

Root Fractures: Scientific Research and Controversies

*New Evidence, Clinical
Significance and Prevention*



1

Present status and future directions: vertical root fractures
in root filled teeth

Patel et al. IEJ 2022

ACTA

2

Retrospective Assessment of Endodontically Treated Teeth
Replaced by Dental Implants.

The leading reasons for extraction were:

1. Caries associated with defective restoration (26.6%)
2. Fracture of coronal structure (21.5%)
3. Vertical root fracture (20.9%)
4. Compromised periodontal condition (13.8%)
5. Endodontic failure (2.4%)

Kim et al. JOE 2024

ACTA

3

Root fractures is more commonly associated with
endodontically treated teeth than with vital teeth

Yoshino et al. COI 2015

ACTA

4

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
- Prevention
- Clinical management
- Conclusions

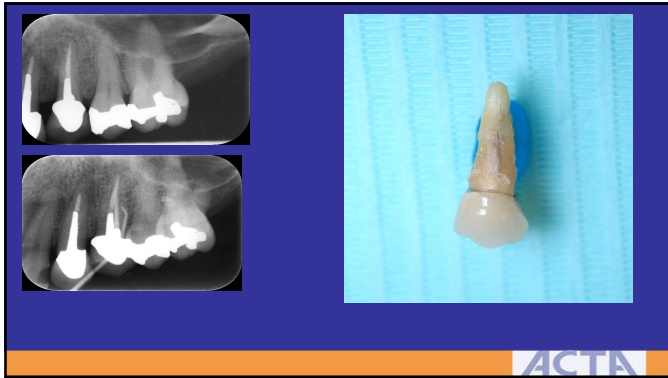
ACTA

5

- Definitions & diagnosis

ACTA

6



7

- 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

8

An evaluation of endodontically treated vertically fractured teeth.

- Survey of 92 teeth with VRF evaluated before and after extraction .
- Most fractured : maxillary 2nd 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

9

VRF

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

- Maxillary second premolars and mesial roots of the mandibular molars

Tamse et al. JOE 1999

10

"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. "

ACTA

11


VRF

- 67% pocket
- 35% Sinus tract


AAE 2008

12



When suspecting a VRF, when are we really sure ?




13




- Sinus tract
- Endodontically treated tooth
- Premolar with a post
- Lateral lesion

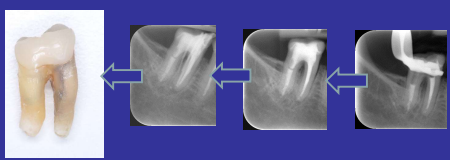
14




- "high" sinus tract
- "double" sinus tract




15




O. Guerreiro Viegas



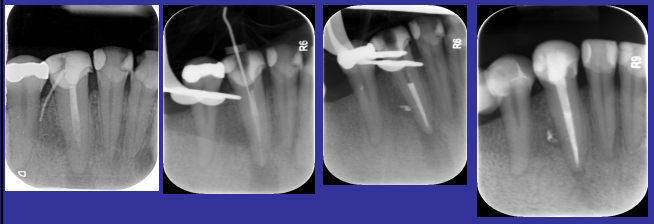
16




- "high" sinus tract



17



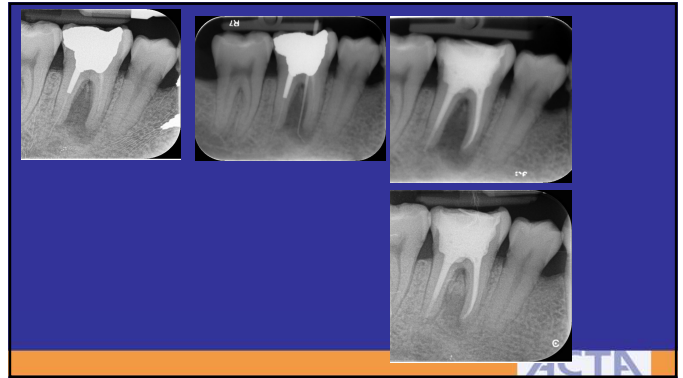
M. Lindtoft



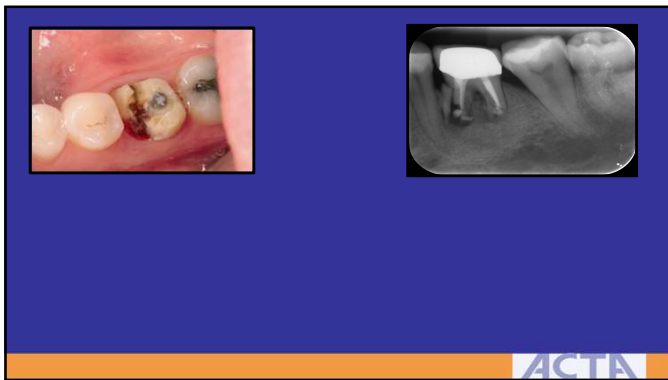
18



19



20



21

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

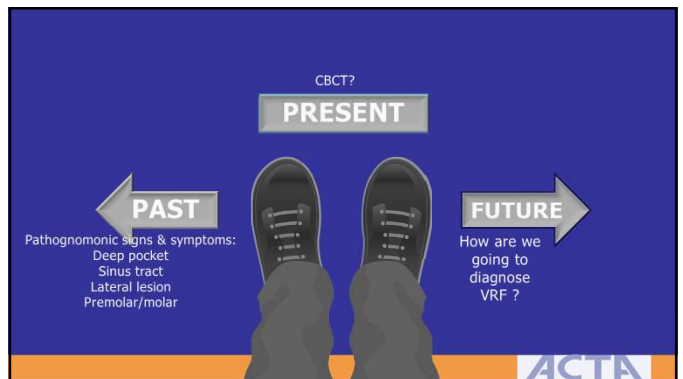
22

Review
 Risk Factors for and Clinical Presentations Indicative of Vertical Root Fracture in Endodontically Treated Teeth: A Systematic Review and Meta-analysis

Conclusions: Four clinical presentations were identified to be the most significant signs or symptoms for a VRF : presence of sinus tracts, increased probing depths, swelling/abscess, and tenderness to percussion.


Haupt et al. JOE 2023

23



24



Do we have more VRF recently?



25

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

Are there more fractured or cracked teeth lately ???

26



Maybe we just see them more...?

Operating microscope

CBCT

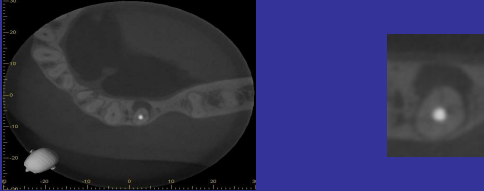



27


28

CBCT



Detection of VRF in endodontically treated teeth by a CBCT

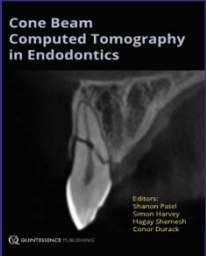
Hassan et al. JOE 2009




29

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”



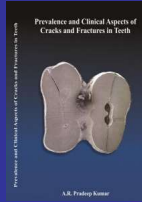
Patel et al. IEJ 2013



30

Diagnosis of VRF by CBCT in Root-filled Teeth with Confirmation by Direct Visualization: A Systematic Review and Meta-Analysis.

"CBCT imaging is still not a good tool for diagnosing VRFs in root-filled teeth compared with direct visualization".



PradeepKumar et al. JOE 2021

ACTA

31

" Although the accuracy of CBCT imaging for the diagnosis of subtle VRFs in endodontically treated teeth in vivo was poor, vertical buccopalatal (lingual) bone loss is an important indirect sign for the diagnosis of VRFs, which can be found on CBCT images."

Zhang et al. JOE 2019

ACTA

32

Evaluation of the efficacy of the metal artifact reduction algorithm in the detection of a VRF in endodontically treated teeth in CBCT images: An in vitro study.

The MATLAB artifact removal software can enhance the detection of VRFs on CBCT scans to some extent.

Saati et al. Dent Med Probl 2019

ACTA

33

A Novel Thresholding Based Algorithm for Detection of Vertical Root Fracture in Nonendodontically Treated Premolar Teeth.

Johari M et al. J Med Signals Sens. 2016

Effect of object position in the field of view and application of a metal artifact reduction algorithm on the detection of vertical root fractures on cone-beam computed tomography scans: An in vitro study.

Nikbin A et al. Imaging Sci Dent. 2018

Performance of an artefact reduction algorithm in the diagnosis of in vitro vertical root fracture in four different root filling conditions on CBCT images.

de Rezende Barbosa GL et al. Int Endod J. 2016

ACTA

34

Detection of vertical root fracture with OCT

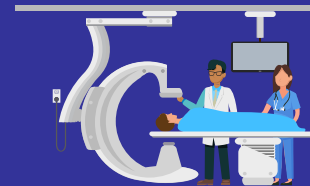


Shemesh et al. JOE 2009

ACTA

35

Accuracy of Magnetic Resonance Imaging in Clinical Endodontic Applications: A Systematic Review.



Candemil et al. JOE 2024


ACTA

36

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)

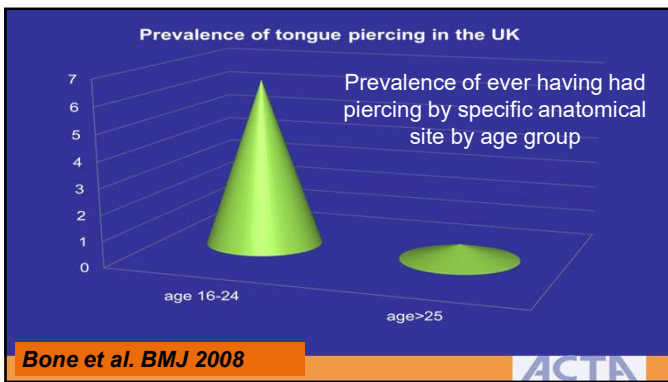


37

Maybe we just have more fractures?

38




39

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




40

Dental Jewellery

A new threat to adolescent oral health: the grill.



Hollowell & Childers Pediatr Dent 2007




41

Maybe we perform more complicated procedures?

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

Altshul et al. 1997 JOE



42

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 ?



ACTA

43



44



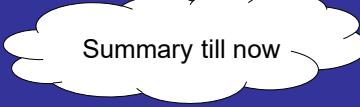
45

- The incidence of VRF increases with age and is most prevalent in patients older than 40 years

PradeepKumar et al. JOE 2016

ACTA

46



Do we have more cracked teeth?

Another potential reason : Endodontic procedures are evolving

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

ACTA

47

Effects of endodontic procedures

ACTA

48

The effect of endodontic procedures on the root canal wall

ACTA

49

Definitions

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

ACTA

50

Defects

Shemesh et al. IEJ 2010

ACTA

51

260 lower premolars

n=40 neg. Control	n=20 Preparation with Hand files (40 /step back tot 80)	n=200 preparation with Ni-Ti rotary systems:
		n=50 ProTaper (F4)
		n=50 GT (40 0.06)
		n=50 ProFile (40 0.06)
		n=50 S-Apex

The roots were sliced 3,6,9 mm from the apex and inspected under a microscope

ACTA

52

Results- different instrumentations

Number of teeth with defects

- Hand preparation- no defects
- S-Apex
- ProTaper
- Percentage of defected teeth

Instrumentation	Number of teeth with defects
Control (hand-files)	0
GT	1
ProFile	2
ProTaper	7
S-Apex	0

Bier et al. JOE 2011

ACTA

53

Conclusions

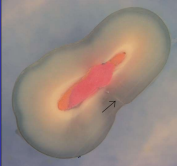
- Some rotary Ni-Ti systems could cause dentinal defects.
- The taper might have a determinant role in the appearance of dentinal defects.
- Gates Glidden drills could significantly contribute to the appearance of dentinal defects in vitro

ACTA

54

Limitations

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




ACTA

55

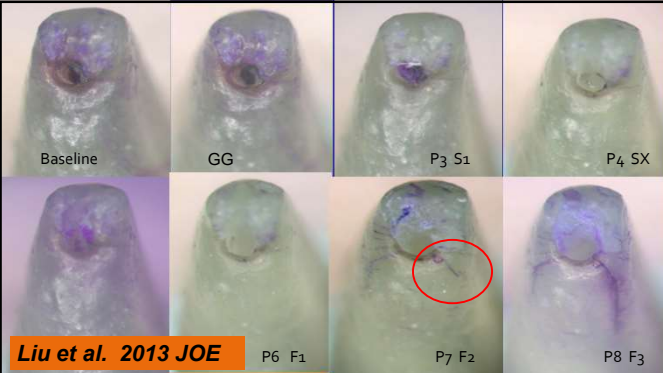
Apical cracks

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



Adorno et al. 2009, 2010 **ACTA**

56



Liu et al. 2013 JOE **ACTA**

57

Limitations of in-vitro crack research

ACTA

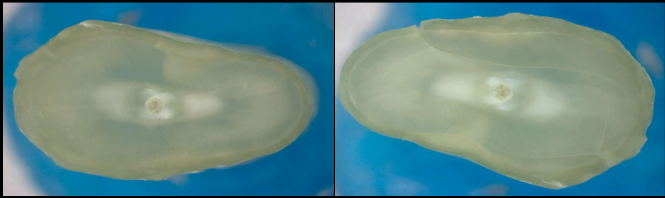
58

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

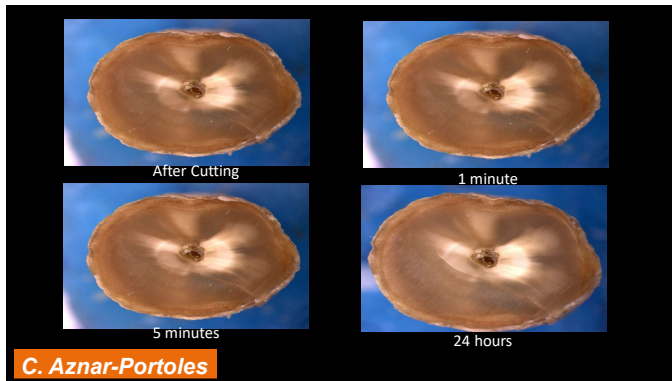
ACTA

59



C. Aznar-Portoles

60



61

LED transillumination assessment of freshly extracted roots with class II or III mobility showed smaller number of dentinal defects than roots with uncontrolled storage time and extraction forces. The use of freshly extracted roots with mobility should be considered for future dental defect assessment studies.

Coelho et al. JOE 2016

62

Effect of Root Canal Preparation Techniques on Crack Formation in Root Dentin

Shantiaee et al. JOE 2019

63

Micro CT studies

64

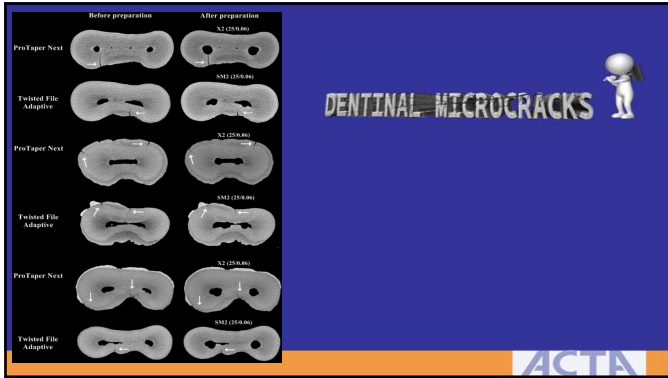
- Non-destructive methods (μ CT)
- Repeat the experiments on cadavers (PDL!)
- Attention to preselection of roots
- Clinically relevant preparations
- Larger groups of teeth
- Clinical significance!

65

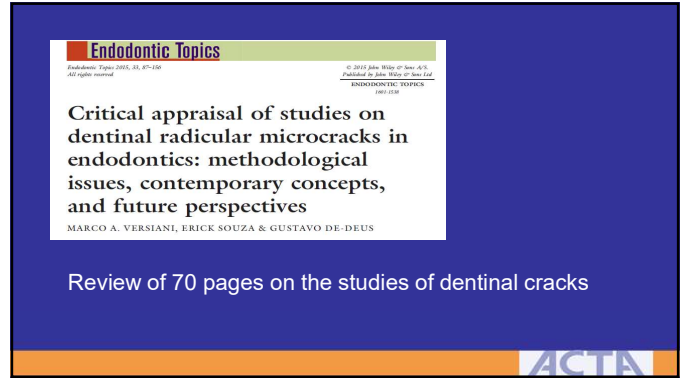
- De-Deus et al. JOE 2014 Lack of causal relationship between dentinal microcracks and root canal preparation with reciprocation systems.

De-Deus et al. JOE 2014

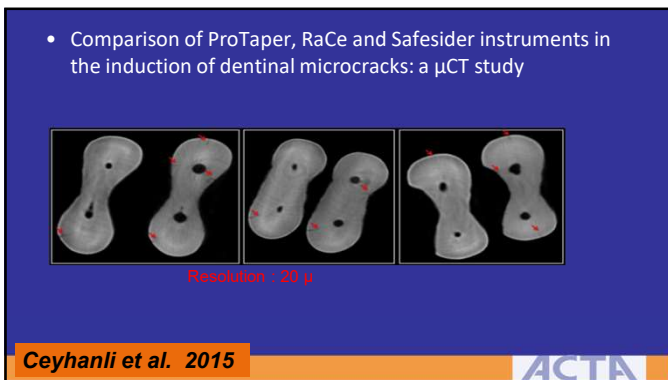
66



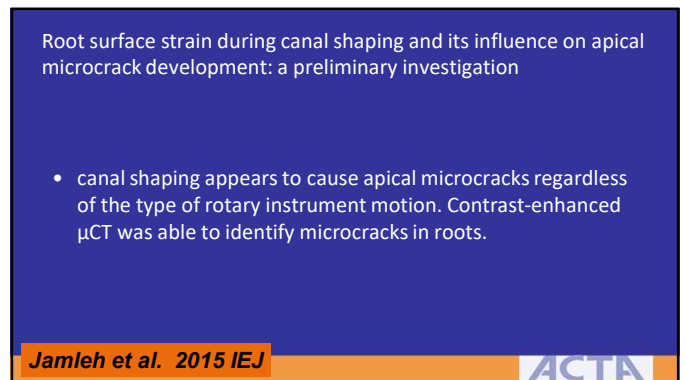
67



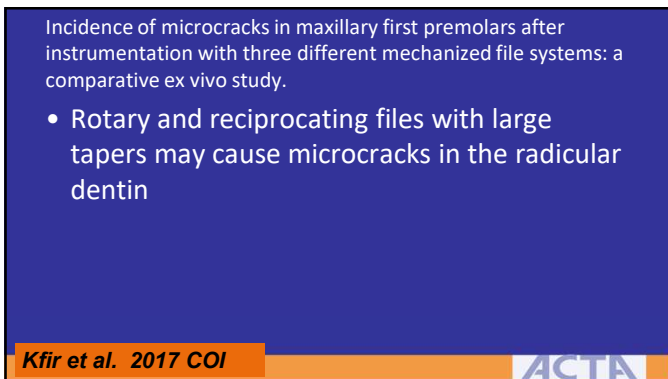
68



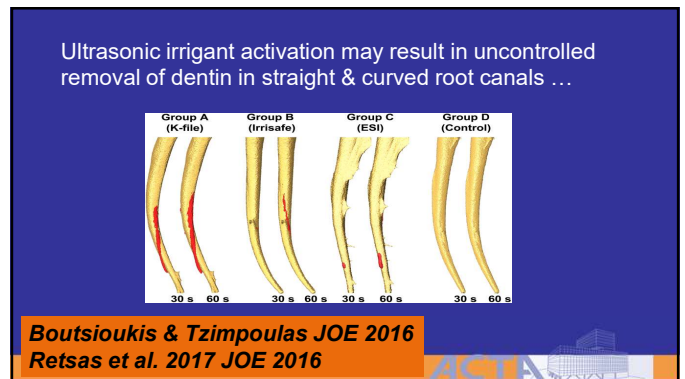
69



70



71



72

Micro CT studies- limitations

- Unfortunately were done in dry conditions
 - Almost all teeth demonstrate fractures BEFORE
- Is it possible that fractured teeth transfer stress differently than non fractured teeth ?**
- Resolution is limited (typically 15-20 μ)
 - Pixel sizes, phase limitations, computer programs, filters, interpretations

73

μ CT scanning- dry or wet ?

Scanning should be performed on dried specimens to allow reliable identification of dentinal defects. Formation of new cracks during dry periods up to 24 h was disproved.



Dehydration may induce cracks in dentin regardless of canal instrumentation

Rodrig et al. IEJ 2018

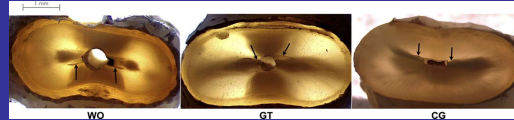
Shemesh et al. JOE 2018

74

Cadaver studies

75

- 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

76

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

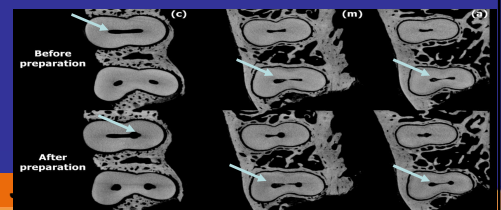
There was no difference in the frequency of microcracks among the experimental groups instrumented with TS, WO, and KF or uninstrumented controls.

Bahrami et al. JOE 2017

77

Dentinal Microcrack Development after Canal Preparation: A Longitudinal In Situ μ CT Study Using a **Cadaver** Model.

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



De-Deus et al.

78

- 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

79

Summary till now

Two major research methodologies were used

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

80

In vitro studies

81

Clinical studies

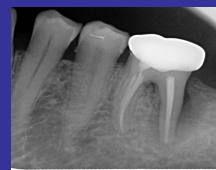
82

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

83



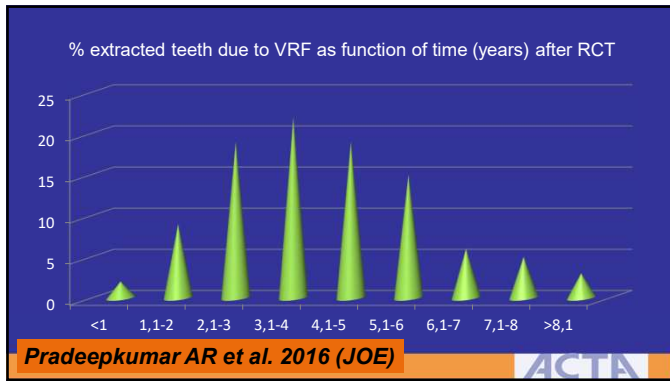
Diagnosis of VRF in restored endodontically treated teeth- A time dependent retrospective cohort study.

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)

84



85

What do we know:

- VRF are a clinical problem (diagnosis, prognosis)
- Cracks and fractures are often seen

What don't we know:

- Connection between cracks/ microcracks and VRF
- Reasons for cracks

86

New conclusions

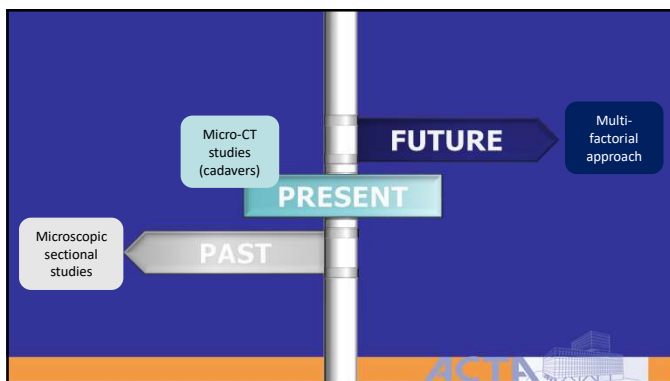
Less invasive techniques

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

87

New directions and research ideas

88



89

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

90

New theories

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

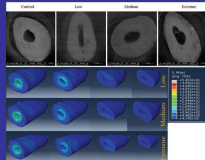
Kim et al. JOE 2013




91

- 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




92

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

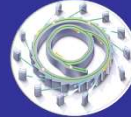


93


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.



94



DESY – Hamburg, Germany


BESSY – Berlin, Germany

ESRF – Grenoble, France

Illinois, USA




95

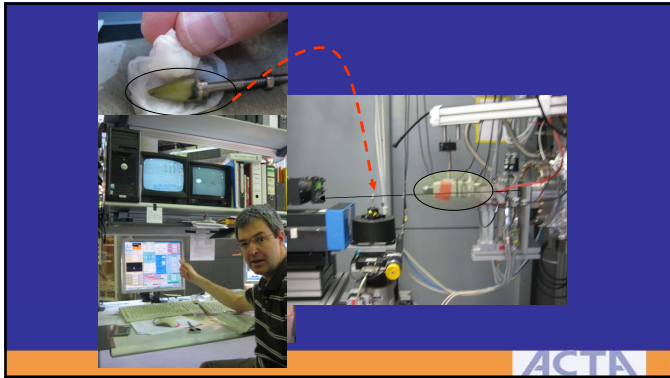


SOCIEDAD MEXICANA DE LUZ SINCROTRÓN A.C.

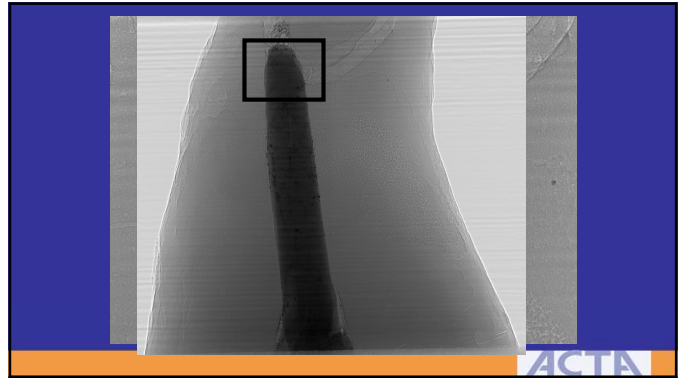
The Mexican synchrotron facility will be completed by 2030. Mexico could become the second Latin American country to host a synchrotron facility, after Brazil.



96



97

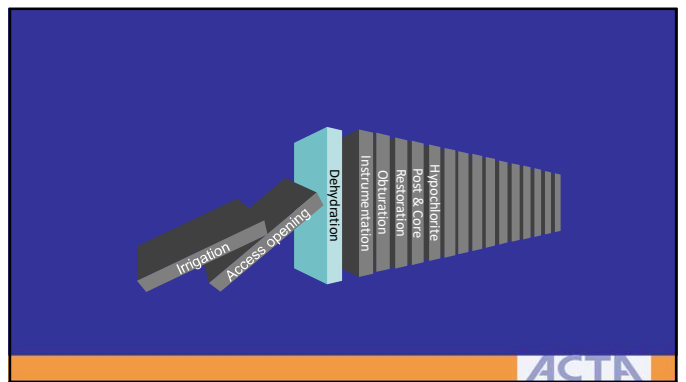


98

Dehydration

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

99



100

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

101

Prevention

102

Prevention of root fractures

- Parafunctions
- Vital pulp therapies
- Minimal invasive
- No-treatment ?

ACTA

103

Resistance to fractures

- Opening: contracted vs. conventional
- Instrumentation: Taper/ size/ length
- Irrigation
- Obturation : Materials/ technique
- Restoration : Materials/ Fiber-post

ACTA

104

Impact of Contracted Endodontic Access Cavities on the Fracture Resistance of Endodontically Treated Teeth After Mechanical Aging by Simulated Chewing Forces.

Conclusions: There was no difference observed in the fracture resistance of mandibular molars with TECs and CECs subjected to masticatory loading.

Selvakumar et al. JOE 2023

ACTA

105

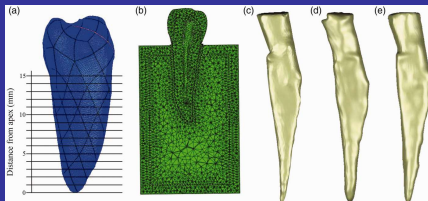
The minimally invasive era

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

ACTA

106

- 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

ACTA

107

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

ACTA

108

Influence of selective retreatment on resistance to fracture

Shemesh et al. In process

ACTA

109

Treatment & clinical management

ACTA

110

The prognosis of endodontically treated teeth with a VRF is poor

In most cases- extraction

Other options :

- Root resection
 - Novel techniques using intentional replantation, surgery and adhesive resins, cements, glass ionomer , bioactive materials
- Insufficient evidence

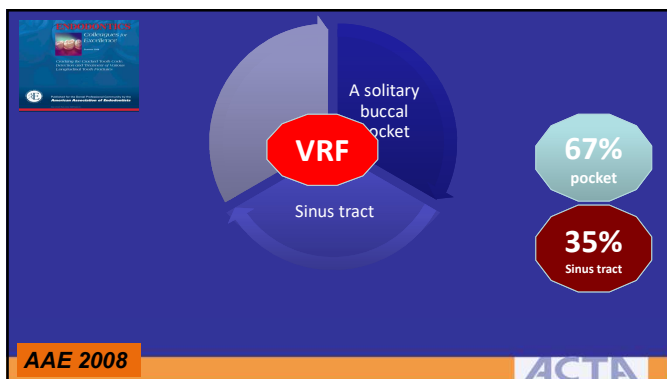
Patel et al. IEJ 2022

ACTA

111

Conclusions & take home message

112



113

How to diagnose VRF ?

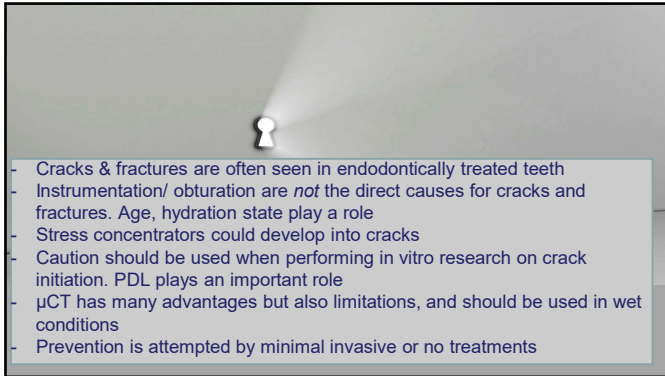
Combination of factors, but no clear-cut rule:

- 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



ACTA

114



115