The Epidemic of Cracked and Fracturing Teeth

David Clark, DDS

Teeth are fracturing today in record numbers. Cracked and fractured teeth are now the third leading cause of tooth loss in industrialized nations.[1] Posterior teeth with conservative amalgams and composites are splitting and losing cusps. Crowned teeth, both posterior and anterior, are fracturing off at tissue level. Endodontically treated teeth are splitting, snapping off, and simply imploding (Figure 1). Additionally, endodontists are reporting that cracked teeth are now replacing carious teeth for causative etiology in numbers of patients referred for endodontic treatment.

We assume that the causes of this pervasive and growing problem are (a) we are living longer; (b) our stress levels are rising, and clenching and bruxism are also more prevalent; (c) the advent of the high-speed handpiece spawned billions of iatrogenic "G.V. Black" cavity preparations that have weakened posterior teeth (Figures 2a and 2b); (d) deep axial crown preparations in the name of porcelain aesthetics; and (e) aggressive "crown-down" endodontic shapes in delicate, non-round roots.

Dentistry's last great mystery, fracturing, is a poorly understood process. A dramatic change in the focus of continuing dental education toward cosmetic dentistry, bleaching, and implants has shifted our attention away from some of the most integral aspects of the healing art of dentistry, and cracks top that list. We now find our profession faced with a monumental problem that will require a significant commitment and reallocation of resources to address appropriately. There is no need to assess blame; we must simply roll up our sleeves and get to work.

Figure 1. An all-too-common sight: one bicuspid with a traditional "G.V. Black preparation" that has predisposed the cusp to fracture, and the other bicuspid fractured off at tissue level following endodontic therapy.

BRINGING DIAGNOSIS AND PREVENTION OUT OF THE STONE AGE

Macroscopic and symptom-driven diagnosis have been the accepted modalities for the diagnosis of cracked teeth. The inherent limitations of the lack of visual confirmation create therapies that oftentimes come too late in the treatment process. One lasting first impression of vision through the clinical microscope is the staggering array of cracks that exist within tooth structures (Figure 3). Traditional visualization (unaided or loupes) limits the clinician's ability to assess the pres-

continued on page ##

Table 1. How Can We Eliminate Tooth Fracturing?

Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:
Elevate our level of diagnosis from end-stage, pain-driven to 16x examination done at regular (1 to 3 years) intervals.	Redesign all of our cavity preparations in posterior teeth, then create better instruments and materials to facilitate the restorative.	Deconstruct, then reconstruct endodontic access and coronal canal shaping based on advanced magnification and biomimetic principles.	Revert back to delicate axio-marginal tooth reduction, now possible with new, zirconia-based porcelains or old-fashioned gold collars.	Re-commit our profession to understanding, controlling, equilibrating and protecting the occlusion.

Table 2. Quick Reference Guide for Microscopic Cracks in Posterior Teeth.

1) Most teeth in aging adults display enamel cracks.

2) Enamel cracks, even dramatic cracks, do not necessarily indicate that the tooth is cracked.

3) Many enamel cracks do not penetrate significantly into dentin.

4) Many enamel cracks have multiple features; many teeth have multiple cracks.

5) Three types of underlying pathology will produce enamel cracks:

   Dentinal cracks, decay, and undermined enamel often contributing to microleakage around a restoration.

6) Dentinal cracks should be considered as structural cracks.

7) Dentinal cracks fall generally into 2 types: a) vertical, generally positioned in the middle of the pulpal floor, are "pre-radicular," and b) oblique, generally positioned at line angles of cavity preparations, are "pre-cuspal" (Figure 5).

8) Many teeth exhibit both types of dentinal cracks; hybrid cracks are also common. Rigorous classification will be less important than early recognition and treatment. All teeth with dentinal cracks should be considered as structurally unsound.

Associated Microscopic Findings:

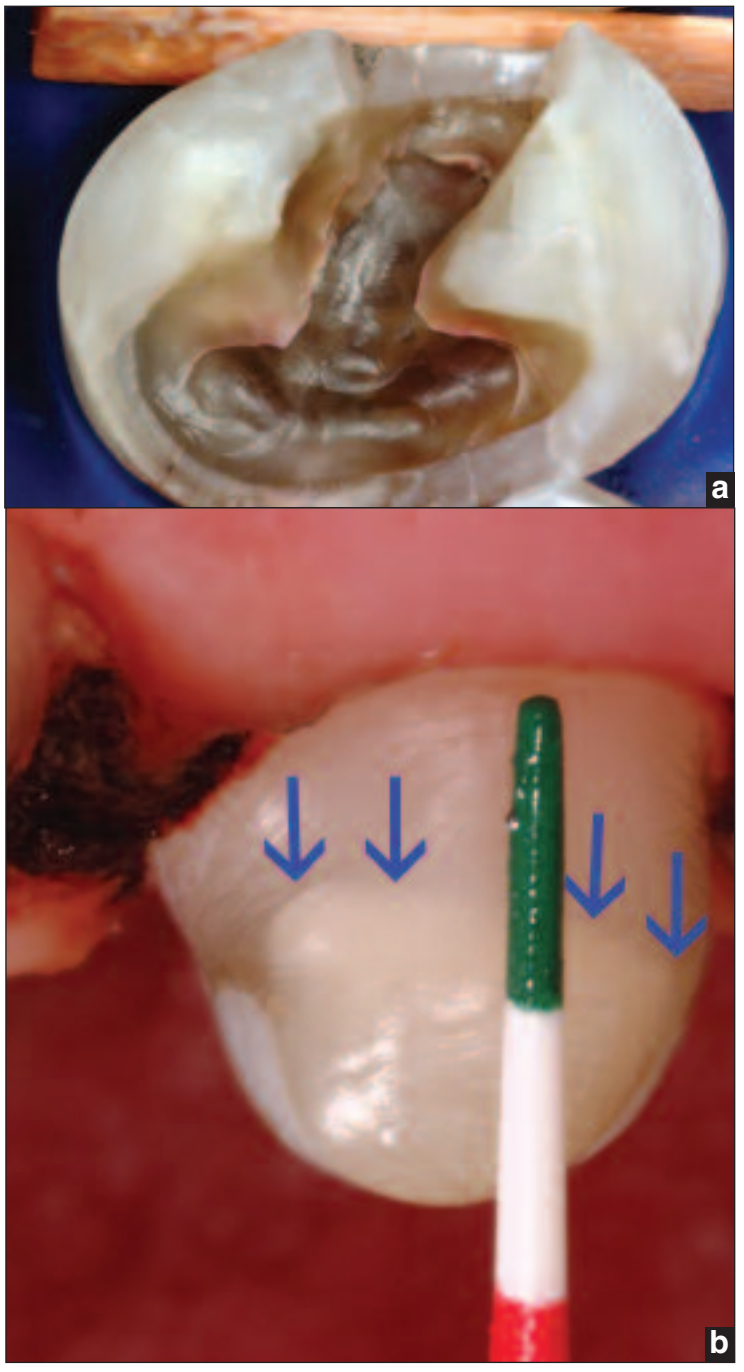
1) Microscopic cracks in restorative materials can also indicate a lack of coronal structural integrity.

2) Well-defined discoloration of a cusp or cusps can indicate a lack of structural integrity.

3) Unusual or unilateral gapping between an occlusal restoration and tooth structure can indicate a lack of structural integrity.

The Epidemic of Cracked...

continued from page



Figures 2a and 2b. Figure 2a shows the fracturing pattern following the exact line angles of the class II preparation, an absolute indictment of a long-accepted method of cavity preparation. Figure 2b: Tooth from Figure 2a after crown preparation. Crown or onlay margins should extend at least 2 mm apical to cracked dentin.

ence or severity of the majority of these cracks.

At extreme magnification levels (13x and beyond) the translucent nature of enamel yields a wealth of information. Subtle color changes within the enamel may indicate early decay, microleakage, and lack of structural integrity of dentin and enamel (Figure 4).

Seeing previously invisible clues can lead restorative dentists to more appropriate early treatment of compromised teeth before devastating fractures, pulpal involvement, and periodontal breakdown occur. The value of early diagnosis of the structural breakdown of teeth will become even more significant with our aging population, especially in light of its increasing tooth retention. **[Author: is above sentence correct as edited?]**

The purpose of this article is to present an intuitive system for detecting and describing enamel and dentinal cracks based on visual examination at 16x magnification. Experienced clinicians using the clinical microscope have reached a general consensus that 16x provides an idealized magnification level for the evaluation of enamel cracks, with a range of 13x to 18x.[2] This magnification level provides optimal information about enamel cracks, and falls within the range of magnification the majority of current microscopes feature today.

In this and 2 upcoming articles to be published in *Dentistry Today,* we will explore solutions to this dilemma. **[Author: is above sentence OK as edited?]**

PARADIGM SHIFT ONE: 16x MAGNIFICATION IS THE KEY

In 2003 I collaborated with Drs. Cherilyn Sheets and Jacinthe Paquette to propose the first guide to diagnosis of enamel and dentinal cracks based on high-level magnification in the carefully peer-reviewed *Journal of Esthetic and Restorative Dentistry*.[3] This complete and updated guide is available at lifetime-dentistry.net. At 11 pages and 36 images it is beyond the size allowance for this publication. Highlights are presented in this article.

PARADIGM SHIFT 2: ENAMEL AND DENTINAL CRACKS ARE VASTLY DIFFERENT IN CHARACTER AND ARE OFTEN UNRELATED TO EACH OTHER

Dentinal Cracks

Dentinal cracks should be considered as structural cracks. They typically fall into 2 types: (a) vertical, generally positioned in the middle of the pulpal floor, and (b) oblique, generally positioned at line angles of cavity preparations. These very early fractures are preliminary in nature and need protection to minimize crack propagation (Figure 5).

Nomenclature and Classification System for Enamel Cracks

With the introduction of high-level magnification and illumination through the clinical microscope, a refined nomenclature and classification system for enamel cracks is indicated. The following is a template for a classification system of enamel cracks based on a combination of visual observation at 16x and existing opinions in the current literature. It is important that the clinician recognizes that these are diagnostic "clues" and not a definitive diagnosis. The clinician must also bear in mind while assessing enamel cracks that other variables such as the age of the patient, location of wear facets, parafunctional activity patterns, and the actual position of the crack as it relates to occlusal loading and existing restorations must be considered in the diagnostic process. As additional research is added to this current clinical data, it will provide a more systematic approach for diagnosis and treatment.

Type I Enamel Cracks: Have Little or No Risk of Underlying Pathology

(a) Craze lines. These are usually linear, vertical, and do not widen or become more pronounced as they extend from gingival to occlusal (Figure 4).

(b) Vertical cracks not associated with restorations and without environmental stain penetration.

(c) Cracks that follow natural anatomic grooves.

(d) Cracks with superficial environmental stain penetration (Figure 4).

(e) Cracks that result from polymerization shrinkage of composites.

(f) Enamel crackling **{Author: crackling or cracking?]** in aging, thin cervical enamel.

Treatment modalities for Type I defects could include preventive measures such as no treatment, continued observation, occlusal adjustments, and protective occlusal splints.

Type II Enamel Cracks: Have Moderate Risk of Underlying Pathology

(a) Wedge-shaped enamel ditching resulting from loss of enamel tooth structure with no prior restoration, often associated with a wear facet and localized occlusal loading centered over an otherwise benign crack.

(b) Wedge-shaped enamel ditching resulting from loss of

continued on page ##

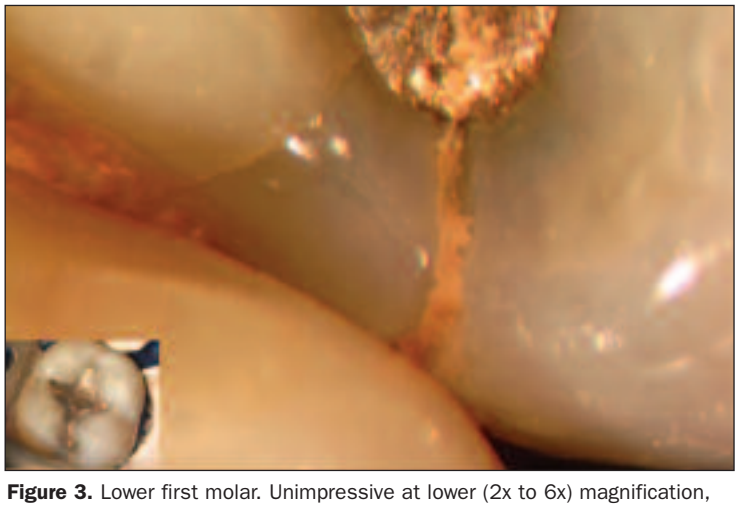


Figure 3. Lower first molar. Unimpressive at lower (2x to 6x) magnification, this crack gives a wealth of information when observed with the microscope. A significant vertical crack was observed in dentin after amalgam removal.

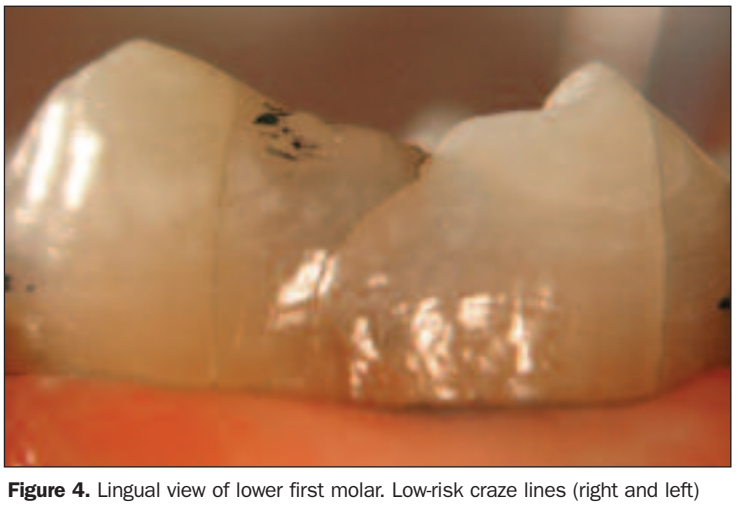


Figure 4. Lingual view of lower first molar. Low-risk craze lines (right and left) are present along with a high-risk diagonal crack (center). Characteristics of craze lines: linear, vertical, and do not widen or become more pronounced as they extend from gingival to occlusal. Characteristics of diagonal cracks: nonlinear, narrow as they extend apically. In this example, subtle brown and gray halos are centered over the diagonal crack in a bull's-eye pattern.

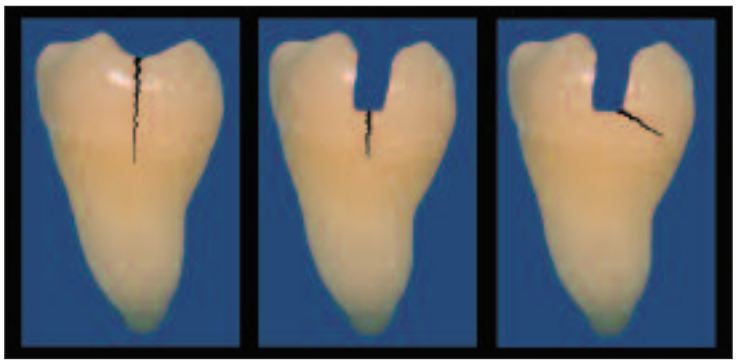
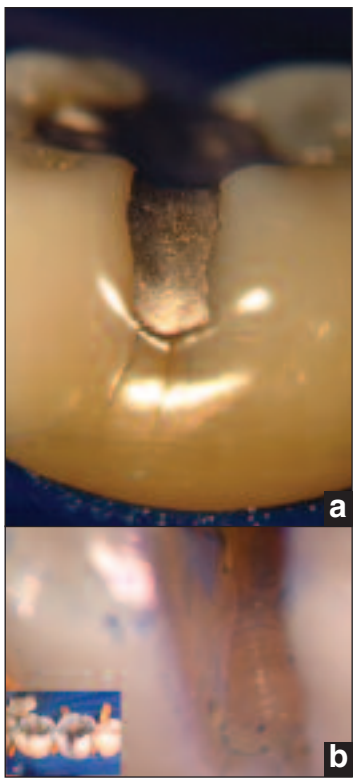


Figure 5. Late-stage progression of coronal cracks: endodontic, periodontal, and restorative problems are now brought into play. Regular microscopic examinations can significantly reduce the number of teeth that reach traditional, symptom-driven diagnosis and treatment.



Figures 6a and 6b. Three cracks are present on the facial view of the lower right first molar. After removing amalgam, we observe that the diagonal crack on the left has severely undermined the disto-buccal cusp. Vertical cracks (center and right) were insignificant.

Figure 7. Author pictured with the Global G6 microscope (Global Surgical Corporation) with 2.5, 4, 6.5, 10, 16, and 24 power steps of magnification.

enamel tooth structure with an adjoining restoration, often associated with a wear facet and localized occlusal loading centered over an otherwise benign crack.

(c) Cracks that detour from or do not follow anatomic grooves (Figure 4).

Treatment modalities for Type II defects could include preventive measures, review of patient history of thermal and functional sensitivity, restorative investigation, or definitive restorative treatment if the current restoration is deemed compromised.

Type III Enamel Cracks: Have High Risk of Underlying Pathology

(a) Diagonal cracks branching off a vertical crack. These often are indicative of a late-stage oblique incomplete fracture (Figure 4).

(b) Horizontal or diagonal cracks that normally emanate from the corner of a restoration. They narrow as they extend gingivally and are typically nonlinear (Figures 4 and 6).

(c) Cracks that house debris, with or without previous restorations (indicative of a crack size of approximately 200 µm or greater; Figure 3).

(d) Pair of cracks that outline an area (cusp, cusps, or marginal ridge) of discolored enamel. These show a high potential for an underlying dentinal crack and future complete fracture (Figure 3).

(e) Crack with corresponding halo of brown, gray, or white centered on crack (Figure 4).

Treatment modalities for Type III defects: The protocol for high-risk enamel cracks calls for removal of the old restoration, if present. If decay or microleakage is the underlying pathology, then standard treatment is recommended. If a dentinal (structural) crack is the underlying pathology, then protection of the incomplete fracture from occlusal forces is indicated. How early and in what manner teeth with microscopic dentinal cracks should be treated depends upon the clinician's assessment.

CUMULATIVE DIAGNOSIS

The sources of enamel cracks can be multifactorial in nature and can develop over lengthy time frames. The presence of enamel cracks, even dramatic ones, does not necessarily indicate the presence of an incomplete coronal fracture or a "cracked tooth syndrome," as enamel cracks do not always penetrate into dentin. Also, significant enamel cracks often exist in the absence of dentinal cracks. Three types of underlying pathologies are often seen accompanying enamel cracks. These pathologies are dentinal cracks, decay, and severely undermined enamel that allow microleakage.

THE 4 MOST COMMON QUESTIONS REGARDING CRACKS/FRACTURES

(Q) *I don't have a microscope yet. Can I use loupes or my intraoral video (wand style) camera?*

(A) No and yes. First, let me share what Dr. Rella Christensen, director of Clinical Research Associates (CRA), says: "Every general dentist should use a microscope" (Figure 7). Loupes are simply not enough when it comes to diagnosing cracks; 13x magnification is the minimum. I was impressed while evaluating intraoral video cameras at CRA that a few had enough resolution and magnification to do a reasonable job for crack diagnosis.

(Q) *If I discover a dentinal crack (incomplete fracture) during routine operative but the patient can't afford a crown, can I splint the tooth together with bonded composite or amalgam?*

(A) No. The same occlusal forces that caused the first fracturing will cause propagation of the crack.[5] **[Author: You did not list a reference No. 5. Is this supposed to be reference No. 4? If not, please provide info for citation No. 5.]** You may onlay the tooth with composite or amalgam to buy some time, the thicker the better, and the more that the tooth is "wrapped," the safer. Don't leave it out of occlusion either; the tooth or opposing tooth will eventually supererupt and ruin the arch form. I frequently scold endodontists for this treatment.

(Q) *When I find an oblique dentinal crack (cracked cusp), should I remove all of the cracked tooth structure before proceeding with the crown or onlay?*

(A) This is a hotly debated topic without good research to guide us. One school of thought says that the crack will continue to spread as the tooth flexes, so we should "amputate" all cracked dentin. The second school says to "chase" the crack with fissurotomy burs because these cracks harbor bacteria. The third school says to maintain the cracked dentin but splint the tooth with a crown or onlay. Until further research is done, I recommend staying conservative (Figure 2a).

(Q) *When a vertical crack extends into the gingival attachment, should I "chase" it and do crown lengthening?*

(A) In the age of implants this is ill-advised. If the attachment is diseased or compromised, then an implant is more predictable. However, if the crack is small, the attachment does not probe, and the patient is in his or her 60s or older, I temporize and re-evaluate after 6 months. If there is no probing at the 6-month follow-up, then the prognosis is good. Either way it is contraindicated to "chase" the crack to cover it with a crown margin if you encroach upon the biologic width

CONCLUSION

For some clinicians today, the microscope is to cracks what radiographs are to diagnosing interproximal decay or bone levels. The nature of very early incomplete fractures requires the use of high-level magnification technology for discovery. The clinical microscope at magnification levels of 13x and above allows detection of significant cracks long before incomplete coronal fractures and cracked teeth become symptomatic. Increasing numbers of clinicians today are beginning to visualize these conditions through the clinical microscope. The preponderance and magnitude of enamel and dentinal cracks is just now beginning to be revealed. The microscope provides clinicians, especially restorative dentists and periodontists, the opportunity to circumvent potential devastation to many posterior teeth.

Prevention of dental disease in the past has meant brushing, flossing, fluoride, and sealants. Today, prevention of oral disease has a much broader definition and should include early, methodical detection of enamel and dentinal cracks. The clinical microscope will make possible the treatment of asymptomatic but structurally unsound posterior teeth. Although this may require a fundamental change in the thought process for some clinicians, waiting for symptoms in teeth with high-risk enamel cracks may eventually be compared to waiting to treat decay until symptoms occur (Tables 1 and 2).✦

References

1. Lynch CD, McConnell RJ. The cracked tooth syndrome. *J Can Dent Assoc.* 2002;68:470-475.
2. Clark DJ, Piontkowski P. Enamel and dentinal cracks observed under the operating microscope. Presented at: Academy of Microscope Enhanced Dentistry inaugural meeting; 2002. **[I could not verify date or location of meeting. AUTHOU: Please verify.]**
3. Clark DJ, Sheets CG, Paquette JM. Definitive diagnosis of early enamel and dentinal cracks based on microscopic evaluation. *J Esthet Restor Dent.* 2003;15(spec issue):7-17.
4. Erhardson S, Sheikholeslam A, Forsberg CM, et al. Vertical forces developed by the jaw elevator muscles during unilateral maximal clenching and their distribution on teeth and condyles. *Swed Dent J.* 1993;17:23-34. **[This ref is NOT cited in the article. AUTHOR: Please verify where it goes in the text.]**

Dr. Clark founded 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, Calif. He is co-director of Precision Aesthetics Northwest in Tacoma, Wash, and an associate member of the American Association of Endodontists. He lectures and gives hands-on seminars internationally on a variety of topics related to microscope-enhanced dentistry. He has developed numerous innovations in the fields of micro-

continued on page XX

Xxxx

continued from page

dental instrumentation, imaging, and dental operatory design. Dr. Clark has authored several landmark articles about microscope dentistry including *Aesthetic Dentistry*, *Sealants*, *The Role of Ultrasonics in Three Dimensional Shaping and Restoration of Non Vital Teeth*, *Micro-Imaging and Practice Management*, and *Crack Diagnosis*. Dr. Clark is proud to join with Clinical Research Associates in the "Update Series" lectures and also to participate in their important research. He is the editor-in-chief for the future launch of *The Journal of Microscope Dentistry*. He is also developing new techniques and materials to better restore endodontically treated teeth, including the Endo-Restorative Casting. Dr. Clark is a 1986 graduate of the University of Washington School of Dentistry. He maintains a microscope-centered restorative practice in Tacoma and can be reached at drclark@microscopedentistry.com or by visiting micoscopedentistry.com.

Disclosure: Dr. Clark is not a paid spokesman for Obtura/Spartan or any microscope manufacturer. Royalties from sales of the Clark Explorer Series are donated to the Academy of Microscope Enhanced Dentistry.

continued on page ##