
[8] Apotheker H: A microscope for use in dentistry. J Micosurg 3:7, 1981.
[9] Carr, GB, Microscopes in endodontics. CDA Journal 20:55-61.
[10] Carr, GB, Common Errors in Periradicular Surgery, Endo Report 8(1):12-18, 1993.
[11] Mounce, R, Surgical Operating Microscope in Endodontics; The Paradigm Shift. General Dentistry, 43:346-349, 1995.
[12] Feldman, M, Microscopic Surgical Endodntics, NYSDJ, 10:43-45.
[13] Ruddle, CJ, Endodontic Perforation Repair using the Surgical Operating Microscope. Dent Today May 1994, pp 49-53.
[14] Ruddle, CJ, Nonsurgical Endodontic Retreatment. CDA Journal, 25 (11): 769-799, Nov. 1997
[15] Tsesis I, Rosen E, Schwartz-Arad D, Fuss Z. Retrospective evaluation of surgical endodontic treatment: traditional versus modern technique. J Endod. 2006 May;32(5):412-6.
[16] Schirrmeister JF, Hermanns P, Meyer KM, Goetz F, Hellwig E., Detectability of residual Epiphany and gutta-percha after root canal retreatment using a dental operating microscope and radiographs--an ex vivo study. Int Endod J. 2006 Jul;39(7):558-65.
[17] Sempira HN, Hartwell GR, Frequency of second mesiobuccal canals in maxillary molars as determined by use of an operating microscope: a clinical study. J Endod. 2000 Nov;26(11):673-4
[18] Schwarze T, Baethge C, Stecher T, Geurtsen W., Identification of second canals in the mesiobuccal root of maxillary first and second molars using magnifying loupes or an operating microscope. Aust Endod J. 2002 Aug;28(2):57-60.
[19] Gorduysus MO, Gorduysus M, Friedman S. Operating microscope improves negotiation of second mesiobuccal canals in maxillary molars. J Endod. 2001 Nov;27(11):683-6.
[20] de Carvalho MC, Zuolo ML., Orifice locating with a microscope. J Endod. 2000 Sep;26(9):532-4.
[21] Buhrley LJ, Effect of magnification on locating the MB2 canal in maxillary molars. J Endod. 2002 Apr; 28(4):324-7.
[22] Stropko JJ. Canal morphology of maxillary molars: clinical observations of canal configurations. J Endod. 1999 Jun;25(6):446-50.
[23] Coutinho Filho T, La Cerda RS, Gurgel Filho ED, de Deus GA, Magalhaes KM. The influence of the surgical operating microscope in locating the mesiolingual canal orifice: a laboratory analysis. Pesqui Odontol Bras. 2006 Jan-Mar;20(1):59-63. Epub 2006 May 22.
[24]. Carr GB. Microscopes in endodontics. J Calif Dent Assoc 1992;20(11):55-61..
[25] Michaelides PL., Use of the operating microscope in dentistry. J Calif Dent Assoc 1996 Oct;24(10):9.
[26] Ruddle, CJ, Nonsurgical Endodontic Retreatment. CDA Journal, 25 (11): 769-799, Nov. 1997
[27] Shanelec, DA, Current Trends in Soft Tissue Grafting. CDA Journal, Dec. 1991.
[28] Shanelec, DA, Microsurgery and Gingival Grafting, CDA Journal, Jan. 1991.
[29] Shanelec, DA, and Tibbetts, LS, Periodontal Microsurgery. Perio Insights 3: 4-7, Feb, 1994.

[30] Tibbets, LS, Shanelec, DA An Overview of Periodontal Microsurgery. Current Science, 2:187-193, 1994.
[31] Shanelec, DA, and Tibbetts, LS, Current Status of Periodontal Microsurgery. Periodontics 2000, 2:88-92, 1996.
[32] Belcher, JM, A Perspective on Periodontal Microsurgery, International Journal of Periodontics and Resotrative Dentistry. Quintessence, Vol. 21 (2) 191-196, 2001.
[33] Pecora, G. Andreana, S. Us of dental operating microscope in endodontic surgery. Oral Surg Oral Med Oral Path, 75 (6): 751-758, 1993.
[34] Burton JF, Rucker LM. The use of magnification devices in dentistry: a survey of dental practitioners. Proceedings of IADR; Singapore; 1983.
[35] Lunn R, Sunell S. Posture, position, and surgical telescopes in dental hygiene. J Dent Ed. 1996; 60 (2); 122.
[36] van As G., Magnification and the alternatives for microdentistry. Compend Contin Educ Dent. 2001 Nov;22(11A):1008-12, 1014-6
[37] Clark DJ, Sheets CG, Paquette JM, Definitive diagnosis of early enamel and dentin cracks based on microscopic evaluation. J Esthet Restor Dent. 2003;15(7):391-401; discussion 401
[38] van As, GA, Using the Surgical Operating Microscope in General Practice. Contemporary Esthetics and Rest. Practice., pp 34-40, 4(1), January 2000.
[39] van As, GA, Enhanced Acuity through Magnification: Clinical Application for Increased Visualization.. Vol.1 No.2, pp 40-42, Winter 2001.
[40] Martignoni, M, Schonenberger A, Precision Fixed Prosthodontics: Clinical and Laboratory Aspects. Quintessence Publishing Co. Inc., Chicago, 1990.
[41] Sheets, CG, Paquette JM, Enhancing Precision Through Magnification . Dentistry Today. 17(1), January 1998.
[42] Sheets, CG, Paquette JM, The Magic of Magnification. Dentistry Topday. 17(12), pp: 61-67, Dec. 1998.
[43] Friedman, MJ, Landesman, HM, Microscope-Assisted Precision (MAP) Dentistry: Advancing Excellence in Restorative Dentistry. Contemporary Esthetics. Pp 45-50, Sept. 1997.
[44] Cruci, P: An Operating Microscope in General Dental Practice. Dental Practice 37 (9): pp 1-5, May 1999.
[45] Friedman, MJ, Mora, AF, Schmidt, R. Microscope-Assisted Precision Dentistry. Compendium Dentin Educ. Dent. 20(8):723-736., August 1999.
[46] Mora, AF. Restorative Microdentistry: A New Standard for the Twenty-First Century. Prosthet Dent Rev 1(3), 1998.
[47] Piontakowski , PK. The Renaissance of Dentistry:: An Introduction to the Surgical Operating Microscope. Dentistry Today, 17(6), June 1998.
[48] Paquette, JM. The Clinical Microscope: Making Excellence Easier. Contemporary Esthetics and Rest. Practice, Oct. 1998.
[49] Christensen GJ, Magnification in dentistry: useful tool or another gimmick?
[50] Clark DJ, The Big Push to Clinical Microscopes for Esthetic Dentistry., Contemporary Esthetics and Rest. Practice, Nov. 2005. 30-33.
[51] Clark DJ, Kim J, Optimizing Gingival Esthetics: A Microscopic Perspective. Oral Health, April 2005. pg 116-126.
[52] Clark DJ, Microscope Enhanced Aesthetic Dentistry. Dentistry Today, Nov.2004.
[53] Garcia A. Dental magnification: a clear view of the present and a close-up view of the future. Compend Contin Educ Dent. 2005 Jun;26(6A Suppl):459-63
[54] van As, GA, The use of extreme magnification in fixed prosthodontics. Dent Today. 2003 Jun;22(6): 93-9.
[55] van As, GA, The Role of the Dental Operating Microscope in Fixed Prosthodontics. Oral Health, June 2002, 11-25.
[56] Tibbets, LS, Shanelec, DA , Periodontal Microsurgery. Dent Clin North Am. 1998; 42: 339-359.
[57] Carr, GB, Magnification and Illumination in Endodontics. Clarks Clinical Dentistry, 4: 1-14, 1998
[58] Baldissara, P, Baldissara, S, Scotti, R, Reliability of tactile perception using sharp and dull explorers in marginal opening identification., Int.Journal of Prosth., 1998, Nov-Dec;11 (6) 591-594.
[59] Leknius, C and Geissberger, M, The Effect of Magnification on the Performance of Fixed Prosthodontic Procedures, CDA Journal, 23 (12); 66-70, 199
5.

[60] Zaugg B, Stassinakis A, Hotz P. Influence of magnification tools on the recognition of simulated preparation and filling errors. Schweiz Monatsschr Zahnmed. 2004;114(9):890-6
[61]Valachi B, Valachi K. Mechanisms leading to musculoskeletal disorders in dentistry. J Am Dent Assoc. 2004 Mar;135(3):278.
[62]Valachi B, Valachi K. Preventing musculoskeletal disorders in clinical dentistry: strategies to address the mechanisms leading to musculoskeletal disorders. J Am Dent Assoc. 2004 Mar;135(3):278.
[63] Carr GB. Microscopic photography for the restorative dentist. J Esthet Restor Dent. 2003;15(7):417-25
[64] Behle C, Photography and the operating microscope in dentistry. J Calif Dent Assoc. 2001 Oct;29(10): 765-71
[65] van As, GA, Digital Documentation and the Dental Operating Microscope, Oral Health, Vol. 91, (12) pp. 19-25.
[66] van As GA, Erbium Lasers in Dentistry. Dent Clin North Am. 2004 Oct;48(4):1017-59, viii
[67] Britto LR, Veazey WS, Manasse GR. Personal video monitor as an accessory to dental operating microscopes. Quintessence Int. 2004 Feb;35(2):151-4.