

Operating Microscopes and Zero-Defect Dentistry

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ABSTRACT

Operating microscopes are celebrating their 25th anniversary in dentistry. Initially resisted by endodontists and mainstream dentists, there has been a recent surge of interest in microscope-enhanced dentistry. In endodontics, the microscope is becoming standard equipment.

This article discusses a change in the endodontic-restorative protocol and highlights a clinical case that demonstrates the tremendous advantage of advanced magnification when married with other forward-thinking techniques. It concludes with an exploration of the rationale and science of zero-defect restorative dentistry, dentinal caries removal, and finally a review of the science of microscope-enhanced dentistry.

RÉSUMÉ

Les microscopes opératoires célèbrent leur 25^e anniversaire en médecine dentaire. Initialement boudés par les endodontistes et les dentistes, on constate maintenant un intérêt grandissant pour la médecine dentaire de pointe et l'utilisation du microscope. En endodontie, le microscope est maintenant un instrument courant.

Cet article traite d'un changement apporté dans le protocole de l'endodontie et de la médecine dentaire restauratrice et expose un cas clinique qui démontre l'avantage du grossissement combiné à d'autres techniques avant-gardistes. En conclusion, on aborde l'analyse raisonnée et la science de la médecine dentaire zéro-défaut, l'enlèvement des caries de la dentine et finalement on fait une revue de la science de la médecine dentaire de pointe et l'utilisation du microscope.

About the Author

Dr. David Clark, DDS, is the founder of the Academy of Microscope Enhanced Dentistry, an international association formed to advance the science and practice of microendodontics, microperiodontics, microprosthodontics, and microdentistry. He is a course director at the Newport Coast Oral Facial Institute in Newport Beach, California. Dr. Clark served Clinical Research Associates in the "Update Series" lectures and as an interim Dentist/Researcher from 2005 to 2007.



Dr. Clark authored the first comprehensive guide to enamel and dentinal cracks based on 16-power magnification in the Journal of Esthetic and Restorative Dentistry. He has written numerous articles relating to minimally invasive dentistry, biomimetic endodontic shaping, and the role of advanced magnification in modern dental practice.

Dr. Clark has developed new techniques and materials, including the endo-restorative casting; a new shape for the class II composite, the "Clark Class II"; and a matrix and interproximal management system, the Bioclear Matrix System, that promises a real advancement for both bonded porcelain and direct composites. He has helped pioneer the concept of biomimetic micro-endodontics, which is a significant departure from Schilderean shaping.

Operating microscopes are celebrating their 25th anniversary in dentistry. Initially resisted by endodontists and mainstream dentists, there has been a recent surge of interest in microscope-enhanced dentistry. In endodontics, the microscope is becoming standard equipment (Figure 1). At a recent opinion leader's forum, the question was posed: "Should microscopes be required for all endodontic treatment?" This incredible swing in endodontic opinion also is being felt in general dentistry. As dental schools begin to integrate the microscope into the curriculum, two new frontiers in dentistry will be realized: minimally traumatic dentistry and zero-defect dentistry.

This brief article discusses a change in the endodontic-restorative protocol and then highlights a clinical case that demonstrates the tremendous advantage of advanced magnification when married with other forward thinking techniques. The article concludes with an exploration of the rationale and science of zero-defect restorative dentistry, dentinal caries removal and finally a review of the science of microscope-enhanced dentistry.

Modern Decision Making for the Compromised Tooth

Implants have raised the bar to the point where heroic attempts to restore the compromised tooth should generally be accompanied with a conversation that includes the option for implant replacement.

An argument can also be made that the predictability of implants places additional pressure on the restorative dentist; the loss of a restored tooth after a 5-year lifespan may have been acceptable in 1960, but may be unacceptable in 2008.

Microscope-enhanced dentistry is changing the endodontic-restorative protocol, altering the thought process when determining when to save or extract a tooth. Microscopes offer additional methods for caries assessment and endodontic therapy, moving the profession closer to zero-defect restorative dentistry.

The decision to "extract or save" is a constantly evolving art form. In microscope-enhanced dentistry, the thought process in the endodontic-restorative protocol is often inverted. Rather than "endodontics then restorative," it is often "restorative, then endodontics" as clini-



Figure 1. The author at work with his microscope, a G6 Global surgical microscope.

cians can assess the likely outcome and use this information in decision making. Today's finished case should be sealed exquisitely, pleasing esthetically, and accompanied by regenerated papillae. With advanced magnification, the additional visual information afforded to the clinician with the benefit of shadowless, coaxial light combined with infinity corrected optics enhances the clinician's ability to create clean, caries free margins, which, in

turn, can create an optimal restorative seal. Clinicians also can assess the actual invasion of the biologic width and potential for healthy and esthetic soft-tissue contours.¹ For example, in the case presented, caries removal, margin identification, and the potential for papilla regeneration could be verified by restorative investigation. "Restorative investigation" is an important concept that is defined as "The clinical practice of prosthodontic disassembly,

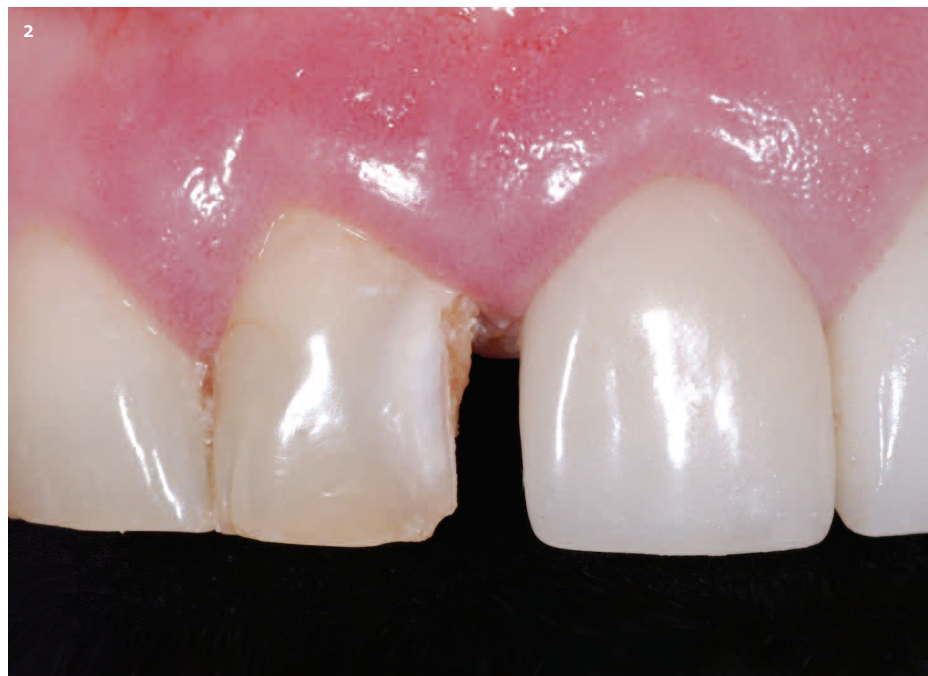


Figure 2. Preoperative view of deep caries on mesial aspect of upper right central incisor.

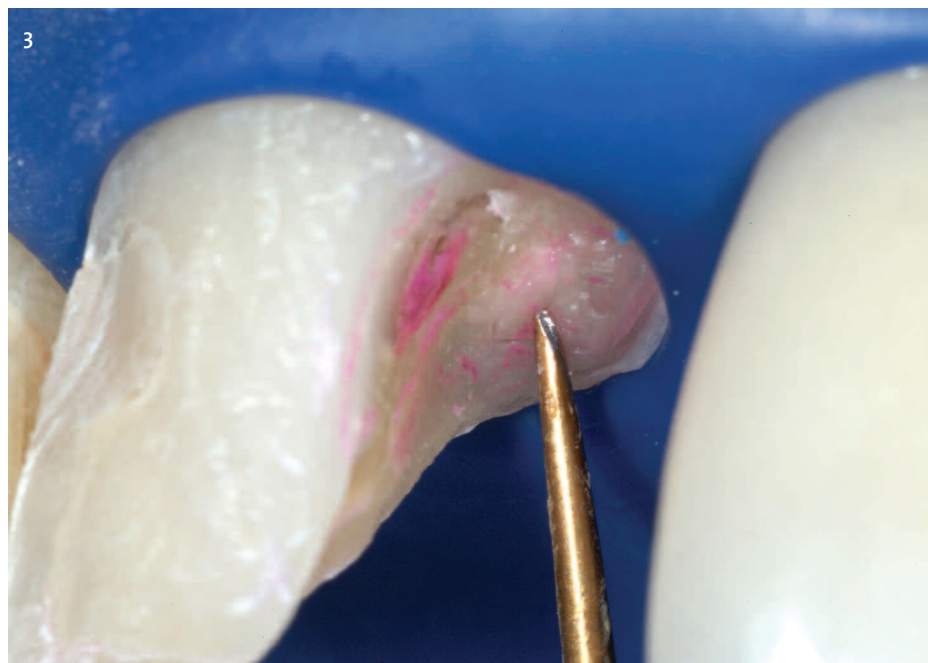


Figure 3. Initial caries removal. Application of caries-indicator solution did not stain the dentin. Extremely soft dentin often does not allow penetration of the dye, creating a false negative caries assessment (original magnification 8x).

restoration removal, caries excavation, microsurgical access, and tissue retraction; the goal of which is to assess the true extent of dental pathology combined concurrent with the long term restorative potential of the tooth.”² After these issues

are deemed satisfactory, then, and only then, is the pulp chamber re-accessed and endodontic therapy initiated. This evolution in triage has the potential to become the standard of care in the modern era of dentistry.

Case Summary

The patient, a 56-year-old woman, was vacillating between treatment plans for her upper arch: a full immediate upper denture or restorative reconstruction. While the treatment for the lower arch was proceeding, she began to experience pain with the upper right central incisor (Figure 2). She had a class reunion that was a week away. She desperately wanted to attend this important function without pain and with a smile that did not embarrass her.

Implants were not an option for the upper arch for financial reasons. She was faced with a decision of either removing the tooth and receiving a temporary partial denture, or initiating restorative treatment combined with endodontic therapy. The patient chose the latter because it allowed for retention of the tooth as an interim treatment until a final decision was reached for the maxillary arch.

Figure 3 demonstrates the tooth after caries removal was thought to be complete. Although the dentin did not stain with caries-indicator solution, in the author’s experience the use of high magnification to evaluate hardness is the ultimate test of sound dentin. Magnification (16x) revealed that gross caries was still present. Figure 4 demonstrates exploration of the deepest layer of “noodle dentin.” Final evaluation of the nuances of sound dentin is demonstrated in Figure 5. A coarse diamond can be used to assess dentin because at 20–24x magnification the scratches can be used as clues to assess dentin hardness.³ Carr has shown that the unaided eye cannot distinguish between two lines that are closer together than 200 microns. With the microscope, 20 micron assessment is possible.

To create an ideal embrasure form, a Bioclear matrix (Tacoma, WA) was used (Figure 6 and Figure 7). This anatomically shaped matrix encourages the papilla to regenerate.⁴

The composite was cured, then shaped and polished. Modern porcelain polishers, such as the D♦Fine™ (Clinician’s Choice, New Milford, CT) or Jazz™ series (SS White Burs, Inc, Lakewood, NJ), yield a finish that is absolutely breathtaking (Figure 8).

After the patient and clinician were confident that the tooth was a good investment, delicate endodontic access (Figure 9) was created and endodontic therapy was completed in a more sterile environment.^{5,6}

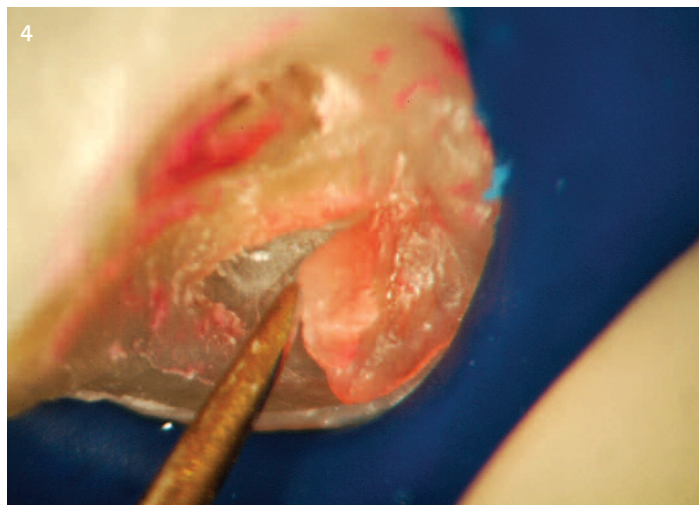


Figure 4. Soft dentin being teased with an explorer (original magnification 16x).

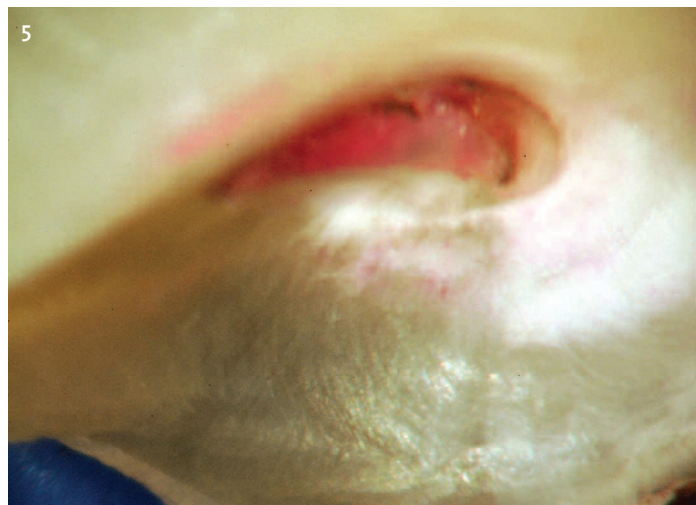


Figure 5. Complete caries removal confirmed by scratch marks from a coarse diamond bur. Softer, infected dentin does not exhibit this type of surface texture (original magnification 24x).



Figure 6 and Figure 7. The anatomically shaped Bioclear matrix in position. The aggressive cervical curvature encourages the static pressure and scaffold needed to stimulate the regeneration of the papilla.

In the traditional approach, endodontics is performed first with either no restorative seal in the interproximal area of caries or a marginally sealed temporary restoration. Bacterial strains such as *Enterococcus faecalis* that are commonly cultured from the root canal systems of endodontic failures are rarely cultured from the pulp spaces of cases of irreversible pulpitis (no radiographic lesion, partially or fully vital pulp) such as the featured case.⁷ The logical conclusion discussed by the endodontic community is that these problematic bacteria can only gain access into the canals and periapical areas through coronal leakage *after* endodontic therapy, *in between* endodontic appointments, or *during* endodontic therapy from inadequate isola-

tion and improper asepsis. Introduction of untoward bacteria into the canal systems both during and after endodontic therapy⁸⁻¹² has been shown in multiple studies to contribute to endodontic failure.¹³⁻¹⁶ Additionally, there are reports of failing endodontic therapy with multiple failed endodontic re-treatments that were ineffective until a well sealed coronal restoration was placed.¹⁷ Other cross sectional studies have shown that a good coronal seal is at least as important as a good root filling.¹⁸

The patient was so impressed with the result (Figure 10) that this one event created the excitement and optimism to retain rather than extract her upper natural den-

tistry, and for the patient, an elevated commitment to lifestyle changes and improved home care. This case also highlights a key factor in many restorative cases, the emotional state of patients that influences decision making and how one small success can turn the tide of decision making.

Zero-Defect Restorative Dentistry

Caries removal is a fundamental task of traditional dentistry. Unfortunately, the commercially driven focus of bleaching, veneers, lasers, and implants has distracted some away from the topic of caries removal. The basic preparation tool (carbide and diamond burs) of dentistry is very similar to what it was generations ago.



Figure 8. A, Preoperative view of deep caries on mesial aspect of upper right central incisor. B, Immediate postoperative view. The long, infinity-edge margin allowed an ideal esthetic result – a heroic composite restoration that is as smooth as the contralateral tooth that has a porcelain crown. This exceeds all expectations of what we can do with composite.

Traditional burs can in no way differentiate between healthy and unhealthy tooth structures. The only known selective hardness cutting instruments are Smartburs™ (SS White Burs, Inc.), which are not readily available. The tactile differences between decayed dentin (soft) and healthy dentin (hard) is the single most common tool that is employed by practitioners in the determination on of which structures to remove.¹⁹ Although there are many ways in which a clinician can assess carious dentin, today's most common approaches include radiographs, caries-indicator dye, spoon excavator or explorer tip (tactile hardness) tests, and laser fluorescence detection²⁰⁻²² (Table 1).

Table 1. Traditional clinical dental caries assessment

• Radiographs
• Dentinal color
• Dentinal hardness (spoon excavator or explorer)
• Uptake of caries-indicator dye
• Laser Fluorescence (Diagnodent)

The presumption that healthy dentin is “harder” is supported by extensive research.²³ The most predictable clinical indicator of sound versus unsound dentin is hardness.²⁴ The Knoop hardness scale of infected dentin ranges from 0 to 30, affected dentin from 30 to 70, and healthy dentin from 70 to 90. Ideally, dentin

removal should be terminated once the affected dentin has been reached, in the 40 to 50 Knoop hardness range. Microscopic evaluation at extreme levels of magnification provides additional visual information to assess the texture and hardness of dentin that can augment the traditional tactile approach to dentin hardness (Table 2). Maintaining areas of affected dentin that may be discoloured will not compromise the tooth-restoration complex.²⁵ However, some studies have shown a compromised long term resin bond to discoloured, affected, and amalgam contaminated dentin.²⁶ In these cases, the use of a glass ionomer sandwich technique is an option,

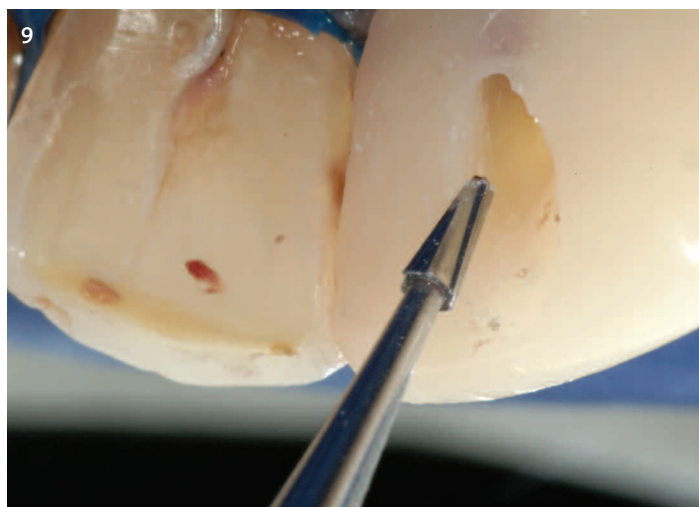


Figure 9. Endodontic access with a conical carbide is less traumatic than with fissure burs or round burs. Pictured is a prototype CK endodontic access bur from SS White Burs, Inc. (original magnification 4x).

Figure 10. At 4 weeks, there was partial papilla regeneration. The patient had very little postoperative discomfort and was ecstatic about the esthetic result.

Table 2. Visual clues of tooth hardness observed by the author under the microscope

1. "Wet sponge" reaction to explorer pressure	8x magnification
2. Dentin-enamel microgapping at dentino-enamel junction	16x magnification
3. Diamond bur scratching	20–24x magnification

which can have a more stable long term bond (glass ionomer-dentin interface) to compromised dentin.²⁷ Alternatively an enhancement of other more predictable surfaces (i.e., creating longer enamel margins or dentinal undercuts) could be utilized in lieu of a glass ionomer sandwich. Dentin colour is one of the least predictable indicators of sound dentin, i.e., black, brown, and green dentin in previously restored teeth is often non-carious and should not be removed.²⁸ Conversely, normal coloured dentin can be soft and grossly infected but appear normal at low magnification. In these cases, caries-indicator dye often can give a "false negative" to stain uptake. In other words, the dentin can have a normal colour, and yet be so soft that no absorption of caries-indicator solution occurs. A study comparing differ-

ent diagnostic approaches to occlusal caries assessment found that visual techniques without advanced magnification were only correct 53% of the time and caries disclosing dyes were only accurate 43% of the time.²⁹ While laser fluorescence can be very accurate,³⁰ its use in most practices is for initial diagnosis. Use of instruments such as a Diagnodent for on-the-fly diagnosis during cutting of the tooth is both impractical and non specific (a positive reading of 20 or above indicates that caries are present but not precisely where the carious and non carious tooth structures are). In the case presented, the dentin in Figure 2 was treated with caries-indicator dye and had no stain uptake. It is my opinion that without the microscope I could have easily been lulled into a false sense of security that caries removal was

complete. Leaving gross residual caries at the margin areas contradicts many restorative principles could doom this case to premature failure.

Clinical Microscopes: Luxury or Necessity?

The operating microscope is not just simply higher magnification than oculars (loupes). It is *better* magnification. Oculars have been very helpful and may always have a role in dentistry, but the optics are crude when compared to the Infinity Corrected Optics of a stereoscopic microscope (Figures 11–14). When combined with the shadowless coaxial light source, they transform the clinician's potential for accuracy of nearly every aspect in the different disciplines in dentistry.

Increasing levels of magnification produce a squared, not linear relationship to visual acuity. In other words, a clinician working at 3.5× sees **10 times** more visual information, 10× magnification allows the human retina to acquire **100 times** more information, and 20× allows **400 times** the visual information³¹ (Table 3).

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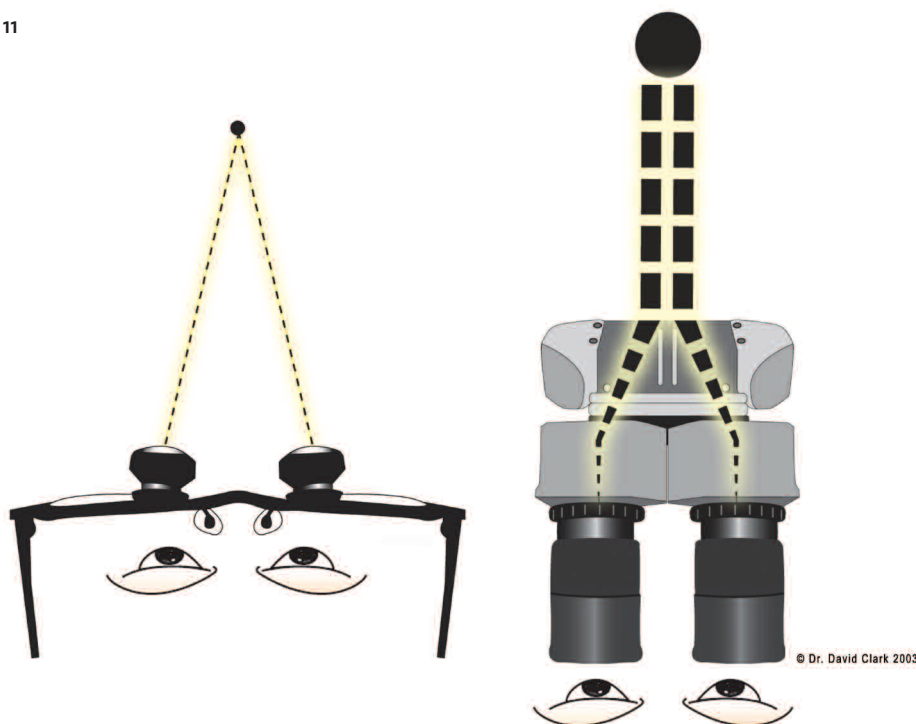


Figure 11. Oculars (loupes) rely on convergent vision that essentially requires an overlap of two images. This form of magnification creates increasing problems and eye strain as magnification power increases. The clinical microscope utilizes a more refined optical system (original magnification 16x).

Improved Outcomes?

Improved outcomes from the use of magnification have been well documented in the medical literature, and scientific validation in dentistry is beginning to emerge.^{32–40} There are no legal requirements in Canada or the United States mandating that dentists use magnification. However, most dental schools today either recommend or require the use of magnifying loupes for both pre-clinical and clinical training. In 1999 the American Association of Endodontists mandated that microscopes be implemented into all US graduate endodontic residency programs. There are scant studies conducted at the highest level as randomized, controlled, and double blind in *any* field of dentistry to prove or disprove most of what we do in private practice. To prove without question that magnification or microscopic magnification provides better clinical outcomes will be as difficult and pointless, in my opinion, as proving that using a bright operatory light is better than a dim light. In spite of this, the "magnification escalation" continues in most nations around the world as even third world countries such as Chile now boast Societies of Microscope



Figure 12. The figure features 8x convergent magnification with loupes and a representation of the two images that the brain receives as the eyes begin to focus.

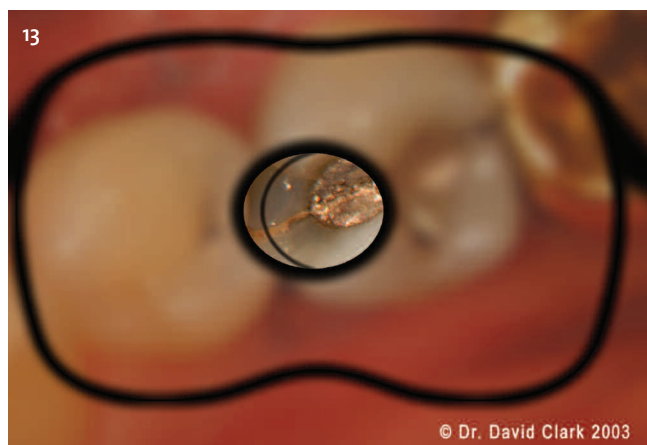


Figure 13. The figure shows a common occurrence of the incomplete merging of the images seen through a pair of loupes. Both Figure 12 and Figure 13 demonstrate the visual noise (blurry periphery) of loupes optics.

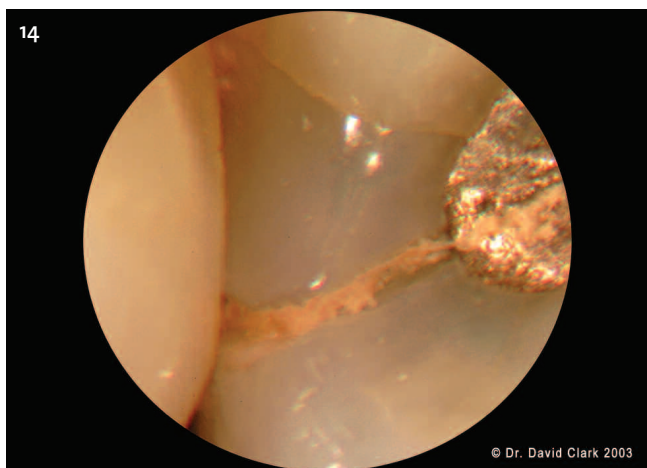


Figure 14. The figure represents the same case seen with a clinical microscope at 24x original magnification featuring infinity corrected optics. There is no eye strain and no visual noise. Loupes magnification at 8x (original magnification) and beyond becomes excruciating for most clinicians. For advanced magnification, the microscope is a superior and healthier choice.

Table 3. Magnification and visual information

Magnification	1x	2x	4x	10x	16x	25x
Information content	1x	4x	16x	100x	256x	625x
Picture element	660	2,640	10,560	66,000	168,960	412,500

Dentistry. Once the bar is raised to allow a new level of diagnostic sensitivity, it is unlikely that a regression toward a lesser capability will occur.

There are many studies that have shown that magnification plays an important role in clinical accuracy, such as the ability to access and shape complex root canal anatomy. In a compelling study, the use of a microscope enabled the author, an endodontist, to improve his ability to find a fourth canal system from 73 to 93% in maxillary first molars.^{41,42} Sadly, most general dentists and endodontists who do not use microscopes rarely report finding four canal systems in maxillary first molars. There are studies showing that use of an operating microscope *can* lead to less postoperative discomfort.⁴³ In periodontics, the microscope enhances the surgeon's visual acuity⁴⁴ allowing better manipulation and more accurate suturing of the soft tissues.⁴⁵ Low tissue trauma, excellent flap control, and a micro-suturing technique that allows primary wound closure may be responsible for improved clinical success.^{46,47} Reduced operator mistakes in endodontics have been reported as a benefit of clinical microscopes.⁴⁸ The ergonomics of the microscope clinician's proper posture have shown a remarkable reduction in back pain and disability, a priceless benefit to the practitioner for a pervasive and serious problem that can destroy our health and diminish the daily enjoyment of our craft.⁴⁹⁻⁵¹

Conclusion

Owning and using a microscope does not make one dentist better than another. Experience, training, commitment, and ability are the key traits that distinguish the *good* from the *great*. Excellence in dentistry is both a choice and a journey, and magnification can be a powerful asset for those who seek absolute clinical accuracy. The testimony of doctors who use the microscope daily in their practices confirms its value; an overwhelming majority affirms that it has improved their clinical skills. The microscope, with instantaneous magnification from 2.5x to 24x, no visual noise, and shadowless coaxial light, offers the best means for achieving complete visual information in dentistry. It can nurture great confidence, healthier posture, and better and surer hands for the clinician. And in the end, the excellent visual information it offers can help the doctor to create more precise, more healthful, and more esthetically pleasing dentistry.

Disclosure

Dr. Clark has no financial interest in any microscope company. Dr. Clark has a financial interest in the Bioclear Matrix System. He is also the co-developer of the CK endodontic access burs.

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