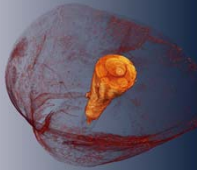


**Damage to root canal dentine after endodontic procedures**  
*New Evidence, Clinical Significance and Prevention*



**Kajoy Shemesh, DMD, PhD**  
 Department of Endodontics  
 Case Western Reserve University  
 10850 University Ave  
 Cleveland, OH 44106-3695  
 Tel: +1 216 368 3113  
 E-mail: kshemesh@case.edu  
 www.case.edu

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 ACADEMIC CENTRE  
 FOR DENTISTRY AMSTERDAM

**Cracks & fractures**



- Definitions, diagnosis
- How can you be sure ?!
- Do teeth crack more lately?
- Research methodologies:
  - a. in-vitro microscopic
  - b. in-vitro micro-CT
  - c. in-vitro cadavers
  - d. Clinical studies
- New directions
- Conclusions

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- An evaluation of endodontically treated VRF teeth: impact of operative procedures. Fuss Z et al. 2001
- An evaluation of endodontically treated VRF teeth. Tamse A et al. 1999
- Prevalence of VRF in extracted endodontically treated teeth. Fuss Z et al. 1999
- Radiographic features of vertically fractured, endodontically treated maxillary premolars. Tamse A et al. 1999

**Tamse, Fuss 1999-2001**

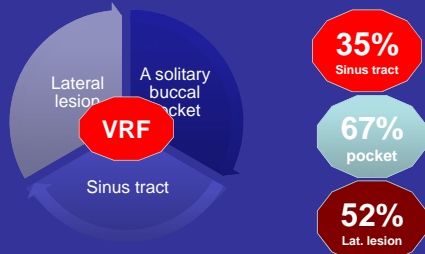
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An evaluation of endodontically treated vertically fractured teeth.

- Survey of 92 teeth with VRF evaluated before and after extraction .
- Most fractured : maxillary 2<sup>nd</sup> premolars and mesial roots of the mandibular molars
- 67.4% -solitary buccal pocket
- 34.8% -sinus tract
- 52% -lateral radiolucency (with or without periapical radiolucency)

**Tamse et al. JOE 1999**

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**VRF**

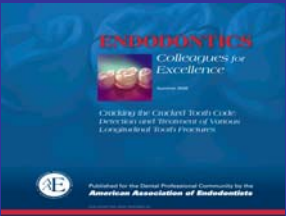
- 35% Sinus tract
- 67% pocket
- 52% Lat. lesion

- Maxillary second premolars and mesial roots of the mandibular molars

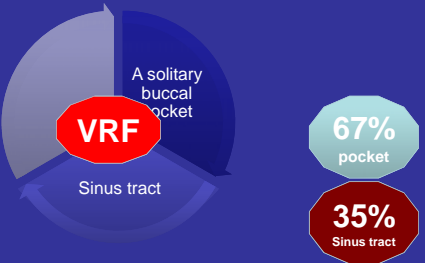
**Tamse et al. JOE 1999**

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“Having a sinus tract and a narrow, isolated periodontal probing defect in association with a tooth that has had root canal treatment, with or without a post placement, is considered to be pathognomonic for the presence of a VRF.”



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A solitary buccal pocket: 67%  
Sinus tract: 35%

AAE 2008

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When suspecting a VRF, when are we really sure ?


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Diagnosis of VRF in endodontically treated teeth based on clinical and radiographic indices: a systematic review.

“ There is no substantial evidence regarding the accuracy of the clinical and radiographic indices for the diagnosis of VRF in endodontically treated teeth” .



Tsesis et al. JOE 2010


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CBCT?

**PRESENT**

**PAST** Pathognomonic signs & symptoms:  
Deep pocket  
Sinus tract  
Lateral lesion  
Premolar/molar

**FUTURE** How are we going to diagnose VRF ?



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...some of us feel that we diagnose VRF more often...

Are there more fractured or cracked teeth lately ???

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Maybe we just see them more...?

Operating microscope

CBCT

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CBCT

Detection of VRF in endodontically treated teeth by a CBCT

Hassan et al. JOE 2009

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The detection of VRF in root filled teeth with periapical radiographs and CBCT scans.

“...periapical radiographs and CBCT were not accurate in detecting the presence and absence of simulated VRF”

Patel et al. IEJ 2013

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Detection of vertical root fracture with OCT

Shemesh et al. JOE 2009

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Maybe we are more aware of them?

Reasons for VRF during treatment

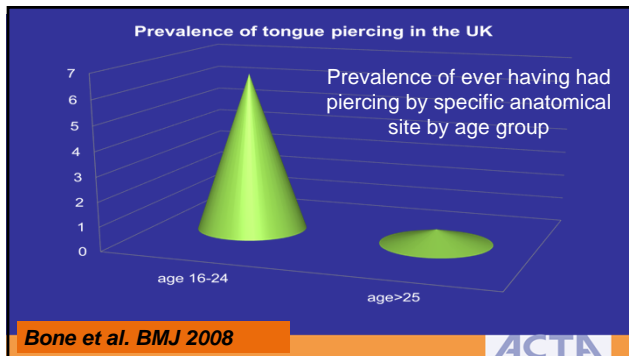
- Instrumentation (Onnink et al. 1994, Shemesh et al. 2008)
- Hypochloride (Sim et al. 2001)
- Anatomy (Wu et al. 2004)
- Post-placement (Kishen 2006)
- Lateral compaction ? (Meister et al. 1980, Shemesh et al. 2009)

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Maybe we just have more fractures?



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Tongue piercing




Tongue piercing is correlated with an increased occurrence of enamel fissures, enamel cracks and lingual recessions. Patients need better information on the potential complications associated with tongue piercing.

Levin & Zadik. Am J Dent 2007  
Ziebolz et al. Clin Oral Inv 2011

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Dental Jewellery



A new threat to adolescent oral health: the grill.

Hollowell & Childers Pediatr Dent 2007

ACTA

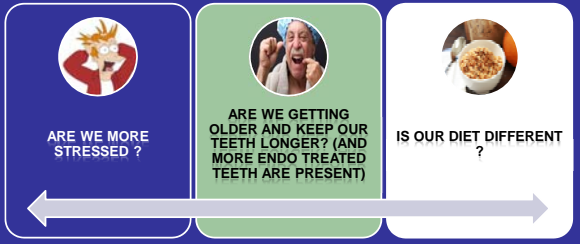
Maybe we perform more complicated procedures?

Comparison of dentinal crack incidence and of post removal time resulting from post removal by ultrasonic or mechanical force.

Altshul et al. 1997 JOE

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Environmental changes



ARE WE MORE STRESSED ?

ARE WE GETTING OLDER AND KEEP OUR TEETH LONGER? (AND MORE ENDO TREATED TEETH ARE PRESENT)


IS OUR DIET DIFFERENT ?

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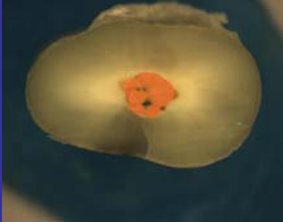

Summary till now

Do we have more cracked teeth lately ?

- We see them better
- We are more aware of them
- Environmental changes





The effect of endodontic procedures on the root canal wall

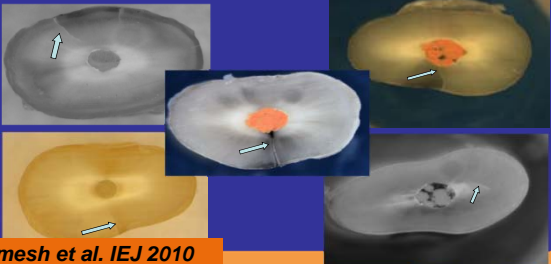



Definitions


- Cracks, intra-dentine cracks, incomplete crack, fracture, incomplete fracture, craze lines, stress lines, vertical root fracture, scratches...

Defects





*Shemesh et al. IEJ 2010*




Limitations

- Destructive method
- The original dimensions of the canal were not standardized





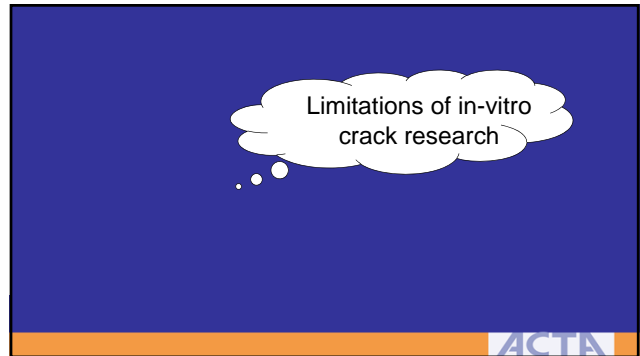
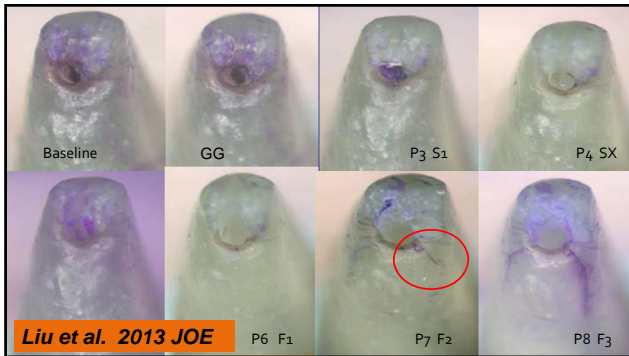
Apical cracks

- The effect of root preparation technique and instrumentation length on the development of apical root cracks.



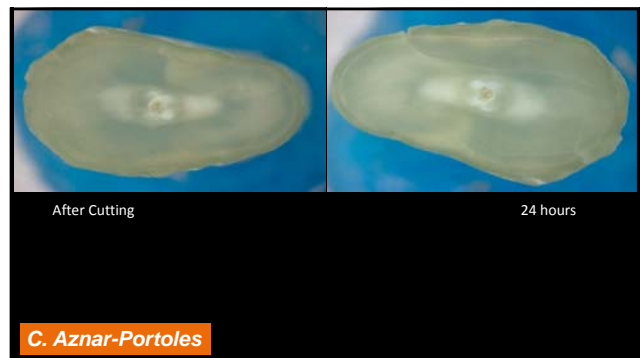

*Adorno et al. 2009, 2010*






Limitations

- Destructive methods
- The original dimensions of the canal were not standardized, apical size..
- Small number of teeth (10 per group)
- Drying of the specimen
- What is the effect of drying time, cutting machine used and different observers on the detection of defects?
- PDL was not always imitated

- Non-destructive methods ( $\mu$ CT)
- Repeat the experiments on cadavers (PDL!)
- Attention to preselection of roots
- Clinically relevant preparations
- Larger groups of teeth
- Clinical significance!

- De-Deus et al. JOE 2014 Lack of causal relationship between dentinal microcracks and root canal preparation with reciprocation systems.



**Endodontic Topics**

**Critical appraisal of studies on dentinal radicular microcracks in endodontics: methodological issues, contemporary concepts, and future perspectives**

MARCO A. VERSIANI, ERICK SOUZA & GUSTAVO DE-DEUS

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**Micro CT studies- limitations**

- Unfortunately were done in dry conditions
- Almost all teeth demonstrate fractures BEFORE instrumentation.
- Resolution is limited (typically 15-20µ)
- Pixel sizes, phase limitations, computer programs, filters, interpretations

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- Arias et al. JOE 2014 Comparison of 2 canal preparation techniques in the induction of microcracks: a pilot study with cadaver mandibles.

*“A relationship between the shaping techniques (GT hand and WaveOne) and the incidence of microcracks could not be shown compared with uninstrumented controls.”*

**Arias et al. JOE 2014**

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Detecting Dentinal Microcracks Using Different Preparation Techniques: An In Situ Study with Cadaver Mandibles.

There was no difference in the frequency of microcracks among the experimental groups instrumented with TS, WO, and KF or uninstrumented controls.

**Bahrami et al. JOE 2017**

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Dentinal Microcrack Development after Canal Preparation: A Longitudinal in Situ µCT Study Using a Cadaver Model.

- In situ root canal preparation of maxillary premolars with Reciproc and ProTaper Universal systems did not induce the formation of dentinal microcracks in a cadaver model as observed by µCT.

Root canals were prepared up to R25 and F2 instruments in the Reciproc and ProTaper Universal groups, respectively.

**De-Deus et al. JOE 2017**

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- It should be assumed that microcracks observed in stored extracted teeth subjected to root canal procedures are a result of the extraction process and/or the post-extraction storage conditions


**De-Deus et al. JOE 2018**

Summary till now

Two major research methodologies were used

- Sectional studies
- Micro CT studies
- Both have advantages and disadvantages

Clinical studies



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Tawil et al. 2015 JOE

- Periapical microsurgery: The effect of root dentinal defects on short and long term outcome
- 155 teeth
- Highly significant difference in healing (95% without defects, 30% with )

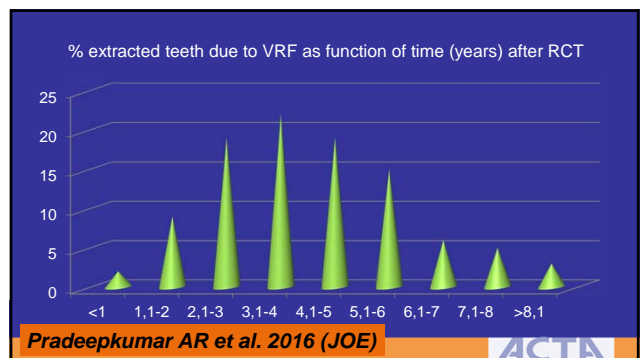
**Tawil et al. JOE 2015**

Diagnosis of VRF in restored endodontically treated teeth- A time dependent retrospective cohort study.

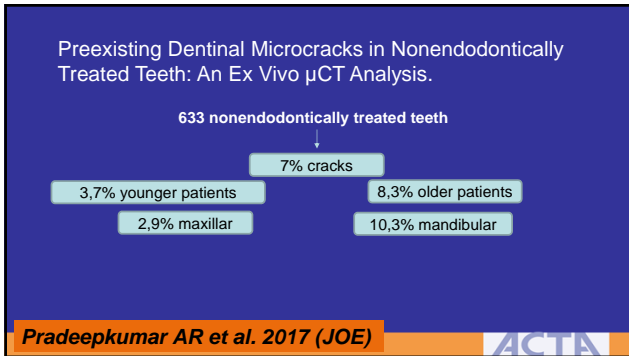
197 root-filled, crowned teeth with no post and suspected of VRF  
Diagnosis of VRF was confirmed after surgical flap elevation

Mandibular molars and maxillary premolars  
Deep pockets  
Halo shaped radiolucency

**Pradeepkumar AR et al. 2016 (JOE)**



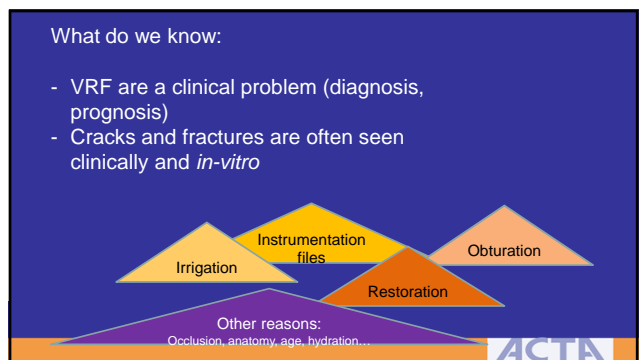
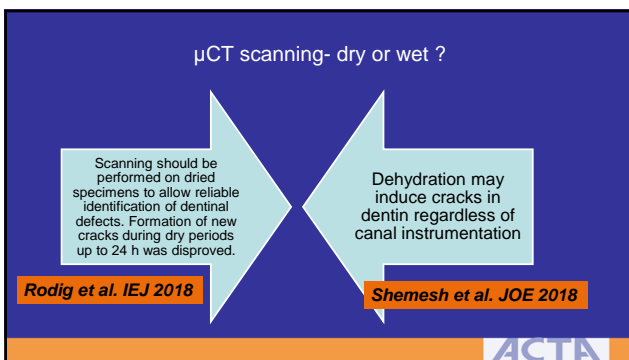




- Residual Microstrain in Root Dentin after Canal Instrumentation Measured with Digital Moiré Interferometry.

Biomechanical response of root dentin to instrumentation was influenced by hydration. Reciprocating, rotary, and hand instrumentation of well-hydrated roots did not cause an increase in residual microstrain or the formation of microdefects ...

Lim et al. JOE 2016



New conclusions

Less invasive techniques

Cracks are frequently seen but it is unclear why are they there

Drying and conditioning plays an important role. The environment is determinant.

Dentine reacts in a special way because of the collagen fibers, the inorganic content and minerals.

Factors such as occlusal forces, habits, age, perio status should be considered

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The minimally invasive era

- Access opening
- Instruments (and irrigation)
- Filling procedure
- Restorations (no crowns?)

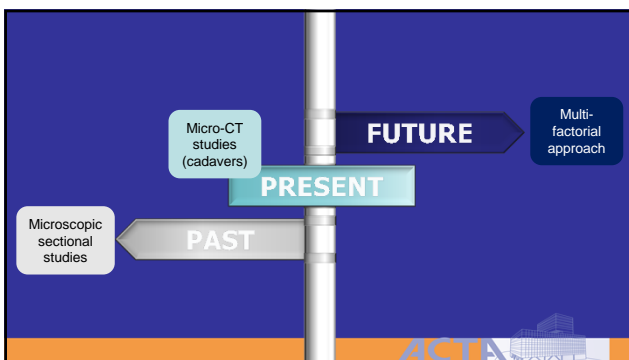
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- Stress distribution in a mandibular premolar after separated nickel-titanium instrument removal and root canal preparation: a three-dimensional finite element analysis

*Na Ni et al. J Int Med Res 2019*

Separated instrument removal caused changes in stress distribution and increases in stress concentration in the straight-line access region of roots

*Na Ni et al. J Int Med Res 2019*



Effect of irrigation/ medication

- Effect of Endodontic **Irrigation Protocols** on Crown Fracture Resistance. Baechtold et al. 2018
- Fracture resistance of weakened bovine teeth after long-term use of **calcium hydroxide**. Valera et al. 2015
- Influence of **Irrigation Sequence** on the Adhesion of Root Canal Sealers to Dentin: A Fourier Transform Infrared Spectroscopy and Push-out Bond Strength Analysis. Neelakantan et al. 2015
- Similar influence of stabilized alkaline and neutral **sodium hypochlorite solutions** on the fracture resistance of root canal-treated bovine teeth. Souza et al. 2014

New theories

- Stress/ force concentrators
- Post & core structures
- Scratches
- High resolution

*Kim et al. JOE 2013*

- Biomechanical studies on the effect of iatrogenic dentin removal on vertical root fractures.

The combined experimental/numerical analyses highlighted the influence of remaining root dentin volume on the radicular bending resistance, stress distribution pattern, and subsequent propensity to VRF.

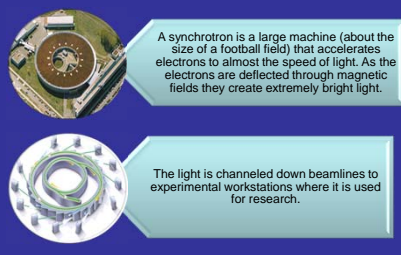
*Ossareh et al. J conserv Dent 2018*

Vertical Root Fracture in Buccal Roots of Bifurcated Maxillary Premolars from Condensation of Gutta-percha.

- The main etiology for VRF is stress concentration resulting from the combined effect of wedgelike canal depression and the flexibility of periodontal ligament tissue joining the root and bone.

**Chai & Tamse JOE 2018**

### What is a synchrotron?


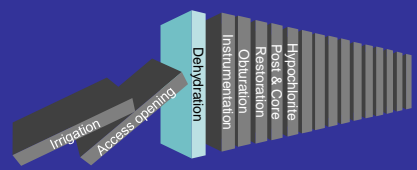


A synchrotron is a large machine (about the size of a football field) that accelerates electrons to almost the speed of light. As the electrons are deflected through magnetic fields they create extremely bright light.


The light is channeled down beamlines to experimental workstations where it is used for research.

### Dehydration

- Does this play an important role in the Clinical situation ?

### Stopping the EFFECT




Teeth crack because of a combination of factors that all contribute to the formation of a crack

Minimally invasive procedures, less taper, cuspal coverage

### How to diagnose VRF ?

Combination of factors, but no clear-cut rule:

- AAE recommendations (combination of deep pocket + sinus tract in an endodontically treated tooth) should be reconsidered
- Occlusal forces, quality of the root canal filling, presence of a post, Lateral lesion , tooth supporting a bridge- should be taken into account
- Adjunct imaging methods could give more info
- Patient's preferences



- Cracks & fractures are often seen in endodontically treated teeth
- Instrumentation/ obturation are *not* the direct causes for cracks and fractures. Age, hydration state play a role
- Stress concentrators could develop into cracks
- Caution should be used when performing in vitro research on crack initiation. PDL plays an important role
- $\mu$ CT has many advantages but also limitations, and should be used in wet conditions