Cracked teeth and Vertical Root Fractures: What do we know now?

February 17th, 2018
San Antonio, Texas
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Diplomate, American Board of Endodontics
Dr. Rob Roda, Past AAE President

“Cracked teeth seem to be a result of repetitive stress injury, and so the longer teeth are in use, the more likely they will become cracked. This is a modern epidemic and something we have never before as a profession had to deal with.”
What does the literature show?

Bader et al. 1995 JADA estimate 1 in 20 people fracture a tooth a yr.

Krell and Rivera 2007 JOE 796 of 8175 cases (9.7%) cracked teeth

*mandibular 2nd molars (30%) > mandibular 1st molars (29%) > maxillary 1st molars (21%)*

Tsesis, et al. 2010 JOE unable to do a systematic review for VRF!
How I will proceed!

- New definitions from 2015!
- Diagnostic tests
- Etiologies
- Treatments
- Outcomes
- Prevention??
What is a “cracked tooth” versus a root fracture?

Types of Longitudinal Fractures
REPORT TO THE BOARD OF DIRECTORS
Annual Meeting – May 4-5, 2015

• SPECIAL COMMITTEE ON CRACKED TOOTH INITIATIVE

• Louis H. Berman, Chair
• Scott L. Doyle
• Gary G. Goodell
• Keith V. Krell
• H Mark A. Odom, Board Liaison
• Helen Jameson, Staff Liaison
Cracked tooth definitions:

• **AAE Glossary**: A phenomenon involving posterior teeth in which fractures usually involve the marginal ridges; primarily in minimally restored mandibular first and second molars; symptoms may vary but pain to chewing and thermal sensitivity are common.

• **Issues**: There are a number of problems with the definition. First, a cracked tooth is not a “phenomenon.” The 2008 *Colleagues for Excellence* article states that, “…cracks present in teeth are findings only; they are not to be considered a pulpal or periapical diagnosis.” Second, the definition does not differentiate a crack from a fracture. Third, describing where they occur on a tooth and on what type of teeth they occur is too specific and limiting.
New Definitions from 2015!

Cracked tooth — A thin surface disruption of enamel and dentin, and possibly cementum, of unknown depth or extension.
New Definitions from 2015!

**Root fracture** — A fracture that exists or extends into the root, to include dentin, cementum, and possibly pulpal space, which may progress to or from the enamel.

**Longitudinal fracture** — A root fracture extending in the axial plane within the tooth.
New Definitions from 2015!

Longitudinal fracture — A root fracture extending in the axial plane within the tooth.

- split root — A continuation of a crack or vertical root fracture whereby the fractured segments are completely separated longitudinally; it may occur buccal-lingually or mesial-distally; it may cause an isolated periodontal defect(s) or sinus tract; it may be radiographically evident.
New Definitions from 2015!

Longitudinal fracture — A root fracture extending in the axial plane within the tooth.

• vertical root fracture — A fracture in the root whereby the fractured segments are incompletely separated; it may occur buccal-lingually or mesial-distally; it may cause an isolated periodontal defect(s) or sinus tract; it may be radiographically evident.
Fractured Teeth

- Fracture (new definition!):
CTS – “Cracked Tooth Syndrome”

- CTS – This term is a misnomer
- Since syndrome is defined as “A number of symptoms occurring together and characterizing a specific disease”
- A crack is NOT a disease nor is it a pathological entity
- But cracks may become portals for bacteria and subsequent diseases:
  - Pulpitis – reversible or irreversible
  - Pulp necrosis and infection the root canals
  - Periodontitis – lateral and/or apical
What is really the difference?

➢ The difference between “cracks” and “fractures” are a matter of degrees of severity. However, the etiology may be very different.
What are predisposing features resulting in a cracked tooth?

Types of Longitudinal Fractures
REPORT TO THE BOARD OF DIRECTORS
Annual Meeting, April 4-5, 2016

• THE SPECIAL COMMITTEE ON METHODOLOGY OF CRACKED TOOTH STUDIES
  – Dr. Shimon Friedman, Chair
  – Dr. Amir Azarpazhooh
  – Dr. George Bruder
  – Dr. Keith V. Krell, Dr. Isabel Mello
  – Dr. Donald Nixdorf
  – Dr. Robert S. Roda, Board Liaison
  – Helen Jameson, Staff Liaison
Survey AAE Members’ Perceptions on RC/F

• 941 of 5204 members responded
• Half the participants (49%) perceived that occurrence of RC/F in the past decade increased compared to previous years
• Majority of participants (72%) agreed that occurrence of RC/F in root-filled teeth was a major concern in endodontics
• 58% agreed it should be a priority to revise endodontic treatment protocols so as to mitigate the risk of RC/F
How do we diagnose a cracked tooth or vertical root fracture?

Types of Longitudinal Fractures
Diagnostic Tests –
Cracked Teeth!
Start with the dental history!
A good dental history can be important, especially, if a recent “biting event” has occurred and they “felt something pop!”

Patient comments of pain when chewing, pain upon release, or “pain when I hit the tooth a certain way” all suggest a crack.

“Fillings that keep falling out”
Diagnostic Tests –
Cracked Teeth!

The Tooth Slooth for a directed “bite” test
Diagnostic Tests – Cracked Teeth!

Transillumination-
Diagnostic Tests – Cracked Teeth!

- Restoration Removal
- Dyes
- Probing
Diagnostic Tests – Cracked Teeth!

Magnification-
Diagnostic Tests –
Root Fractures

- Location: Roots
- Direction: Facial-Lingual, mesial-distal
- Orientation: Root, extending coronal and apical
- Symptoms: Usually none, may present as a periodontal problem
- Signs: Variable
- Radiograph: Bone loss pattern
- CBCT: Study dependent and load dependent
- Probing: A sudden increase in probing depth can suggest VRF when all other probings are “normal”
- ID: Visualization, flap reflection
- Treatment: Removal of the fractured root
- Prognosis: Hopeless, but not all the time!
Diagnostic Tests – Clinical Criteria for High Confidence of fractured roots

THE SPECIAL COMMITTEE ON METHODOLOGY OF CRACKED TOOTH STUDIES

– Triggered biting pain
– Swelling
– One or more sinus tracts
  • Percussion sensitive Mobility
  • Root crack associated with probing is visible with or without magnification
  • Probing greater than 6 mm
• Conventional radiographs
  • Visible fracture or separation of root
  • “J” shape radiolucency
• Small FoV CBCT imaging with visible fracture or separation of root
Diagnostic Tests – Root Fractures

- Radiograph: Bone loss pattern with 2-D radiographs
- “Halo” lesion, perilateral radiolucency, and angular resorption of the crestal bone...indicated a high probability of vertical root fractures in maxillary premolars.

Diagnostic Tests – Root Fractures

• Radiograph: Bone loss pattern with CBCT

• More accurate than 2D (Bernardes, R. 2009. OOORE)

• Accuracy is Machine dependent (Metska, M.E. et al., 2012 JOE)

• Technique dependent- Double Scan TQ (Bruno Azevedo, 2015)
Fifty Shades of Grey

Bruno Azevedo DDS MS
Board Certified OMFR

#1 New York Times Bestseller
“Double Scan” Technique
Baseline Wax
No Wax
No Wax

Wax
Better visualization due to fracture separation
Diagnostic Tests – Root Fractures

• Probing: A sudden increase in probing depth can suggest VRF when all other probings are “normal”
Diagnostic Tests – Root Fractures

• Visualization, flap reflection
Etiologies for Enamel cracks

- Thermal Cycling
- Pin Placement
- Cementation of Inlays
- Masticatory Forces
- Age!
Etiologies-
Cracked teeth

• Enamel Crazings-
  – Most likely – Naturally occurring through normal mastication-
    (Rivera and Walton 2015, Endo Topics)
  or
  – Thermocycling (Brown,’72 JDR)
Etiology

• From the definitions it is obvious there is a difference of degrees of the extension of the crack. This is determined by:
  - Magnitude of Stress experienced by the tooth
  - Mechanical properties of remaining tissue for resisting fracture

  Arola, D et. al “Microstructure and mechanical behavior of radicular and coronal dentin”
  Endodontic Topics, 2012 pp30-51
Fatigue Crack Growth

Propagation life of a material or tooth is comprised of the number of loading cycles required to propagate an existing crack to a critical length that facilitates bulk fracture.

Arola, D et. al “Microstructure and mechanical behavior of radicular and coronal dentin” Endodontic Topics, 2012 pp30-51
Fracture Toughness

• The ability to resist fracture caused by extension of an existing crack.
• Radicular dentin has greater fracture toughness than coronal dentin.
• Coronal fracture is related to orientation of tubules to the force.

Arola, D et. al “Microstructure and mechanical behavior of radicular and coronal dentin” Endodontic Topics, 2012 pp30-51
Age of dentin!

- Age alone has been shown to be a significant factor in dentin fracture.
- Dentin from patients < 35 vs >55 shows a 50% reduction in strength of >55.
- Dentin from patients < 35 vs >55 shows 75% reduction in energy require to FX >55.
- >55 has greater mineral content and avg rate of crack growth 100 X that of <35.

Arola, D et. al “Microstructure and mechanical behavior of radicular and coronal dentin” Endodontic Topics, 2012 pp30-51
Etiologies-
Cracked teeth

Hydration of dentin


- External compressive loads were counteracted by the residual stresses and strains loads.

- Hydrated specimens showed greater toughness vs partially dehydrated specimens. The stress at fracture was significantly higher in Dehydrated specimens than in partially dehydrated specimens.

- Strain at fracture was significantly higher in hydrated dentine specimens (p=0.037).
Etiologies-
Cracked teeth
Hydration of dentin


SIGNIFICANCE: These experiments highlighted the distinct role of free water in the dentinal tubules and hydrostatic pressure on the stress-strain distribution within the bulk dentine.

Assessed the prevalence of oral piercing among young adults and revealed the types and rate of complications following oral piercing in 400 consecutive patients, who randomly arrived at a military dental office.

- Intra-oral examination included special attention to piercing-related complications, such as tooth fractures, gingivitis, bleeding, infections, gingival recessions, etc.
- A total of 389 patients, 54% males, and 46% females agreed to participate.
- Of the participants 20.0% reported having at least one type of oral piercing; lingual piercing was the most common.
  - Swelling and bleeding after piercing were reported by 41 males (51.9%) and 36 females (45.7%) participants.
  - 57.8% were unaware of the dangers of intra-oral piercing.
  - Clinical examination revealed 15 fractured teeth (13.9%) with piercing.
  - Gingival recessions were observed in 26.6%, mostly in the mandibular incisor area.
Etiologies

Cracked teeth

IATROGENIC CONSIDERATIONS

Etiologies
Cracked teeth

IATROGENIC CONSIDERATIONS

– Pin Placement (Standlee et al., 1970, JPD)
– Cavity preps (Reeh, et al., 1989. JOE,)

• Endodontic procedures have only a small effect on the tooth, reducing the relative stiffness by 5%. This was less than that of an occlusal cavity preparation (20%). The largest losses in stiffness were related to the loss of marginal ridge integrity. MOD cavity preparation resulted in an average of a 63% loss in relative cuspal stiffness.
Etiologies
Fractured roots

- Stress from occlusal forces
- Canal preparation
  - Physical
  - Chemical
- Lateral condensation of gutta percha
- Expansion of root fillings
- Cementation of posts
Etiologies
Fractured roots

Stress from occlusal forces

Etiologies
Fractured roots

Stress from occlusal forces
– Chan C.P., et al. 1998. JOE.
Etiologies
Fractured roots

Canal preparation technique

yes: Bier et al. 2009. JOE.

yes: Liu et al. 2013. JOE.
Etiologies-Fractured roots

Canal preparation: length-control


– Length-control is critical
Etiologies
Fractured roots

Canal preparation technique
Tang, Wu, Smales. 2010. JOE.

Conclude:

• Overinstrumentation of root canals + noncircular canals and thin canal walls = Increased risk for root fracture.

• Effect from various Ni-Ti rotary files is somewhat controversial, but hand files have fewer FX
Etiologies
Fractured roots

Canal preparation technique

Irrigants

CaltS, SerperA. Smear layer removal by EDTA. 2000 JOE

- Irrigated with 5.25% NaOCl, 2.5% NaOCl, 3% H2O2, 17% EDTA. All irrigants were found to reduced dentine surface hardness.
Etiologies
Fractured roots

Canal preparation technique

Calcium Hydroxide, MTA NaOCl

White JD, et al. The effect of three commonly used endodontic materials on the strength and hardness of root dentin. 2002 JOE.

After 5 weeks 32% mean decrease in strength after calcium hydroxide treatment,

33% decrease in strength after mineral trioxide aggregate treatment,

59% decrease in strength after sodium hypochlorite treatment
Etiologies-Fractured roots

Lateral condensation of gutta percha

Saw, L.H., Messer, H.H. 1995. JOE.

- Obtura > Lateral condensation > Thermafil condensation
- Thermal expansion large part. Obtura and Thermafil groups was found to be thermal strain.
- The mean load required to cause vertical root fracture was five to six times higher than the load used in obturation.
Etiologies-Fractured roots

Lateral condensation of gutta percha

Wilcox, L.R. et al. 1995. JOE.

– Using a fine finger spreader and standard loads during lateral compaction resulted in craze lines in all 34 maxillary incisor tooth specimens and root fractures when the root canal diameter were enlarged to 40%–50% of the total root widths

– No FX at 20-30% of total root widths
Etiologies-Fractured roots

Expansion of root fillings

The Properties of Endocal® 10 and Its Potential Impact on the Structural Integrity of the Root

Goldberg, R. et al., 2004. JOE.
Etiologies-Fractured roots
Etiologies-Fractured roots

Cementation of posts

• Obermayr G. et al. 1991. JPD.
• Morando G. et al. 1995. JPD.
Treatments-

• Treatment depends on the severity of the crack or fracture. “Split teeth/fractured roots” are considered “hopeless” by most.

• Treatment planning for cracked teeth and cracked roots becomes dependent on the clinical findings at the time of the “discovery”.
Treatments-
Cracked Crown/Root

• Remember!! A crack is now “a thin disruption of enamel and dentin, and possibly cementum, of unknown depth or extension.”

• Ricucci D, et al. JOE 2015 concluded cracks are always colonized with bacterial biofilms. The pulp tissue response varies according to the location, direction, and extent of the crack.

• Treatment planning for cracked crowns and cracked roots becomes dependent on the clinical findings at the time of the “discovery.”
Treatments-Cracked Crown/Root

- Reversible pulpitis- no periodontal pockets associated with the crack-
  - Crown it!
    - Krell and Rivera, 2007. JOE.
    - Around 20% will eventually need Rctx within a yr.
Treatments - Cracked Crown/Root

- Reversible pulpitis - no periodontal pockets associated with the crack
- Sedative Lining and interim restoration
  - 20% eventually needed Rctx within 5yrs
Treatments - Cracked Crown/Root

• Reversible pulpitis - no periodontal pockets associated with the crack -
  – Bonded restoration

  Opdam, et al. 2008. JOE.

  7 % eventually needed Rctx within 5yrs
Treatments-
Cracked Crown/Root

• Irreversible pulpitis- no periodontal pockets associated with the crack-
  – N= 72 of 476 crowned were Dx cracked
  – (45/60) had IP symptoms=> root canal treatment
    – 75 % eventually needed Rctx within 5yrs
Treatments -
Cracked Crown/Root

- Irreversible pulpitis/necrosis - no periodontal pockets associated with the crack -
  - Resin filling, inlays or prov. crown

Kang, Kim and, Kim. 2016. JOE.

50 % eventually needed Rctx within 5yrs
Treatments- Cracked Crown/Root

• Necrosis- no or minimal restoration and periodontal pockets associated with the crack- (fracture necrosis)
  – Extraction!
    Berman and Kuttler 2010 JOE
• --Retention!
• Kang et. al. 2016 JOE
  – Multivariate analysis revealed a weak correlation between multiple crack directions and pulp necrosis at initial examination
12-month Success of Cracked Teeth Treated with Orthograde Root Canal Treatment

Krell KV¹, Caplan DJ²

¹Department of Endodontics
²Department of Preventive and Community Dentistry

Local AADR: February 13, 2018
University of Iowa, College of Dentistry
Objective

To take the first steps in establishing an evidence-based staging system for treatment of cracked teeth by evaluating factors associated with 12-month success of orthograde root canal treatment
Methods

- Secondary data (Krell private practice, 1989-2014)

- Age, sex, date of first visit (patient-level)
  Tooth type
  Restoration (material, # restored surf)
  M/D marginal ridge cracks (y/n)
  M/D pocket depths (mm)
  Pulpal/periapical diagnosis

- Outcome = “success”

- Univariate, bivariate analyses (SAS Version 9.4)
Diagnosed Cracked Teeth (n=2086)

Treated with Root Canal Therapy (n=1406)

Potentially Eligible for Analysis (n=380)

Analyzed (n=363)

Not treated with Root Canal Therapy (n=680)

Did not return for 12-month recall (n=1026)

Ineligible for regression analysis (n=17)
- Outcome “questionable” (n=13)
- Patient <18 years old (n=1)
- Wisdom tooth (n=1)
- Reversible pulpitis (n=1)
- Unknown size of restoration (n=1)
# Tooth, Restoration

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<th>Material</th>
<th>Lower first molar</th>
<th>Upper first molar</th>
<th>Upper second molar</th>
<th>Lower second molar</th>
<th>Premolar</th>
<th>Amalgam</th>
<th>Composite</th>
<th>Metal</th>
<th>None</th>
<th>Other / Missing / Temp</th>
<th>Surfaces</th>
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## Cracks, Pockets, Pulp / Periapical Dx

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Mesial or Distal Probing Pocket Depth ≥5 mm?

Yes

Distal Marginal Ridge cracked?

No

Iowa Stage I: 37% of cases (93% success)

Yes

Periapical Diagnosis CAP, SAP, or AAA?

No

Iowa Stage II: 39% of cases (84% success)

Yes

Iowa Stage III: 15% of cases (69% success)

No

Iowa Stage IV: 8% of cases (41% success)
Discussion

Strengths
- Large number of observations (n=363)
- Single examiner (consistency over time)
- Staging system easily understood by clinicians

Limitations
- 1 operator, 1 city, private practice (generalizability?)
- Outcome (radiographic success vs. tooth survival?)
- 12-month follow-up (clinical relevance?)
- Selection bias (less tx of teeth with deep pockets?)
Cracked Tooth

- **Reversible Pulpitis**
  - Remove Restoration
  - Evaluate Crack

- **Irreversible Pulpitis**
  - Root Involved
  - Extract

- **Necrotic**
  - Remove Restoration
  - Evaluate Crack

- **Pulp Exposure By Crack/Caries**
  - Re-evaluation/Testing 2-3 weeks

- **Symptoms Resolve**
  - Normal
  - Restoration Onlay or Crown

- **Symptoms Continue**
  - Necrotic
  - Recall Evaluations

- **Crack Extends On Root or Floor**
  - Temporary Restoration (SS band/temp crown)
  - Re-evaluation/Testing 2-3 weeks
  - Symptoms Continue
  - Restoration Onlay or Crown
  - Symptoms Resolve
  - Complete Root Canal
  - Recall Evaluations

- **Crack Eliminated**
  - Temporary Restoration (SS band/temp crown)
  - Re-evaluation/Testing 2-3 weeks
  - Symptoms Resolve
  - Restoration Onlay or Crown
  - Recall Evaluations

- **Crack Extends On Root or Floor**
  - Temporary Restoration (SS band/temp crown)
  - Re-evaluation/Testing 2-3 weeks
  - Symptoms Continue
  - Restoration Onlay or Crown
  - Symptoms Resolve
  - Complete Root Canal
  - Recall Evaluations

- **Recall Evaluations**
“Teeth even compromised because of periodontal disease or endodontic problems may have a longevity that surpasses by far that of the average implant (Carnevale et al. 1998; Hardt et al. 2002; Lang and Zitzmann 2012; Salvi et al. 2014; Klinge et al. 2015).”

Giannobile and Lang, 2016
Treatments - Root Fracture

• Remember!! Now, “A fracture that exists or extends into the root, to include dentin, cementum, and possibly pulpal space, which may progress to or from the enamel.”

• Hemisection

• Root amputation

• Extraction - last resort!!
Treatments -
Root Fracture
Hemisection
Treatments
Root Fracture
Root amputation
Herodontics in the 80’s
Herodontics in the 80’s
Herodontics in the 80’s
Herodontics in the 80’s
Treatments
Root Fracture
“split tooth” = Extraction
Outcomes - changes in thinking!
(excerpts from Dr. Hargreaves Jan, 2016)

• survival (a patient-centered outcomes) and “radiographic success” (a clinician-centered outcome)

• “levels of evidence” may be only one way to measure clinical relevance of research. An entirely alternative approach is comparative effectiveness research (also called pragmatic clinical trials)
Outcomes

• Reversible pulpitis+ restoration
  – 80% survival without rctx
  – Krell and Rivera, 2007 JOE
  – Abbott and Leow, 2009 Aust Dent J
Outcomes

• Irreversible pulpitis? - no periodontal pockets associated with the crack
  – Ortho band + vitality tests => 200 Rctx + Cr
  – Sim, et al., 2016 JOE

• The 5-year survival estimate in the absence and presence of crack extension onto the pulpal floor was 99% and 88%, respectively
Outcomes - Cracked crown/root with root canal treatment

50 teeth had a 85% survival rate (2 yrs)  
Tan, Chen, Poon and Wong 2006 IEJ
88 teeth had a 90% survival rate (5 yrs)  
Kang, Kim and Kim 2016 JOE  
(>6mm probings decreased survival)  
Iowa Stage 1 = 93% success  
Iowa Stage 2 = 84% success  
Iowa Stage 3 = 69% success  
Iowa Stage 4 = 41% success  
Krell and Caplan accepted JOE 2018
Outcomes-rctx-fractured root + root resection =

92% survival over 12 yrs

Outcomes - Rctx+fractured root + hemisection =

- 79% success over 1-7 yrs
Prevention???

• Physical anthropologists estimate tooth longevity without modern care to be 30-40 yrs based on enamel wear patterns.

Simon Hillson-Dental Anthropology 1996

Average Life Expectancy USA Circa 1900
Men= 46.3 yrs
Women= 48.3 yrs.

Average Life Expectancy USA Circa 2016
Men= 76.6 yrs
Women= 81.5 yrs
The truth is we are all potentially outliving the structural limits of our natural teeth!

Endodontics is the specialty for definitively diagnosing cracks and fractures!

Periodontists are re-examining their decades old shift to implants and are again realizing the need to preserve the natural dentition.
Summary

• Endodontics never abandoned the need to preserve the natural dentition and we can reassert our leadership role as the only specialty devoted to preserving the natural dentition!
Summary

• Are all fractured teeth “Hopeless”? 
  – Maybe “split teeth”, but multi-rooted teeth can survive, in part, if we want to put forth the effort. Let us all respond to Dr. Giannobile’s request to save the natural dentition again!

Let’s Make Endodontics Great Again!