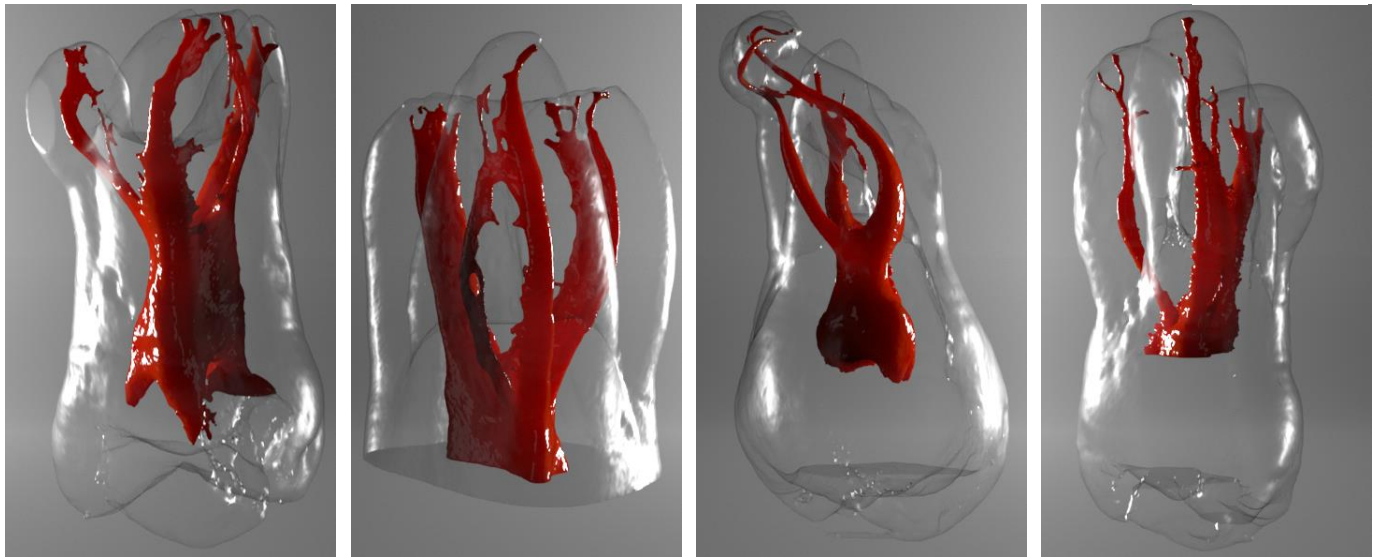
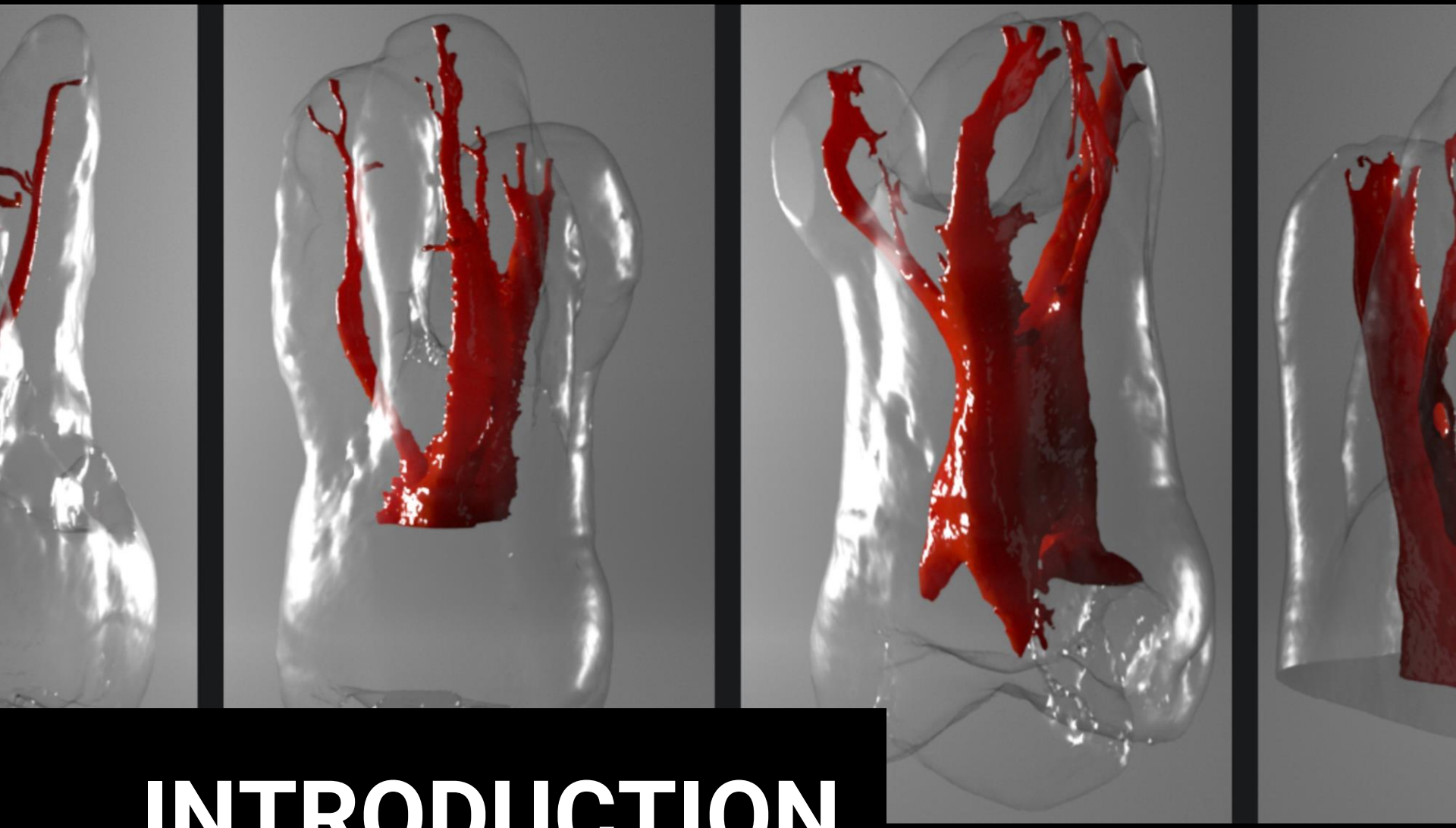


# Bruker Webinar

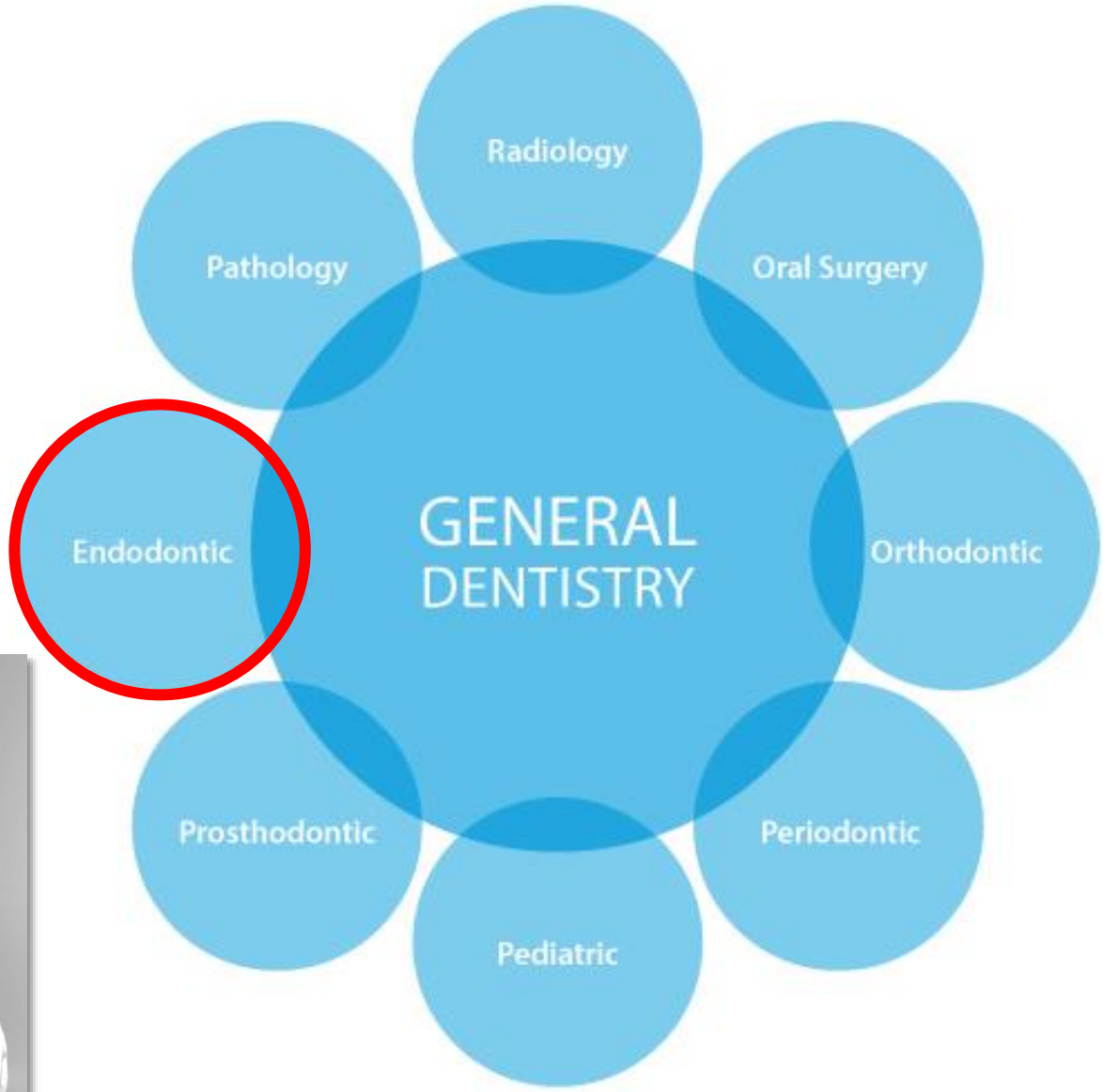
# Endodontic Applications

## of micro-CT for studying root canals

Prof. Dr. Marco Versiani
DDS, MSc, PhD, Post Doctor in Endodontics



# INTRODUCTION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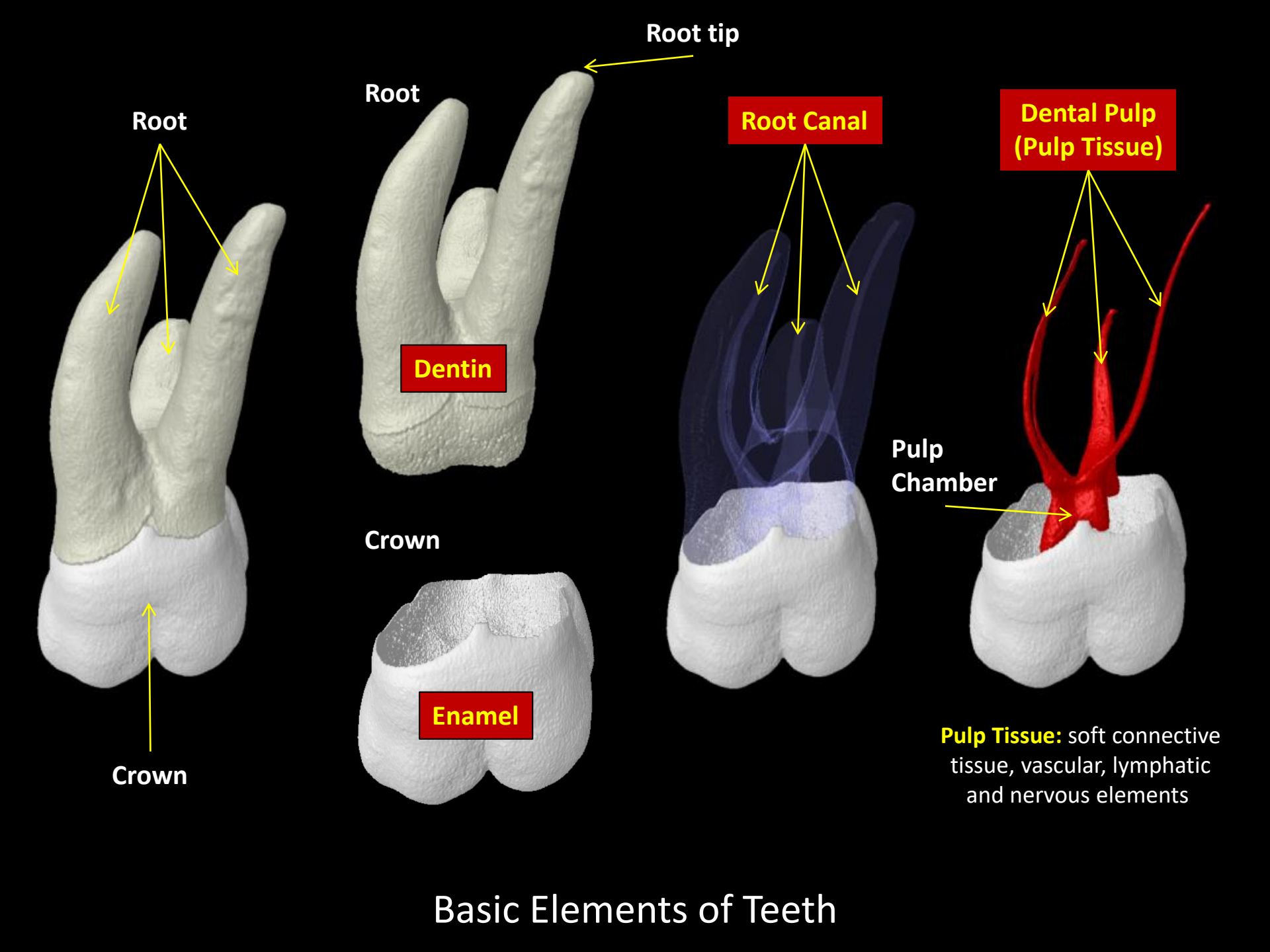
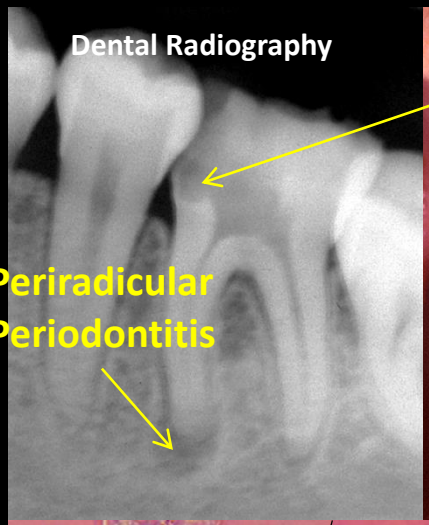
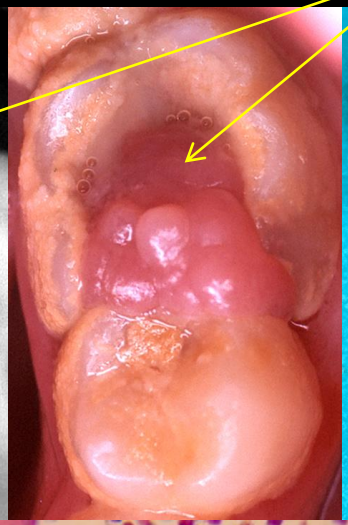
Oral Surgery
Endodontic
GENERAL DENTISTRY
Orthodontic
Prosthodontic
Periodontic
Pediatric

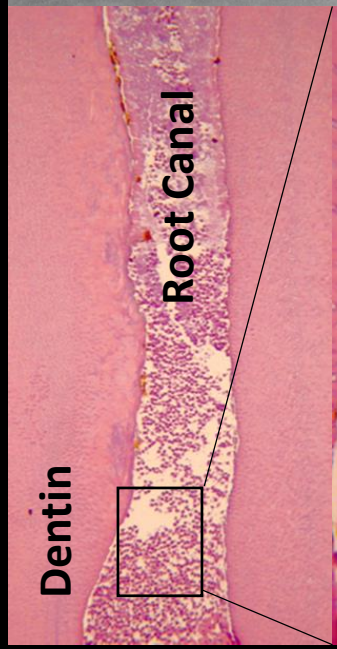


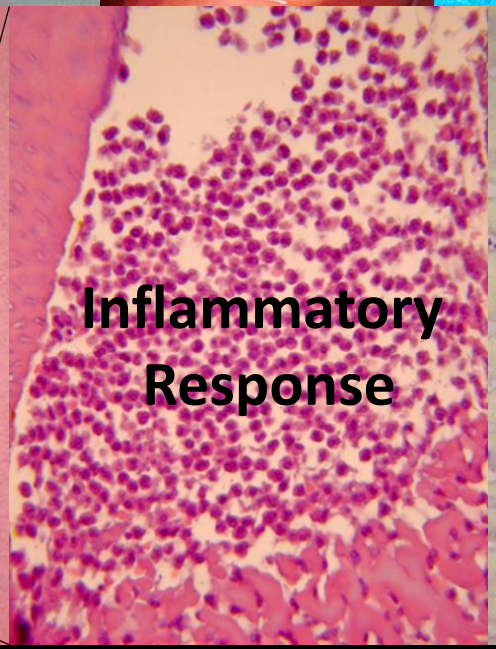

# Basic Elements of Teeth

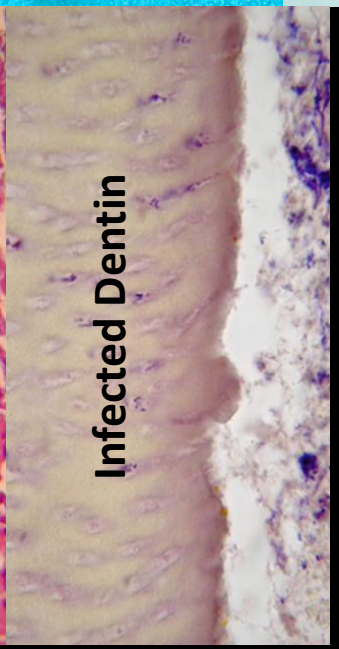
Decay



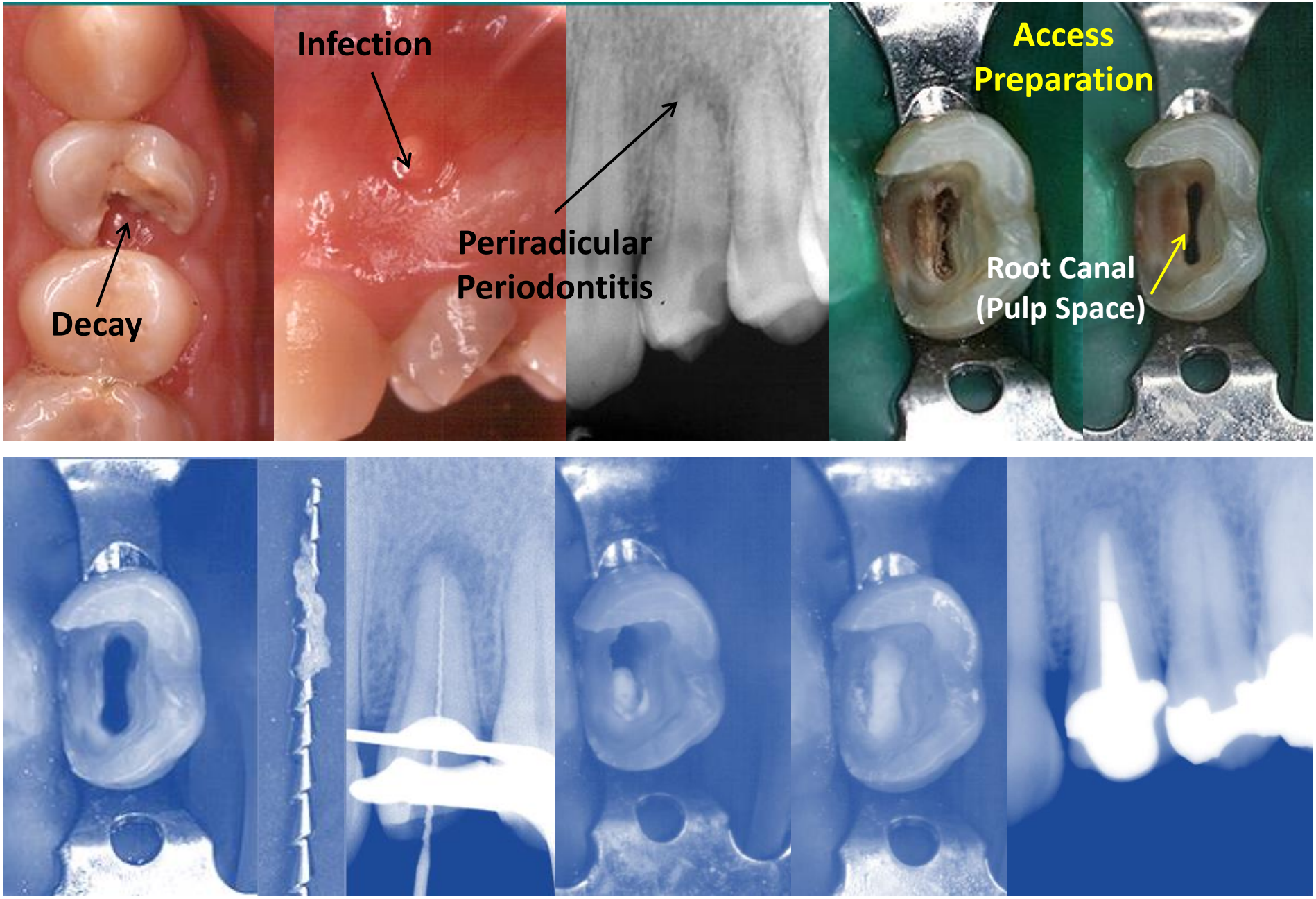



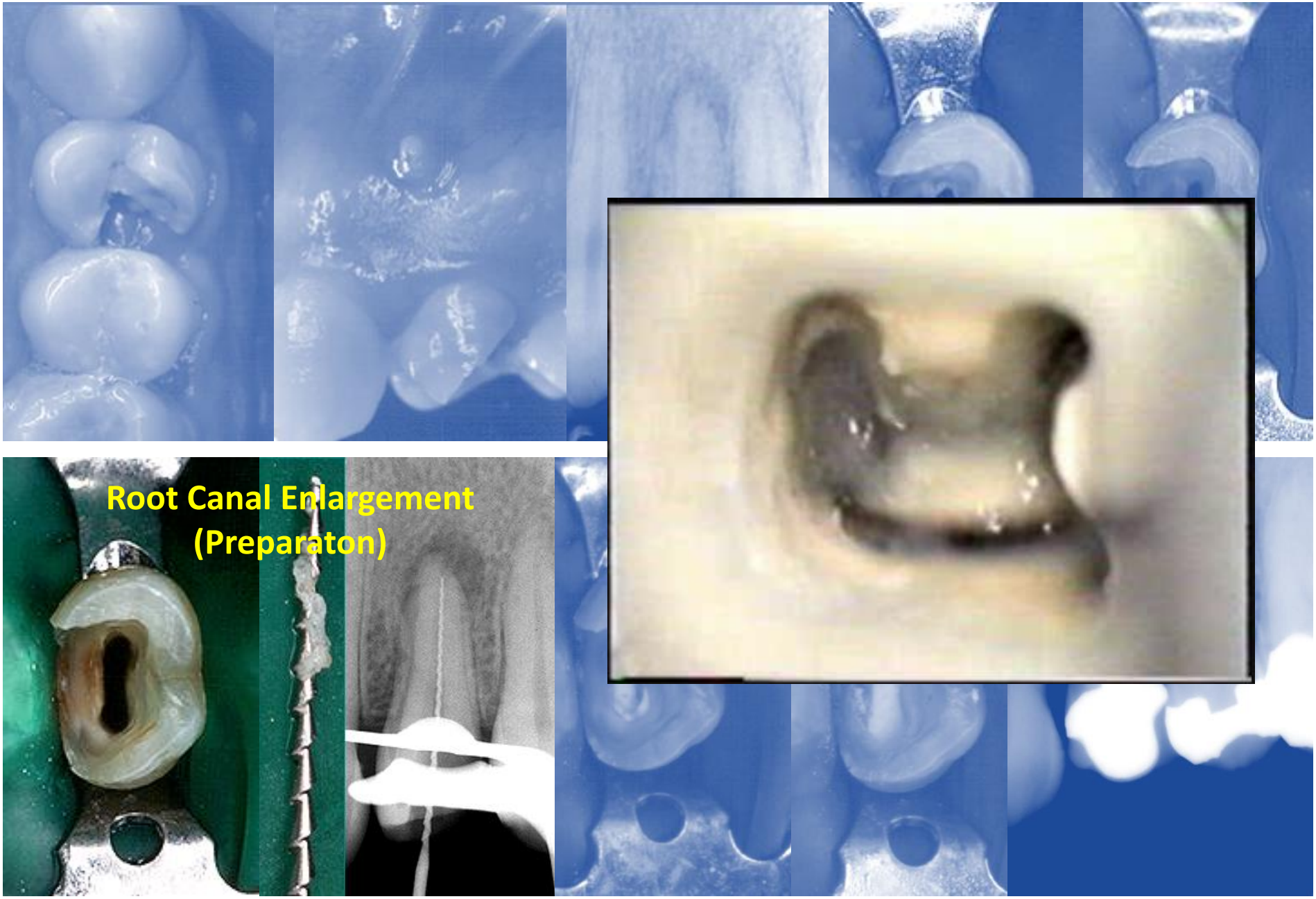

## Root Canal Treatment

Aim to remove pulp tissue, microrganisms and infected dentin in order to cure or prevent periradicular periodontits



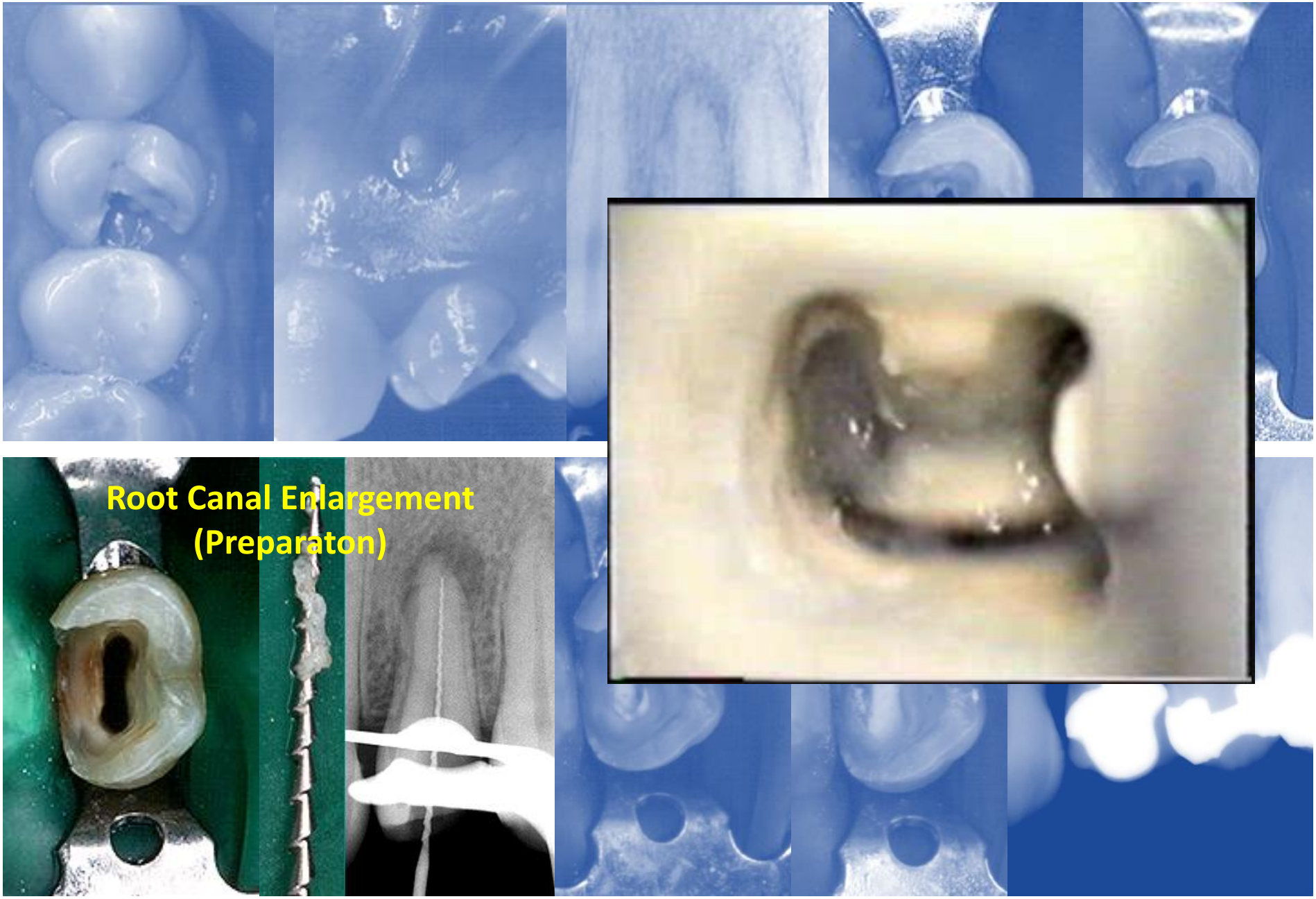

Basic Steps of Root Canal Treatment

Pascon et al.



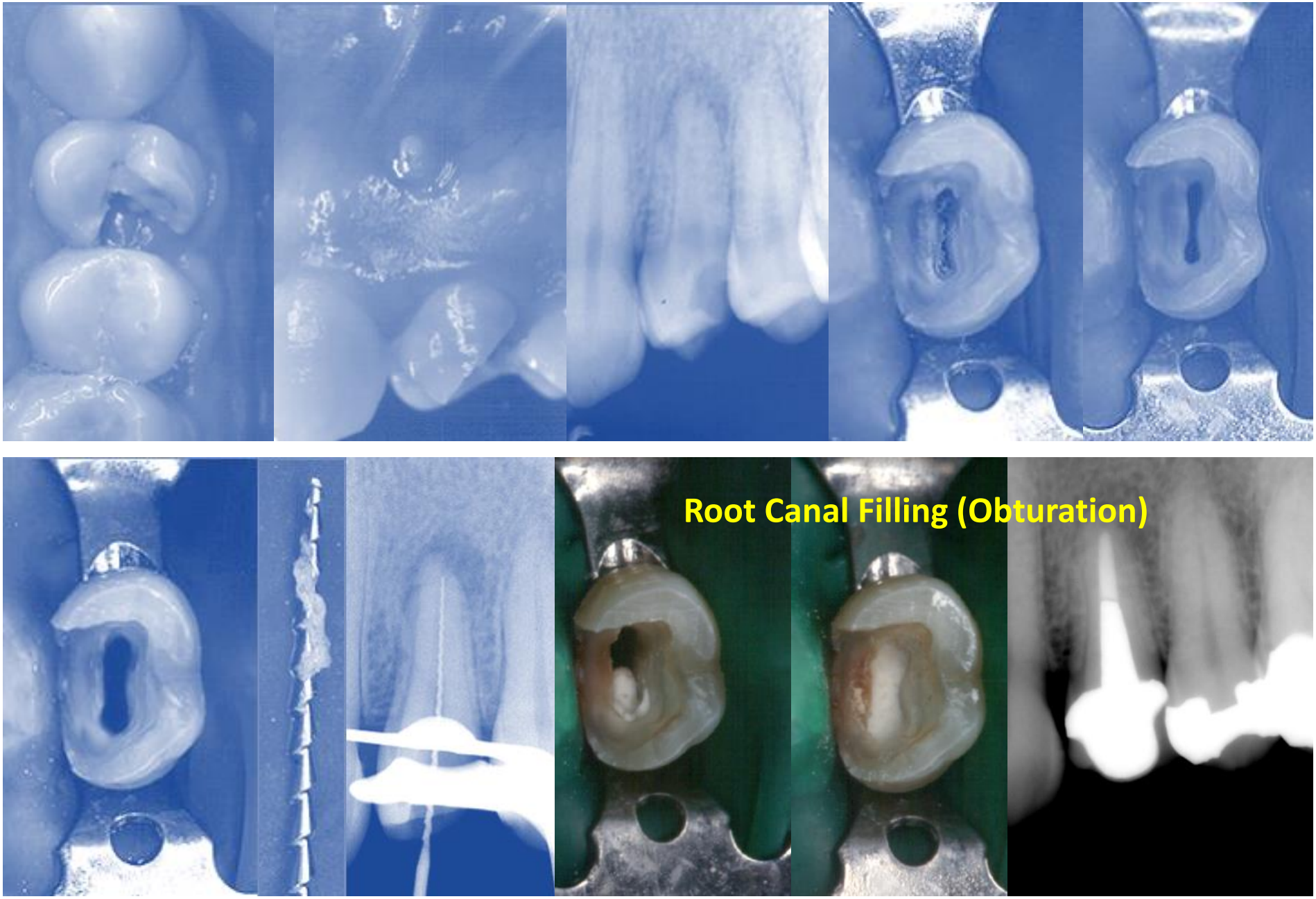

Basic Steps of Root Canal Treatment

Pascon et al.



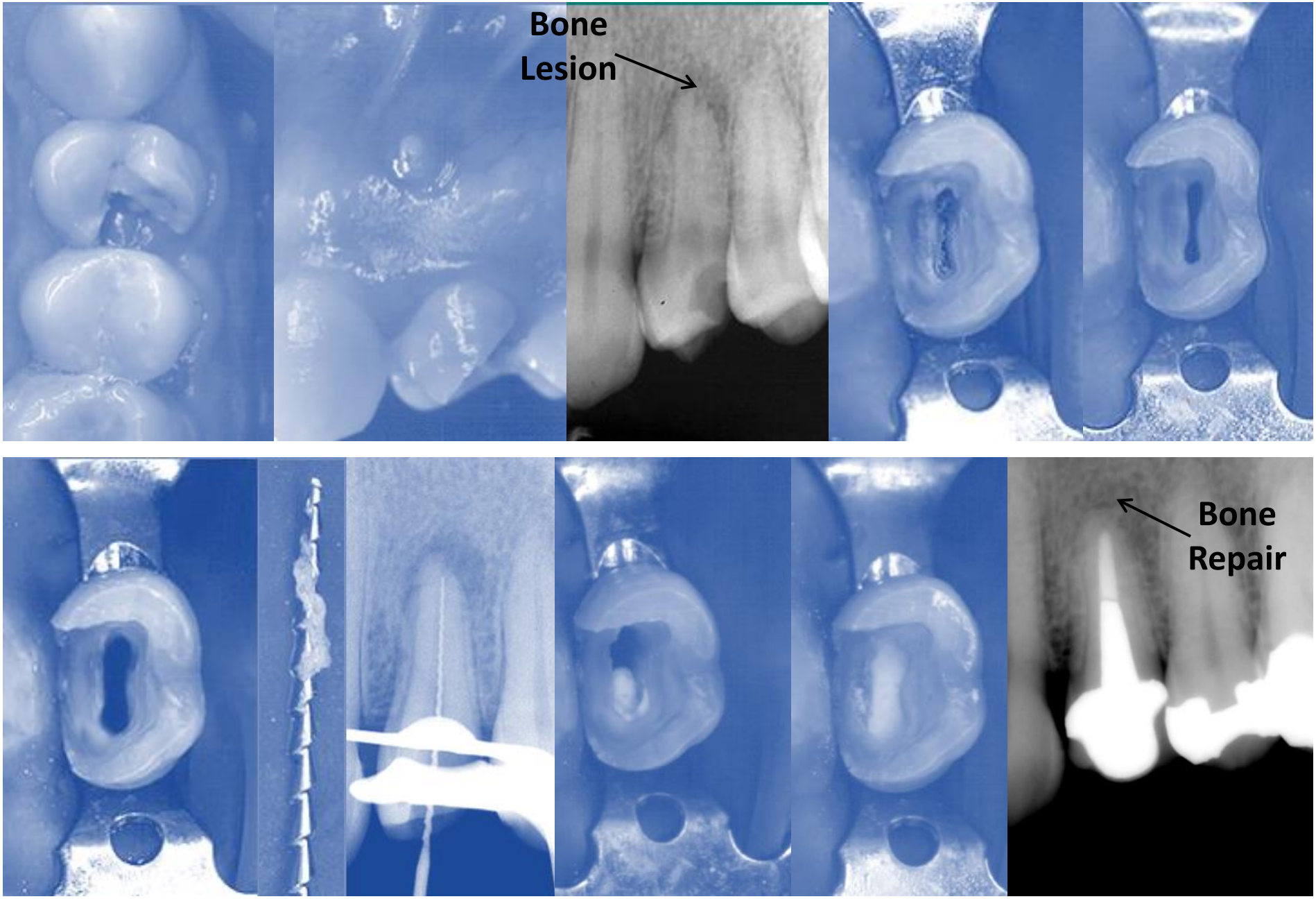

Basic Steps of Root Canal Treatment

Pascon et al.



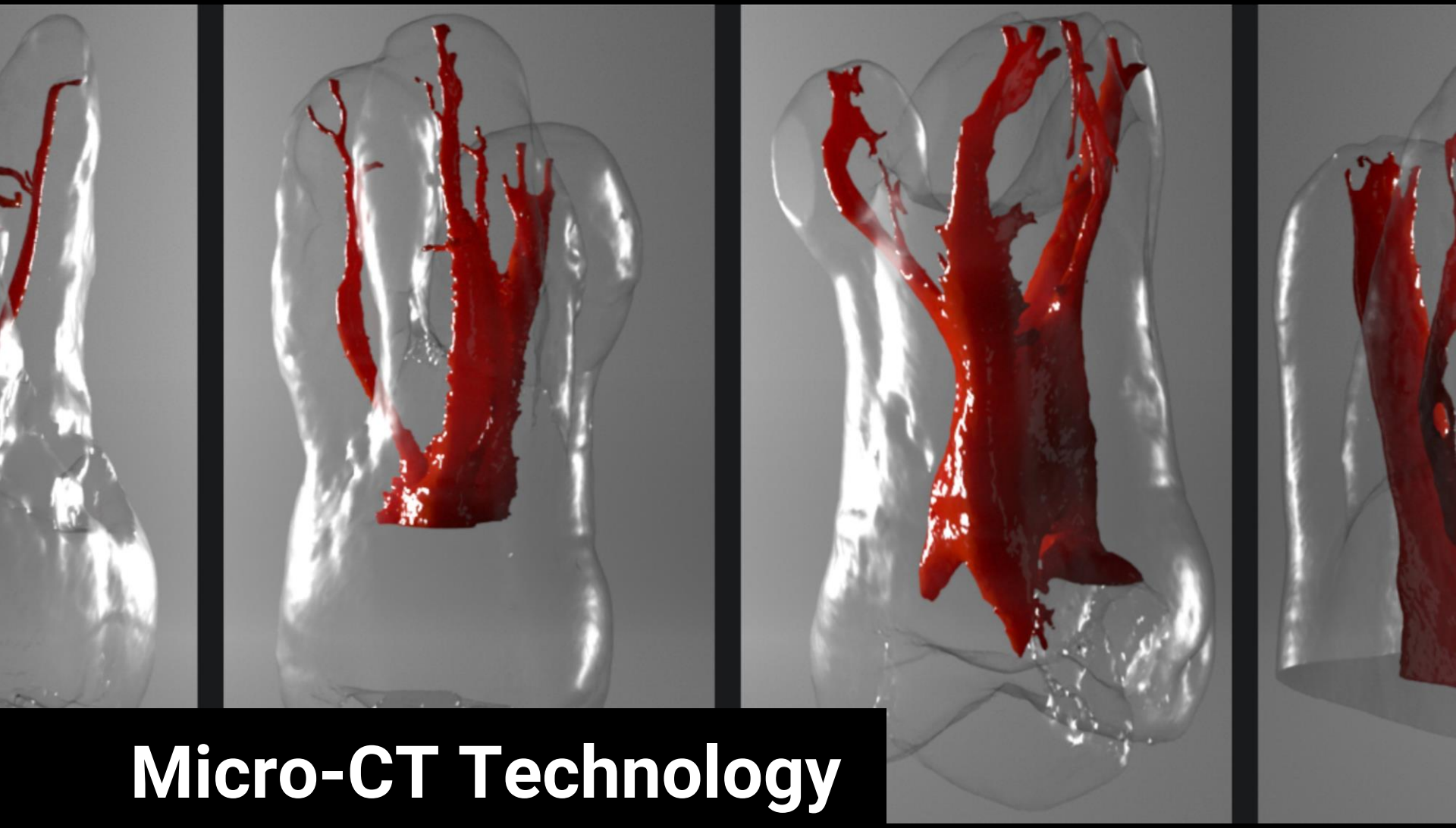

Basic Steps of Root Canal Treatment

Pascon et al.



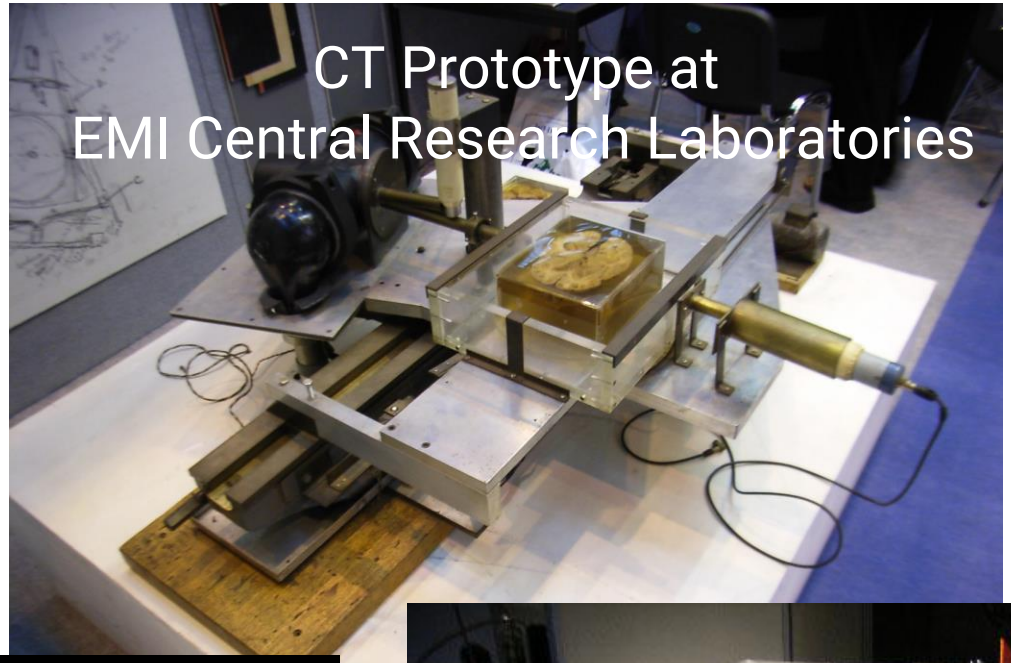

# Basic Steps of Root Canal Treatment

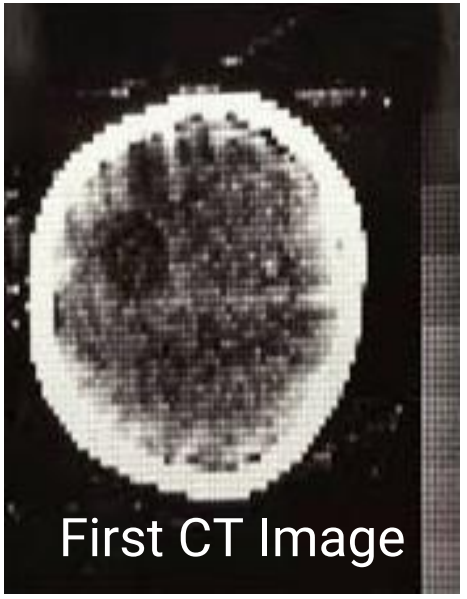
Pascon et al.

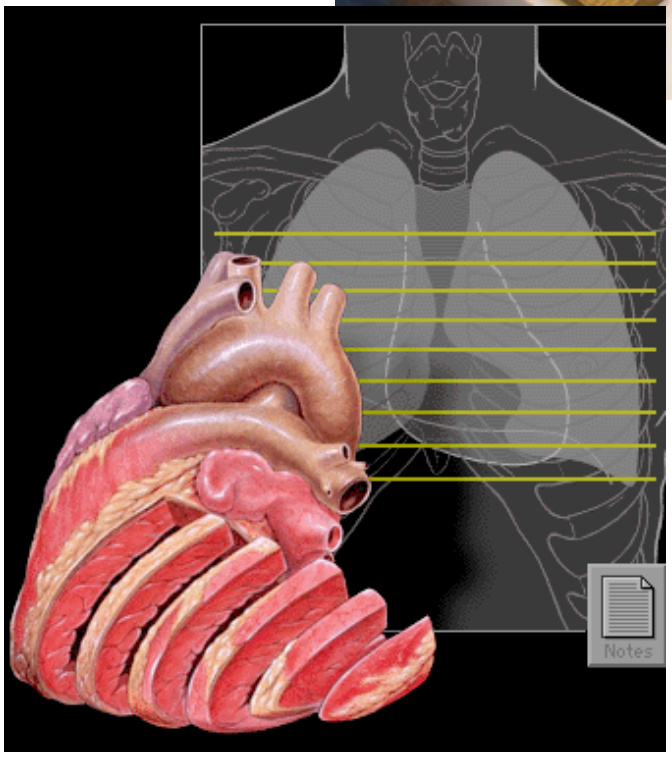


# Micro-CT Technology in Endodontics

Godfrey Newbold Hounsfield

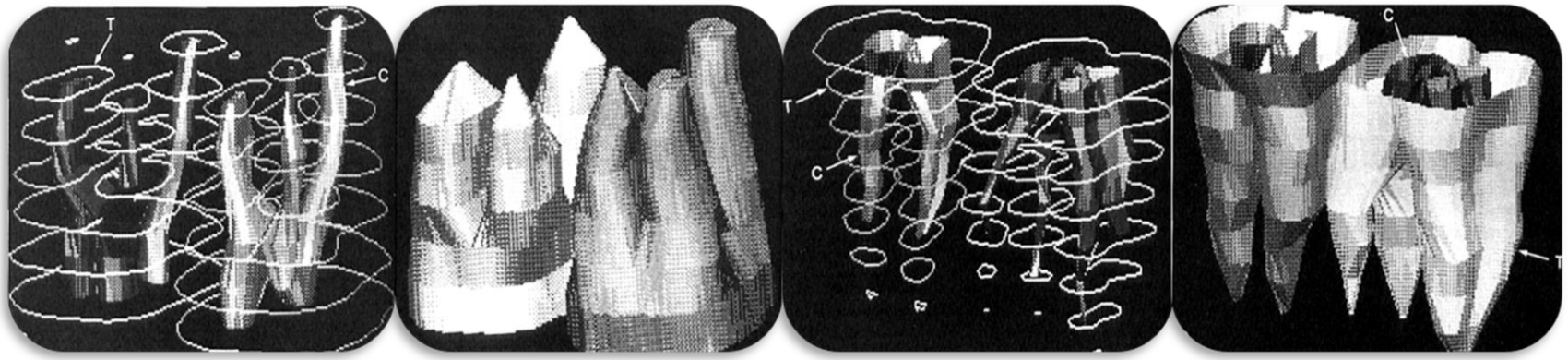



# Applicability of X-ray computerized tomography in endodontics

Tachibana H, Matsumoto K. Applicability of X-ray computerized tomography in endodontics. Endod Dent Traumatol 1990; 6: 16–20.



# X-ray microtomography

*Journal of Microscopy*, *Vol.* 126, *Pt* 2, *May* 1982, *pp.* 211–213.

*by* J. C. ELLIOTT *and* S. D. DOVER*, *Department of Biochemistry, The London Hospital Medical College, Turner Street London E1 2AD, and* *Department of Biophysics, University of London King's College, 26–29 Drury Lane, London WC2B 5RL*

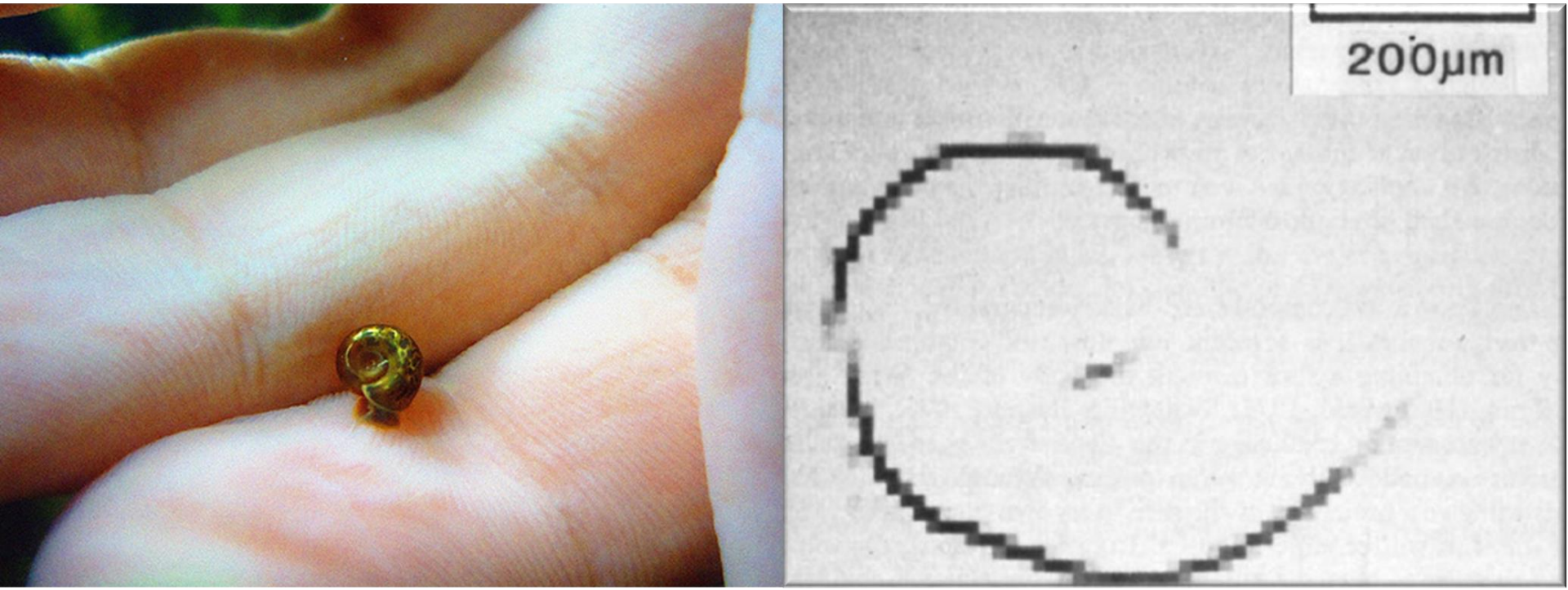


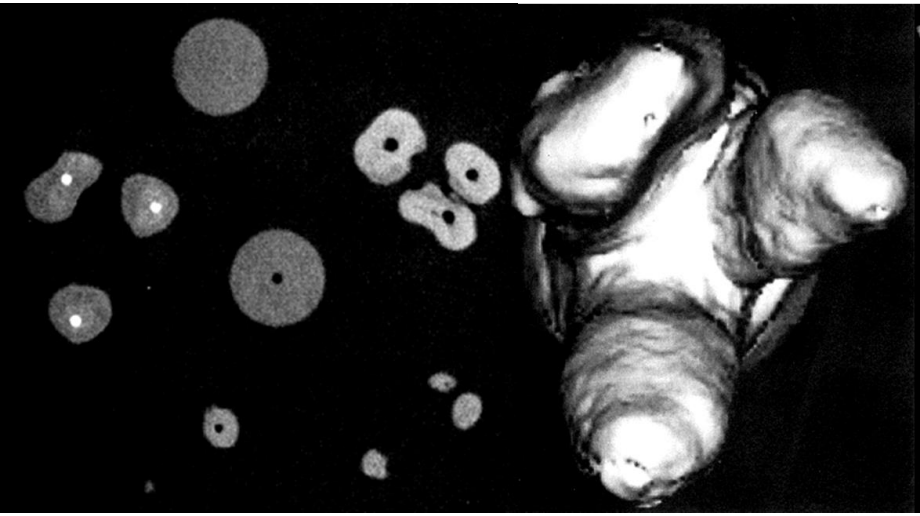

**Fig. 1.** Computed X-ray tomograph of *Biomphalaria glabrata*. Each square that makes up the image is $12 \times 12$ $\mu$m.

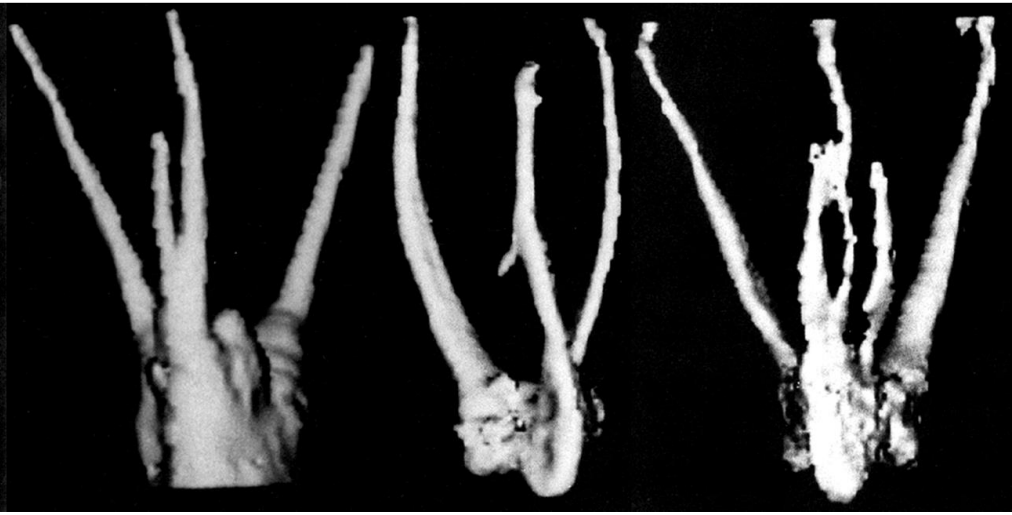
0099-2399/95/2111-0561$03.00/0
JOURNAL OF ENDODONTICS

*Printed in U.S.A.*
VOL. 21, NO. 11, NOVEMBER 1995

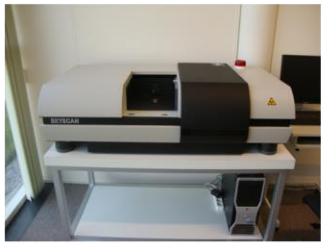
# Microcomputed Tomography: An Advanced System for Detailed Endodontic Research

**R. Blake Nielsen, DMD, Abdalmajeid M. Alyassin, PhD, Donald D. Peters, DDS, MS, David L. Carnes, PhD, and Jack Lancaster, PhD**





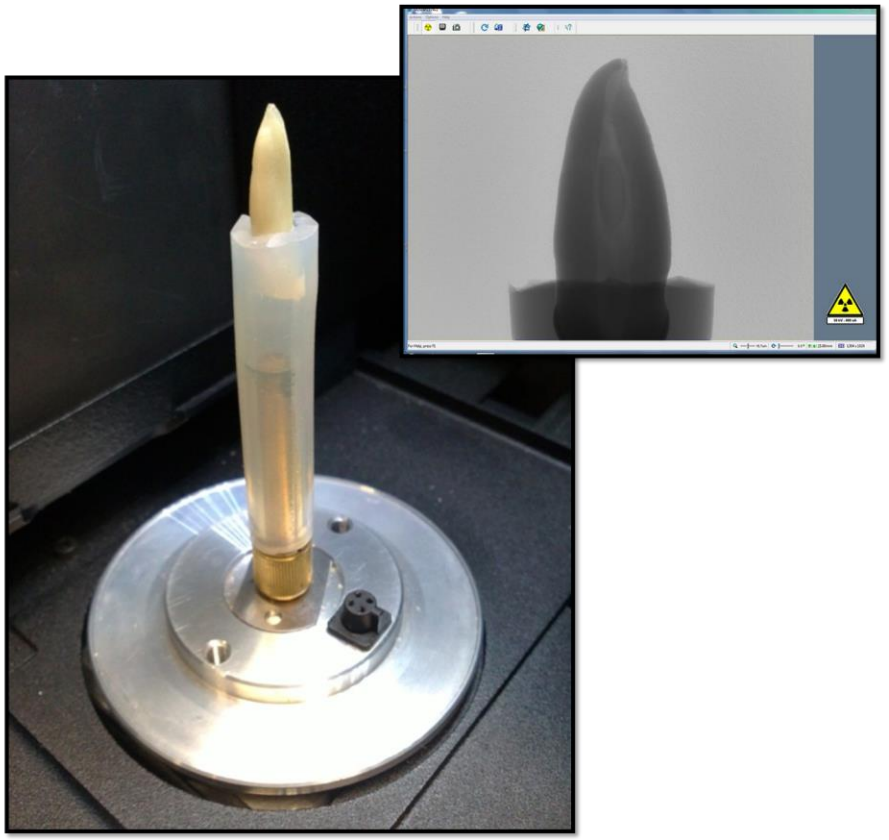

SKYSCAN




SKYSCAN

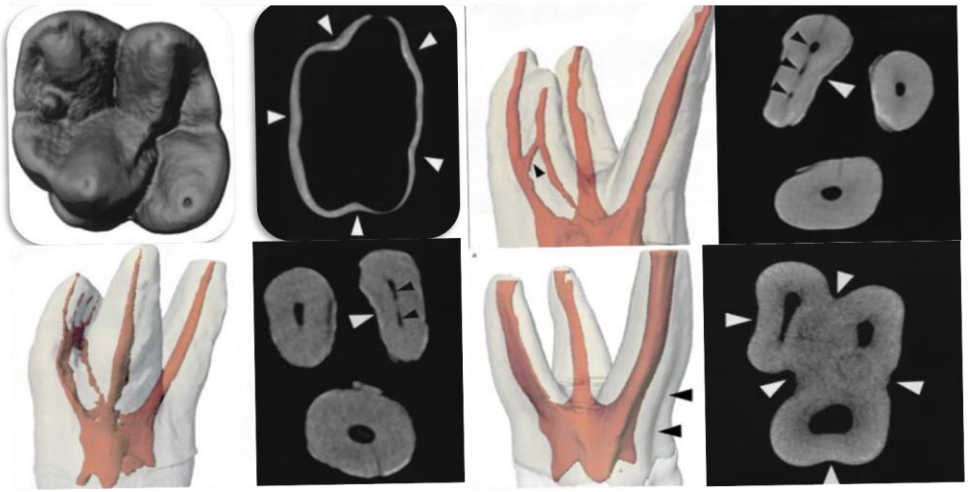

µCT 80
SCANCO MEDICAL


SKYSCAN



# External and internal macromorphology in 3D-reconstructed maxillary molars using computerized X-ray microtomography

L. Bjørndal [1], O. Carlsen [2], G. Thuesen [4], T. Darvann [5] & S. Kreiborg [3]



*ORAL AND MAXILLOFACIAL RADIOLOGY* *Editor: Sharon L. Brooks*

## X-ray microtomography

### Nondestructive three-dimensional imaging for in vitro endodontic studies

Stephanie E. P. Dowker, BSc, PhD, BDS,[a] Graham R. Davis, BSc(Eng), PhD,[b] and James C. Elliott, BA, PhD,[c] London, U.K.
ST BARTHOLOMEW'S AND THE ROYAL LONDON SCHOOL OF MEDICINE AND DENTISTRY, QUEEN MARY AND WESTFIELD COLLEGE

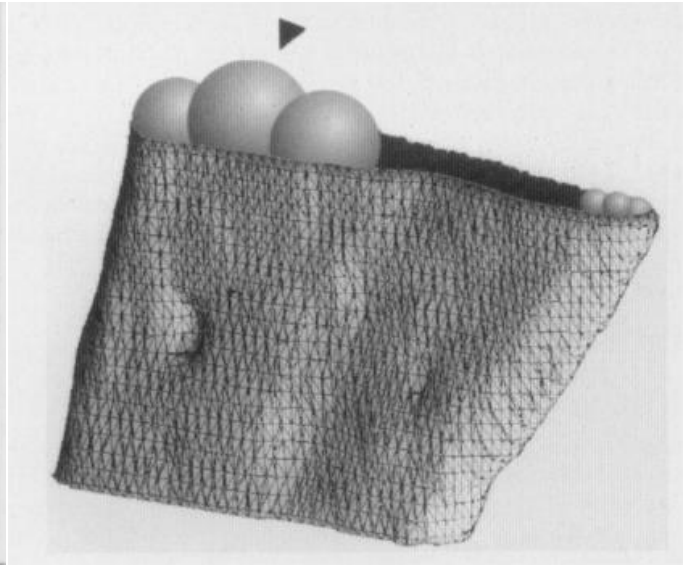
**RESEARCH REPORTS**
Biomaterials & Bioengineering

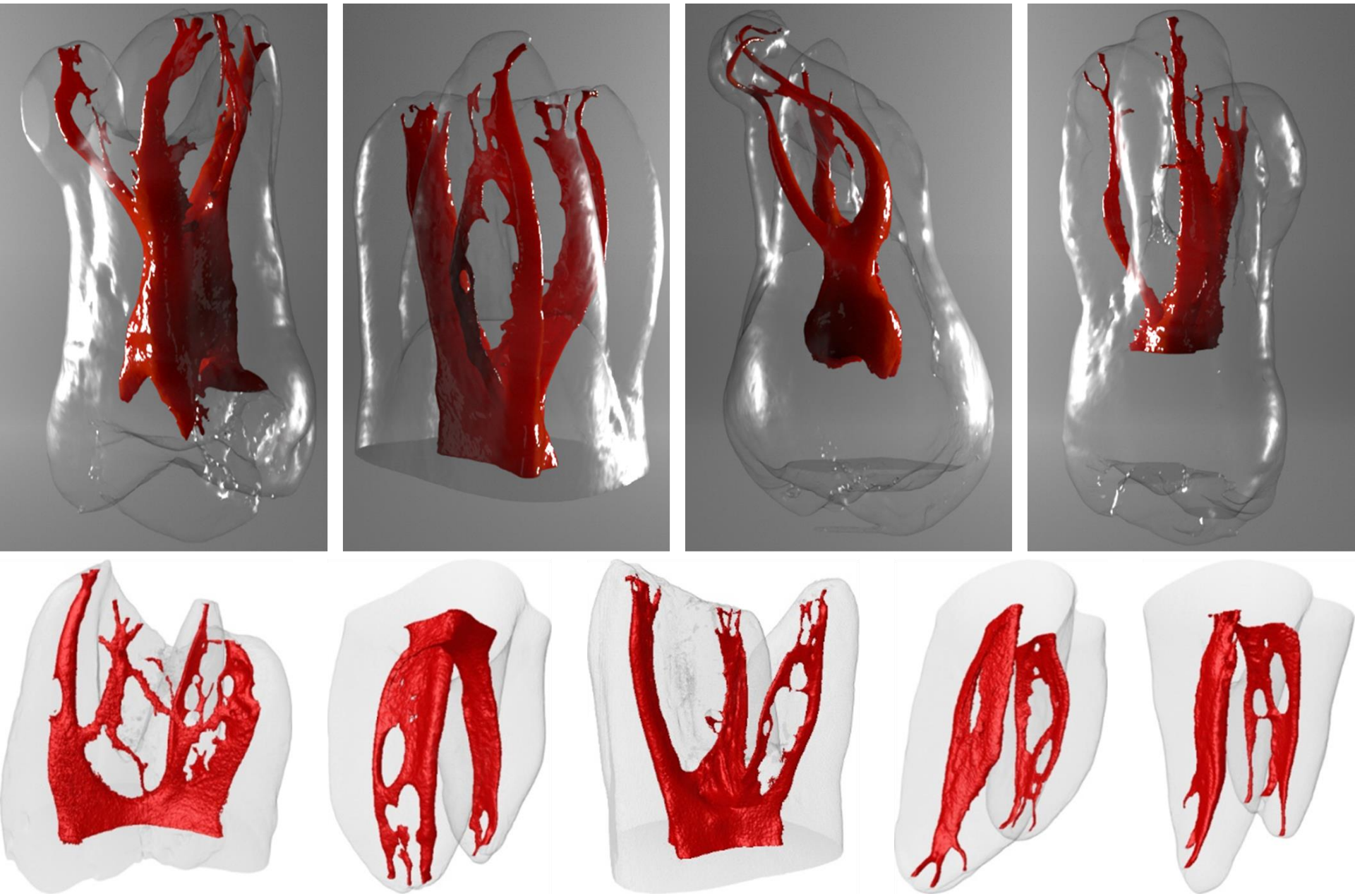
O.A. Peters[1]*, A. Laib[2], P. Rüegsegger[2], and F. Barbakow[1]

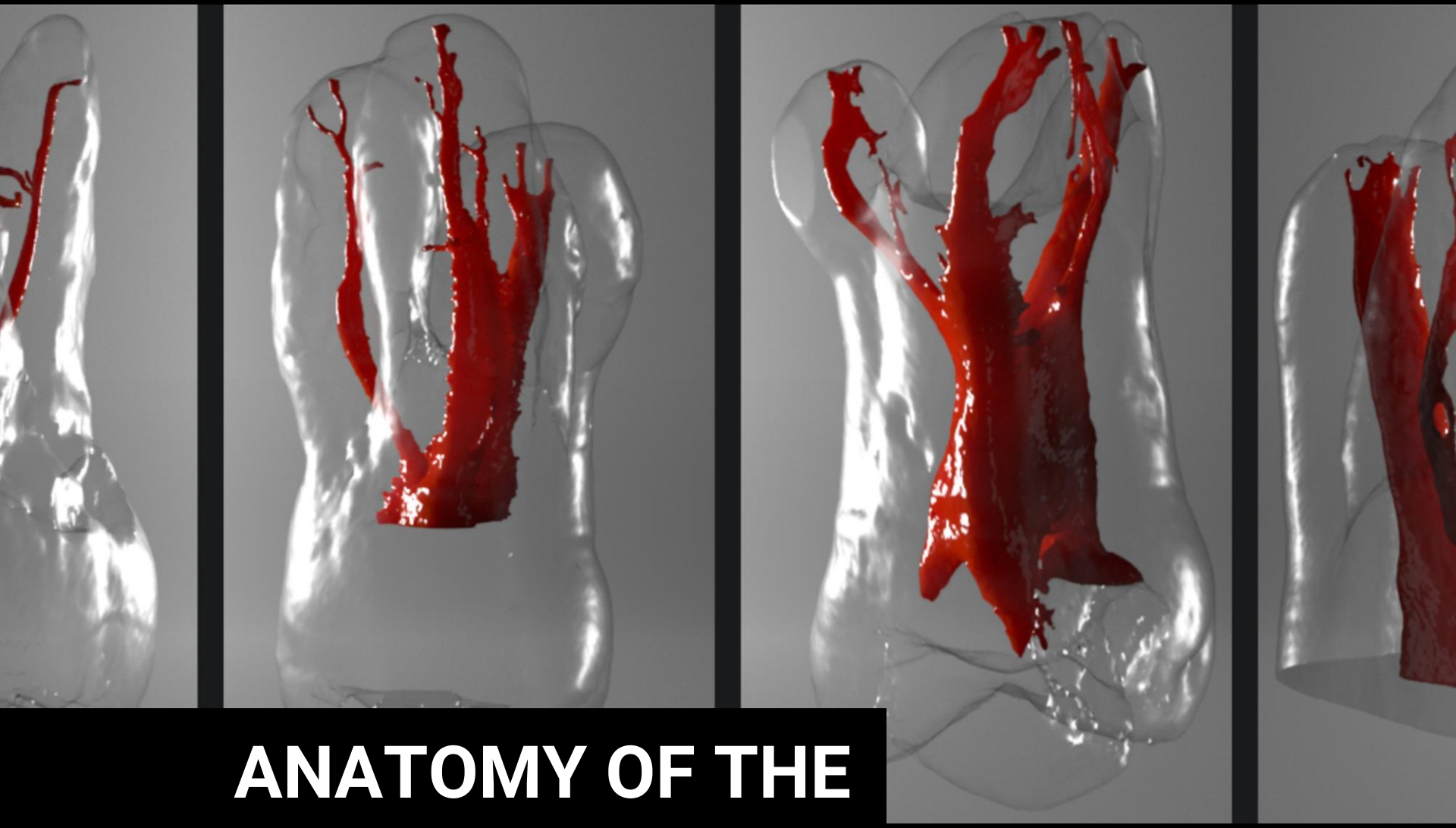
[1]Division of Endodontology, Department of Preventive Dentistry, Cariology and Periodontology, University of Zürich, Plattenstrasse 11, CH-8028 Zürich, Switzerland; and [2]Institute of Biomedical Engineering, ETH Zürich and University of Zürich; *corresponding author, peters@zzmk.unizh.ch

J Dent Res 79(6): 1405-1409, 2000

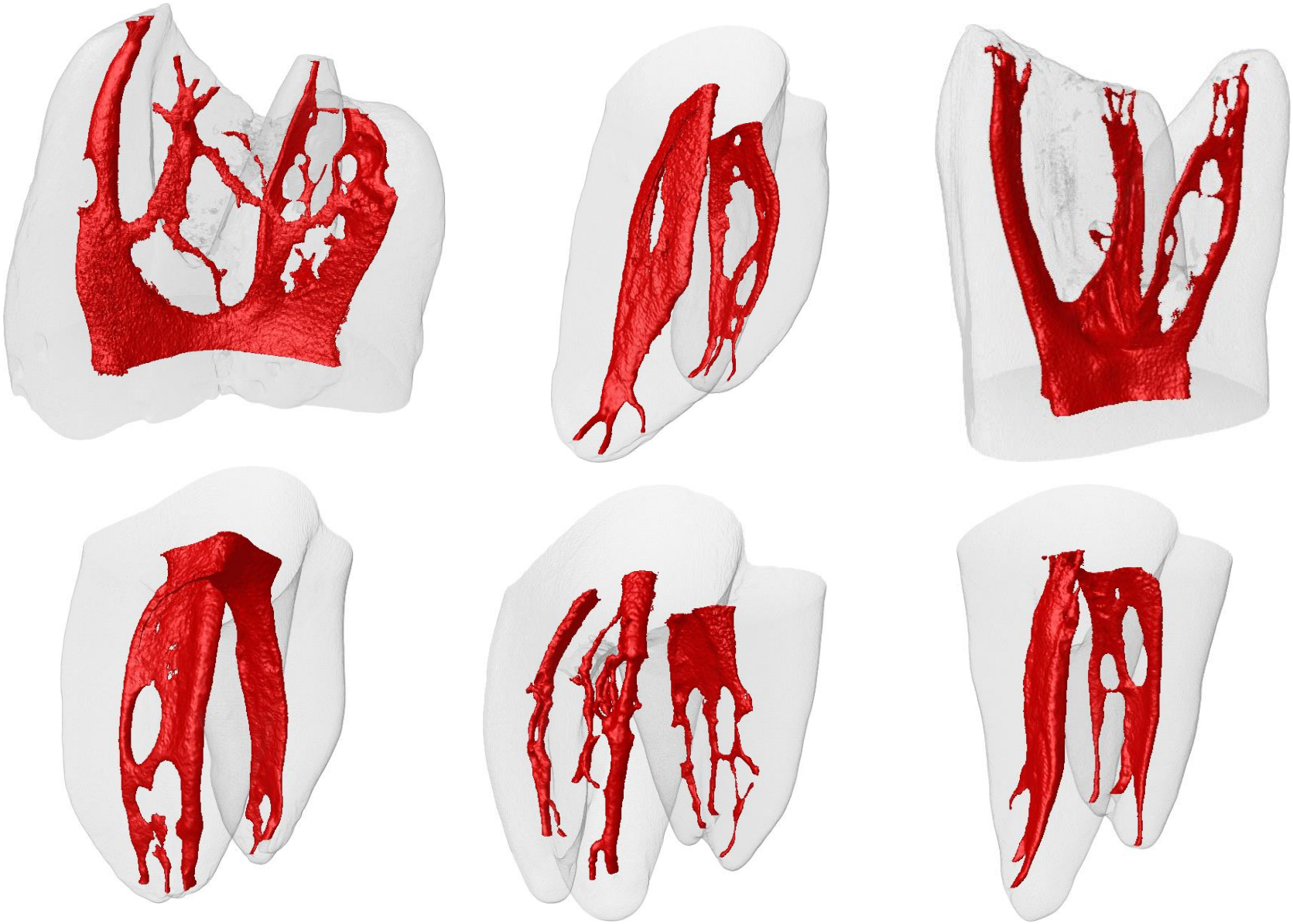
# Three-dimensional Analysis of Root Canal Geometry by High-resolution Computed Tomography



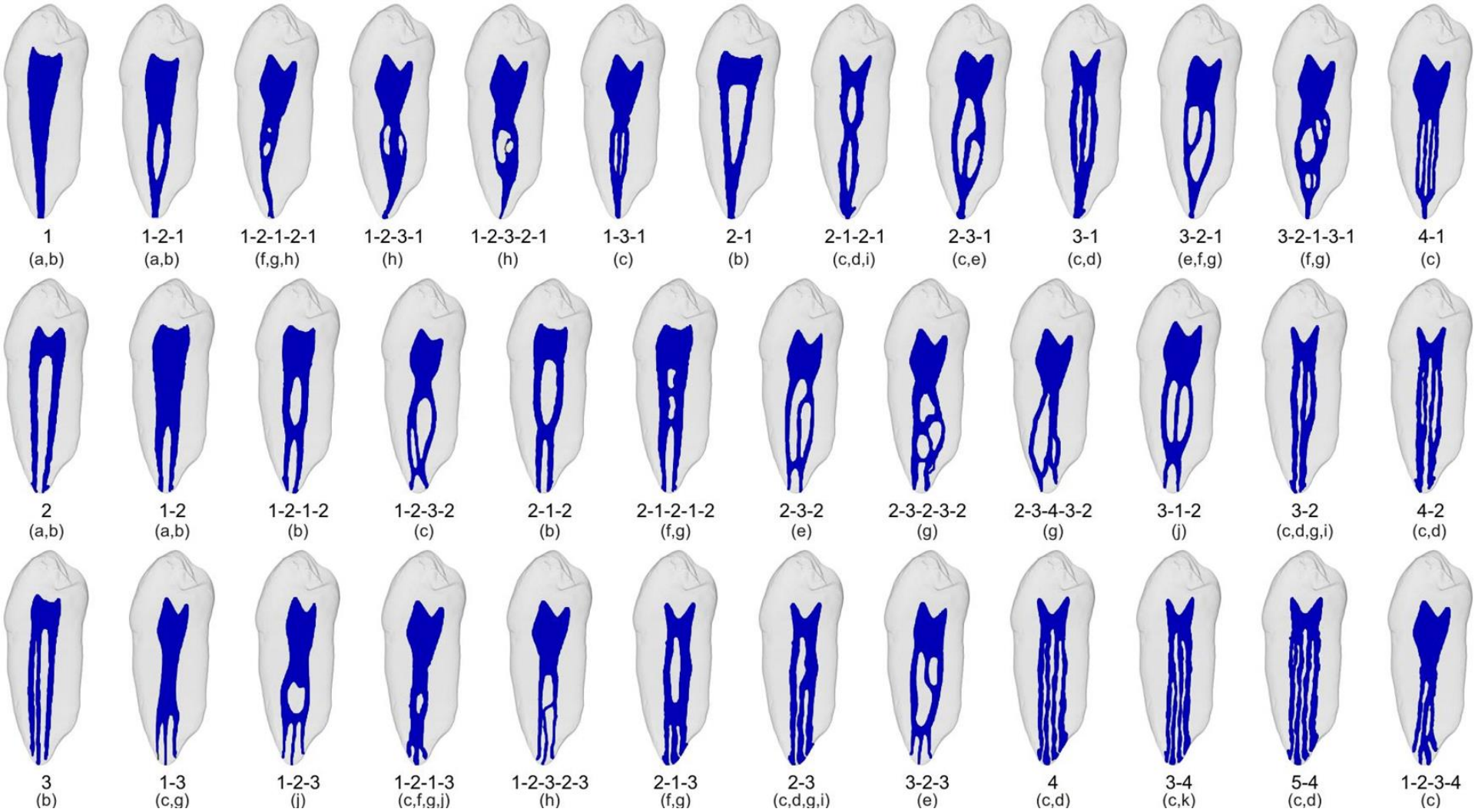




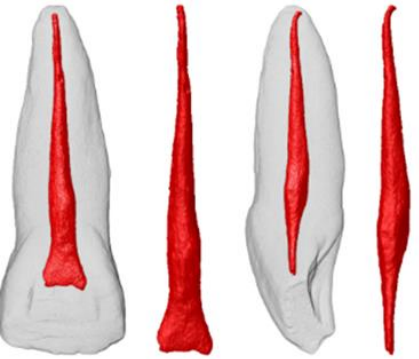
# ANATOMY OF THE ROOT CANAL SYSTEM



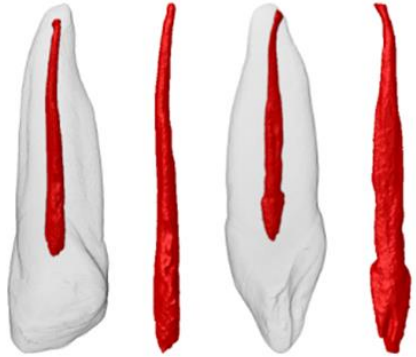
# Root Canal Configurations



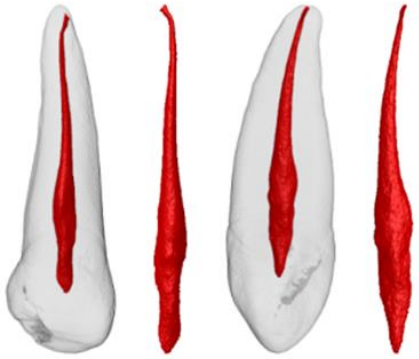

Versiani & Ordinola-Zapata, 2015



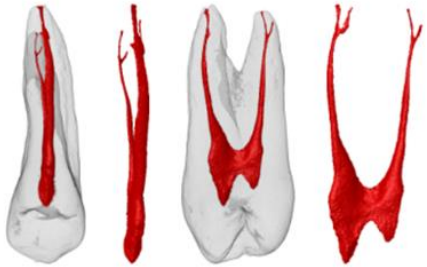
Central Incisor



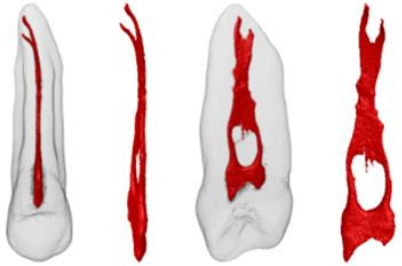
Lateral Incisor



Canine



First Premolar



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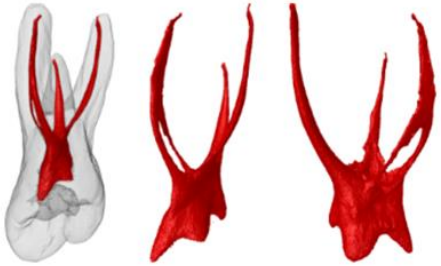

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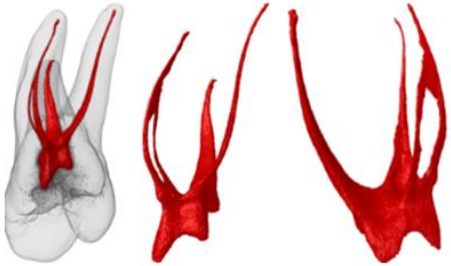

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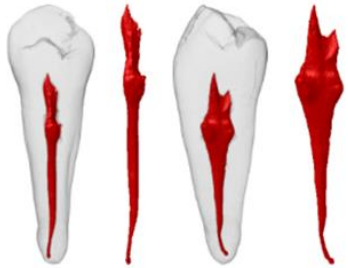

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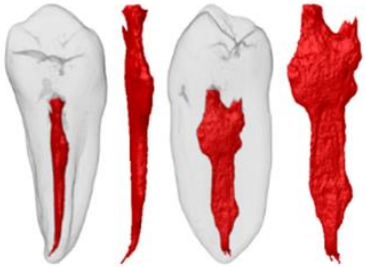

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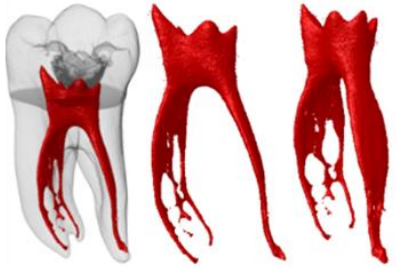
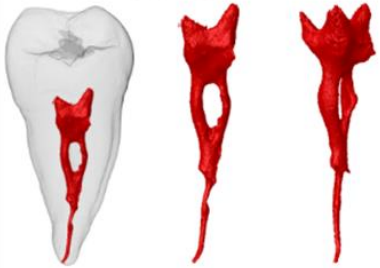
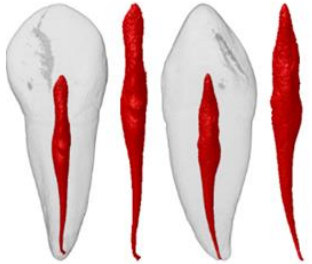


First Molar



Second Molar

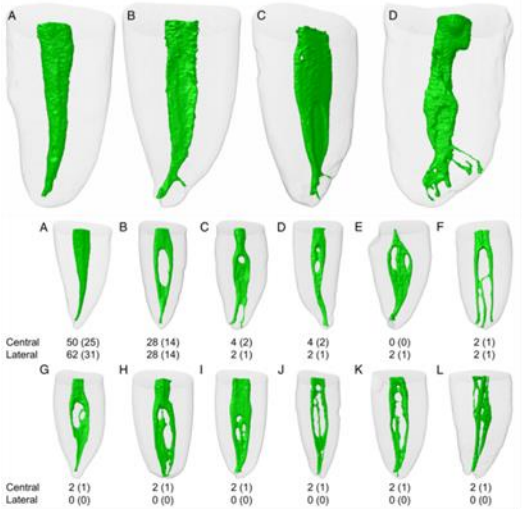
Central or Lateral Incisor



Canine

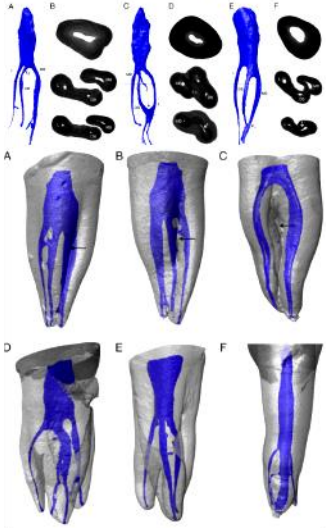
## Micro–computed Tomographic Analysis of the Root Canal Morphology of Mandibular Incisors

*Graziela Bianchi Leoni, DDS, MSc, Marco Aurélio Versiani, DDS, MSc, PhD, Jesus Djalma Pécora, DDS, MSc, PhD, and Manoel Damião de Sousa-Neto, DDS, MSc, PhD*




## Morphologic Micro–Computed Tomography Analysis of Mandibular Premolars with Three Root Canals

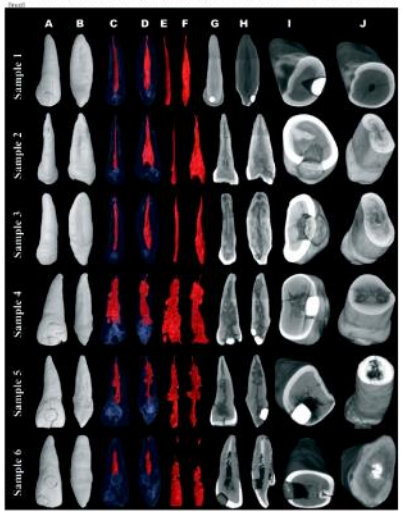
*Ronald Ordinola-Zapata, DDS, MSc,* Clovis Monteiro Bramante, DDS, PhD,* Marcelo Haas Villas-Boas, DDS,* Bruno Carolina Cavenago, DDS,* Marco Hungaro Duarte, DDS, PhD,* and Marco Aurélio Versiani, DDS, MSc, PhD†*




## Pulp pathosis in inlayed teeth of the ancient Mayas: a microcomputed tomography study

M. A. Versiani, M. D. Sousa-Neto & J. D. Pécora

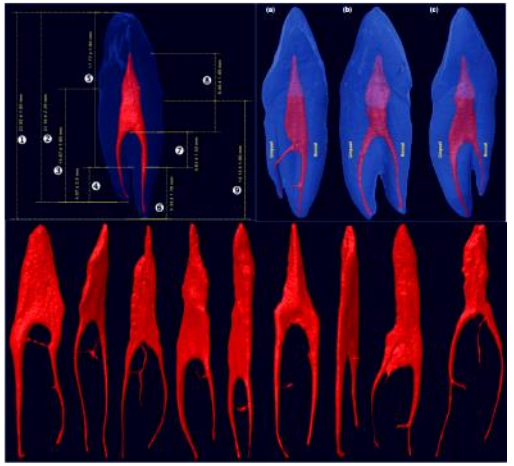
Department of Restorative Dentistry, Dental School of Ribeirão Preto, University of São Paulo (FORP-USP), Ribeirão Preto, SP, Brazil




## The anatomy of two-rooted mandibular canines determined using micro-computed tomography

M. A. Versiani, J. D. Pécora & M. D. Sousa-Neto

Dental School of Ribeirão Preto Department of Restorative Dentistry, University of São Paulo (FORP-USP), Ribeirão Preto São Paulo, Brazil

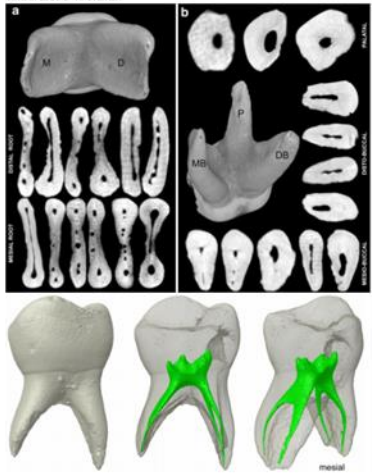



Eur Arch Paediatr Dent
DOI 10.1007/s40368-014-0117-0

ORIGINAL SCIENTIFIC ARTICLE

## Root canal morphology of primary molars: a micro-computed tomography study

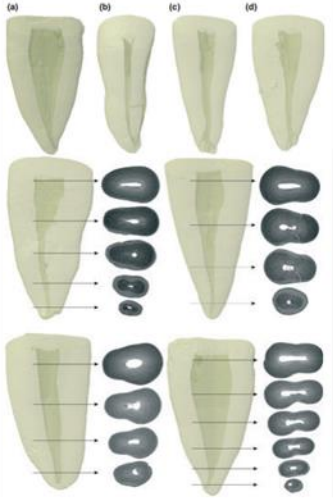
A. C. Fumes · M. D. Sousa-Neto · G. B. Leoni · M. A. Versiani · L. A. B. da Silva · R. A. B. da Silva · A. Consolaro




## Microcomputed tomography analysis of the root canal morphology of single-rooted mandibular canines

M. A. Versiani, J. D. Pécora & M. D. Sousa-Neto

Department of Restorative Dentistry, Faculty of Dentistry, University of São Paulo, Ribeirão Preto, Brazil




## Root and Root Canal Morphology of Four-rooted Maxillary Second Molars: A Micro–Computed Tomography Study

*Marco Aurélio Versiani, DDS, MSc, PhD, Jesus Djalma Pécora, DDS, MSc, PhD, and Manoel Damião de Sousa-Neto, DDS, MSc, PhD*

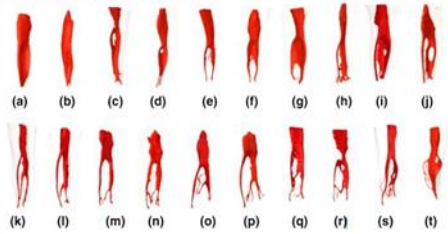

INTERNATIONAL ENDODONTIC JOURNAL

doi:10.1111/iej.12380

## Micro-CT evaluation of C-shaped mandibular first premolars in a Brazilian subpopulation

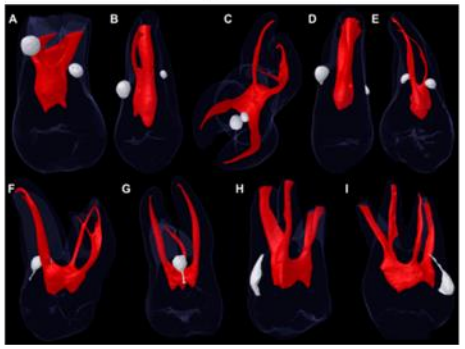
R. Ordinola-Zapata[1], C. Monteiro Bramante[1], P. Gagliardi Minotti[1], B. Cavalini Cavenago[1], J. L. Gutmann[2], B. I. Moldauer[3], M. A. Versiani[4] & M.A. Hungaro Duarte[1]

[1]Department of Endodontics, Rocsa Dental School, University of São Paulo, Bauru, Brazil; [2]Department of Endodontics, Baylor College of Dentistry, Texas A&M University System Health Science Center, Dallas, TX; [3]Advanced Education in General Dentistry Program, Larkin Community Hospital, Miami, FL, USA; and [4]Department of Endodontics, Ribeirão Preto Dental School, University of São Paulo, Ribeirão Preto, Brazil



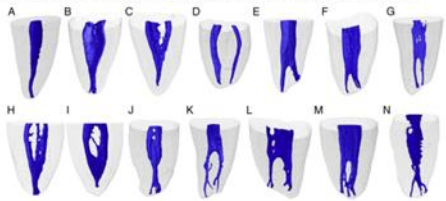

## Enamel pearls in permanent dentition: case report and micro-CT evaluation

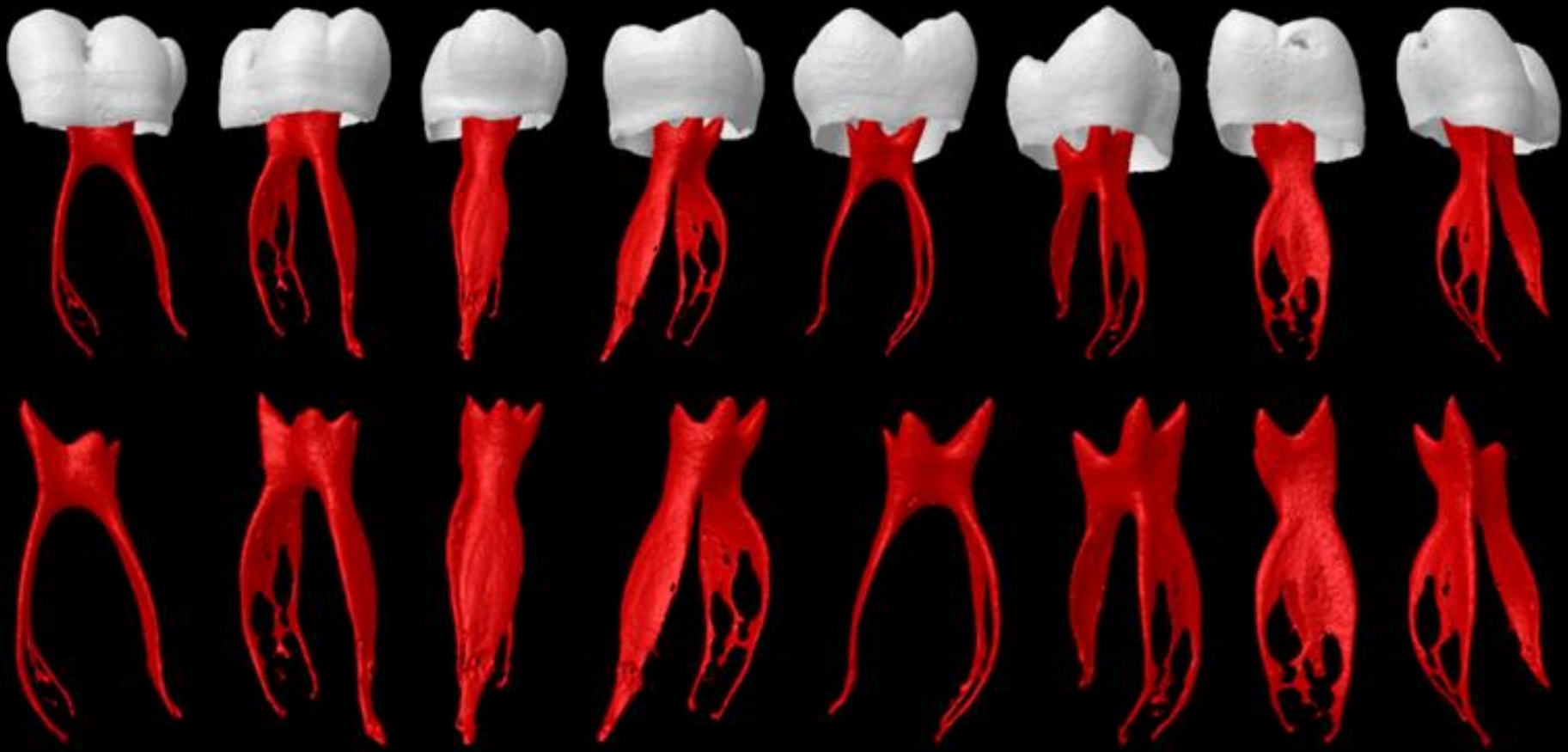
MA Versiani[1,2], RC Cristescu[2], PC Saquy[1], JD Pécora[1] and MD de Sousa-Neto*,[1]

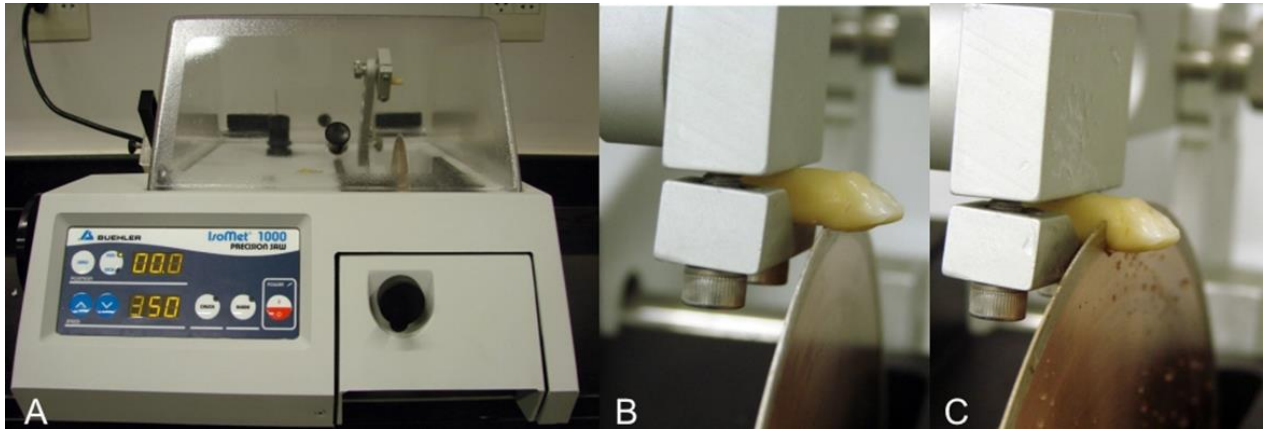



## Micro–computed Tomographic Analysis of the Root Canal Morphology of the Distal Root of Mandibular First Molar

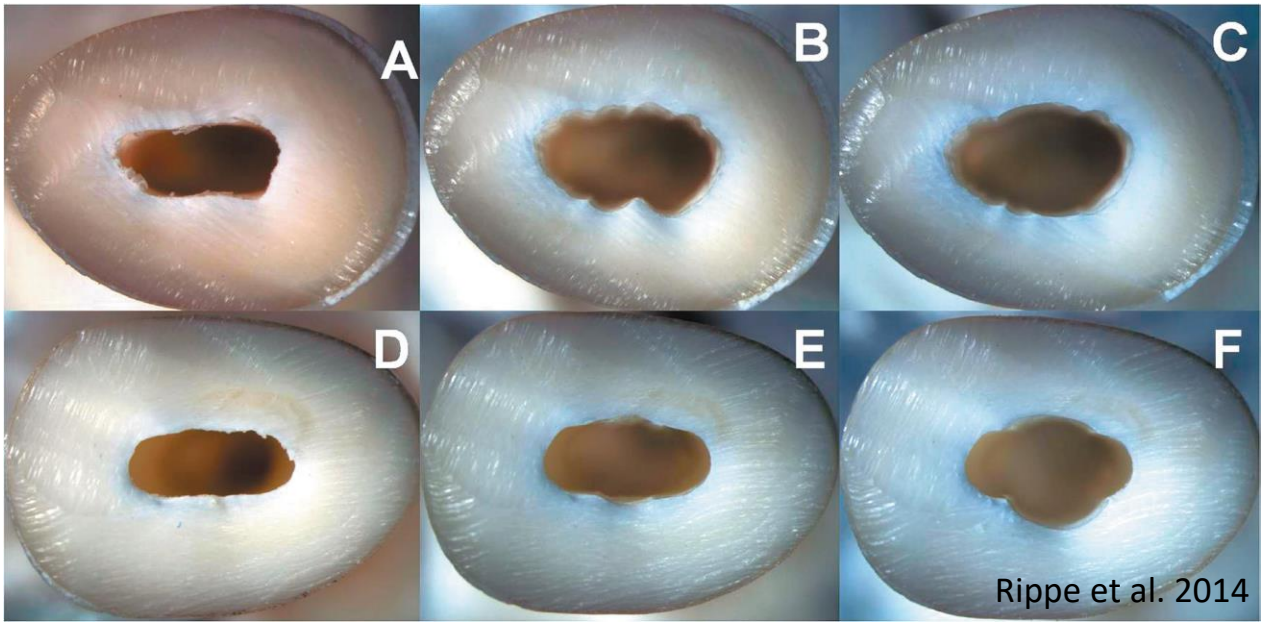
*Carolina Filpo-Perez, DDS, MSc,* Clovis Monteiro Bramante, DDS, PhD,* Marcelo Haas Villas-Boas, DDS, MSc,* Marco Antonio Hungaro Duarte, DDS, PhD,* Marco Aurélio Versiani, DDS, MSc, PhD,† and Ronald Ordinola-Zapata, DDS, MSc, PhD**



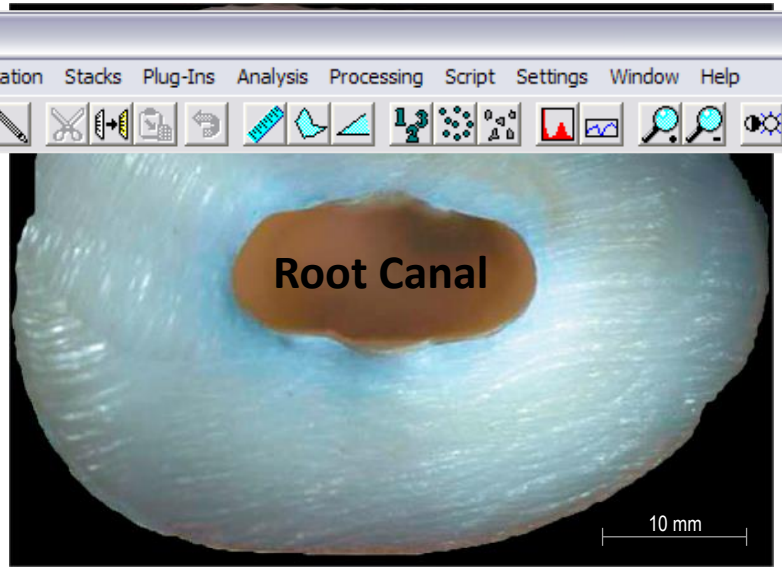


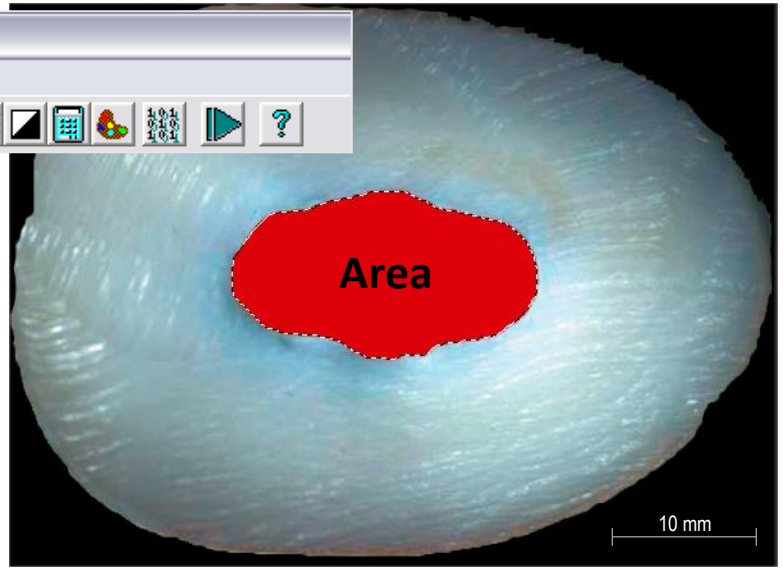



Conventional Sectioning Method

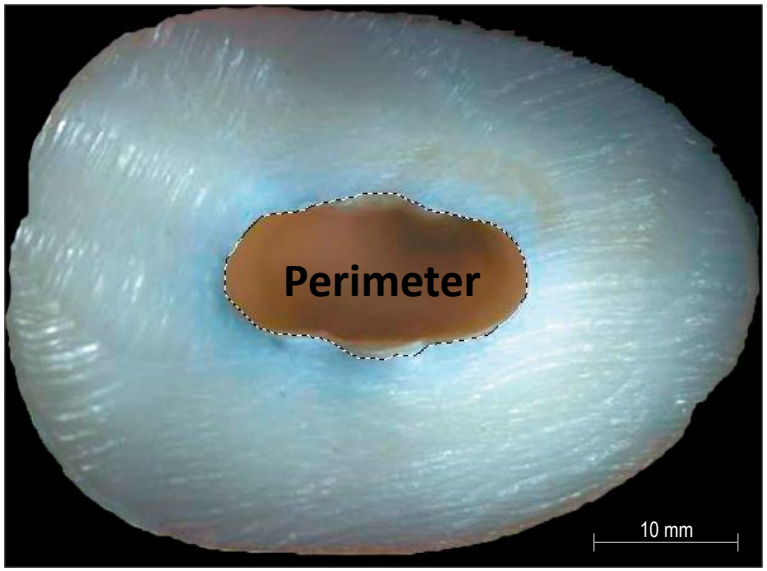



Cross Sections of Roots

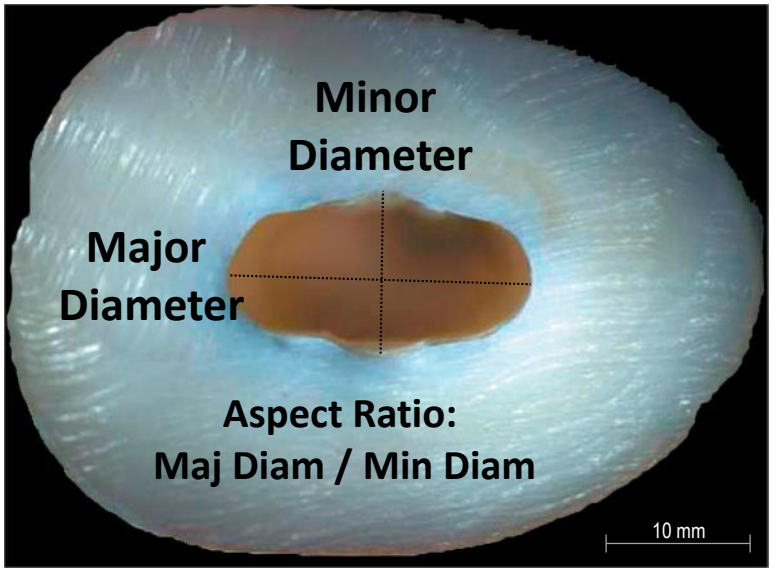



Extent of a 2D root canal shape in the plane

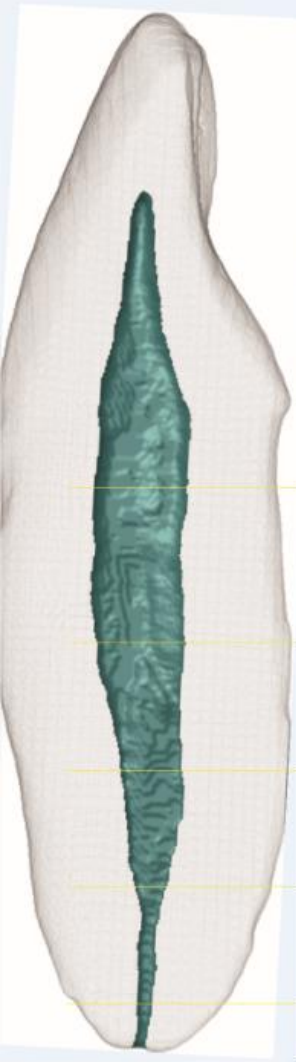



Path that surrounds the 2D shape of the root canal

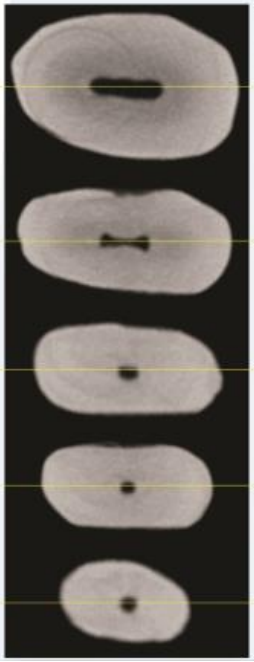



Largest distances between 2 opposite parallel lines tangent to root canal boundaries.

# 2D PARAMETERS



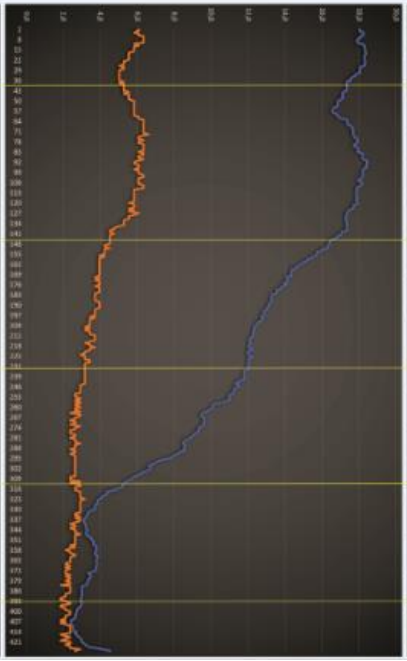
Root Canal Cross-Sections



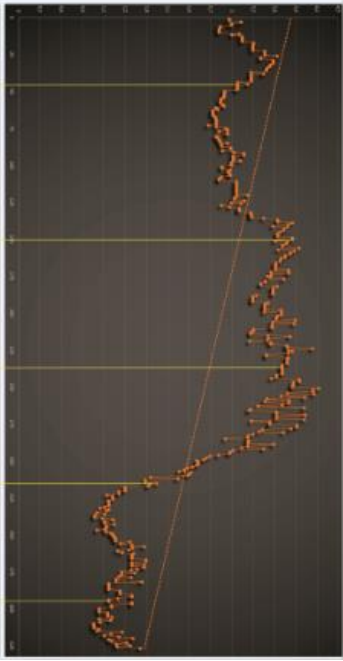
Area


Perimeter

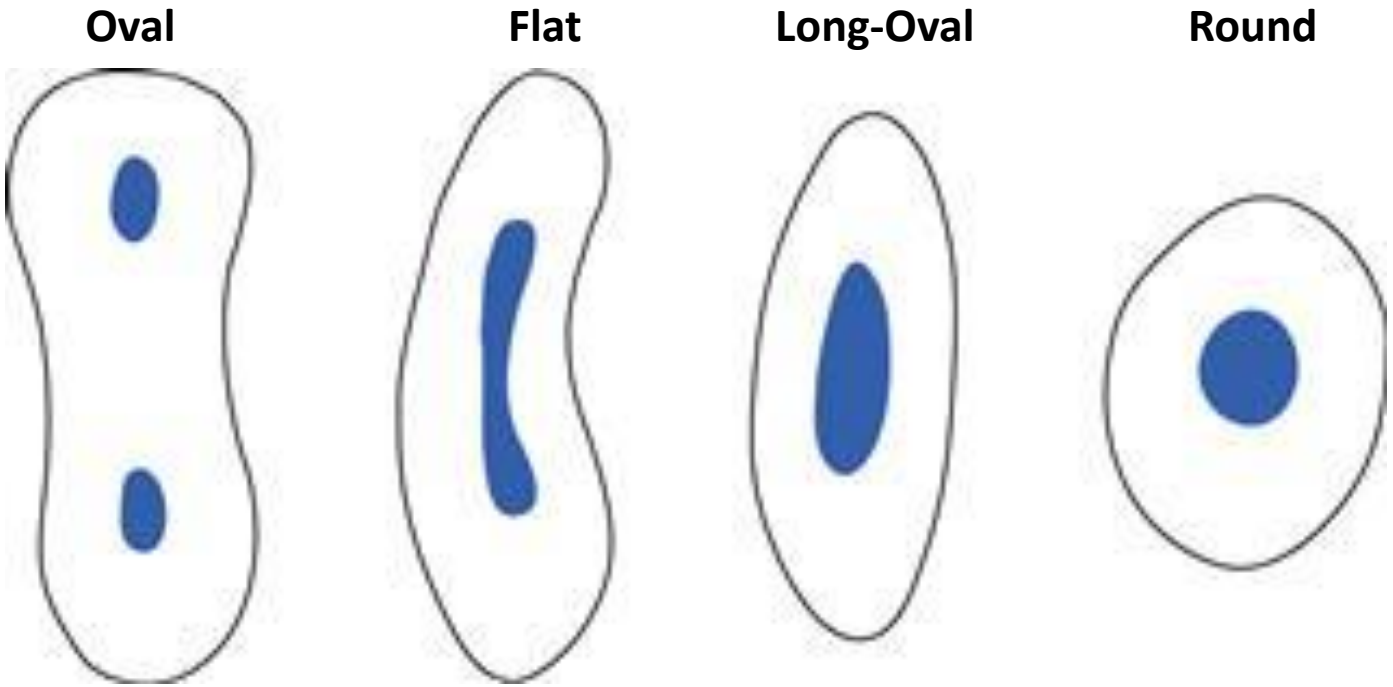

Diameters



Aspect Ratio



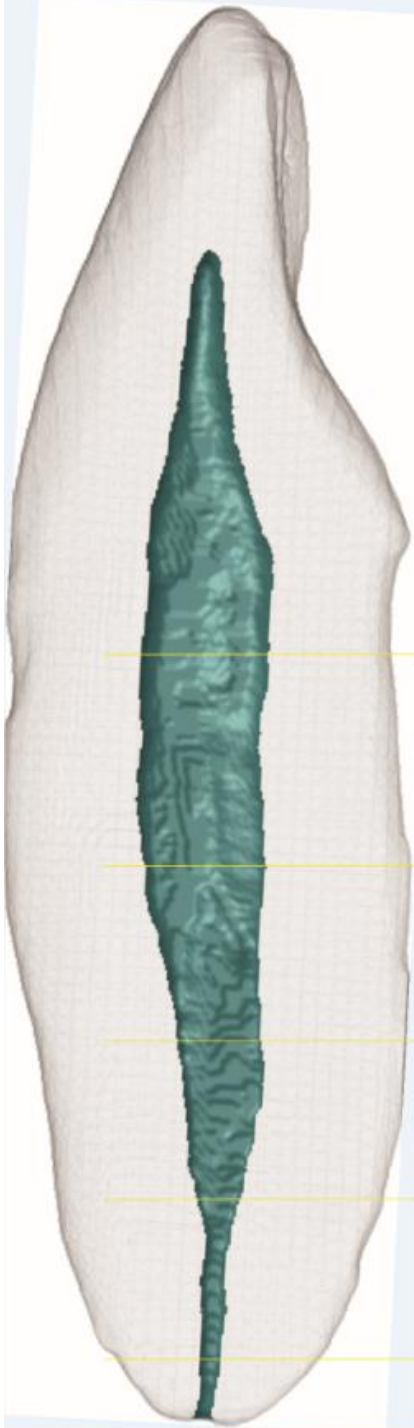
# QUALITATIVE EVALUATION



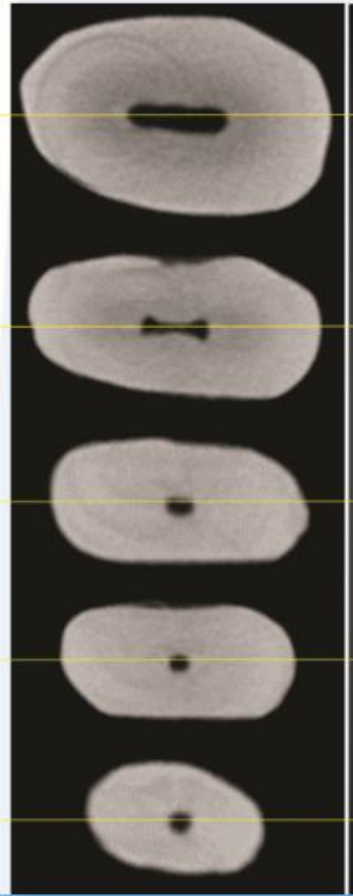

# CONVENTIONAL METHOD

# CROSS-SECTIONAL APPEARANCE

$$R = \frac{4A}{(\pi \cdot (d_{max})^2)}$$



Root Canal Cross-Sections

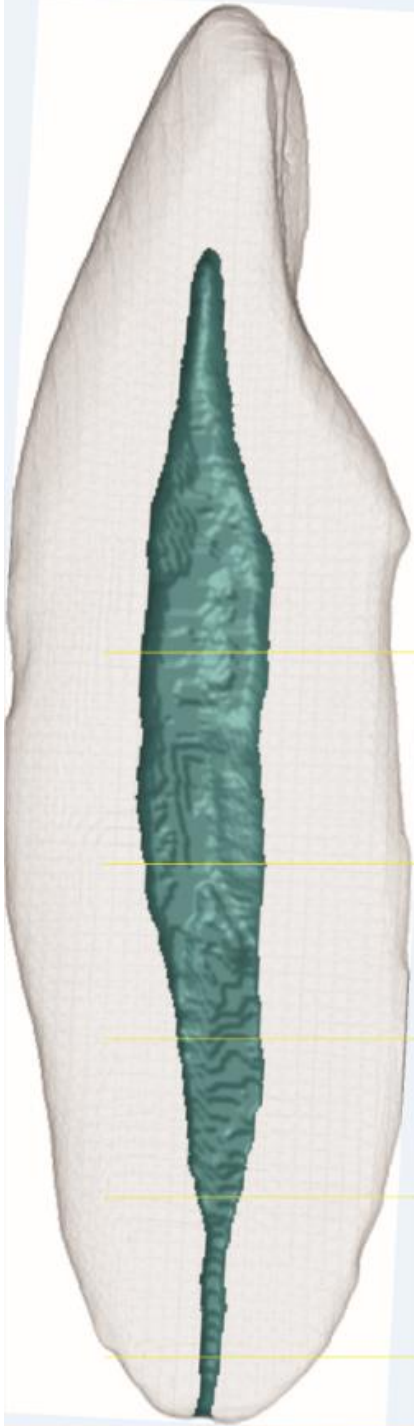


Roudness

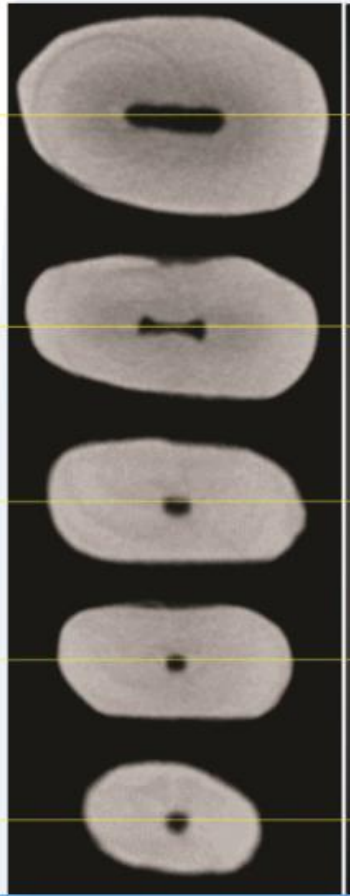

Form Factor

# CROSS-SECTIONAL APPEARANCE

$$FF = \left( \frac{4 \times \pi \times A}{Pm^2} \right)$$



Root Canal Cross-Sections



Roudness


Form Factor

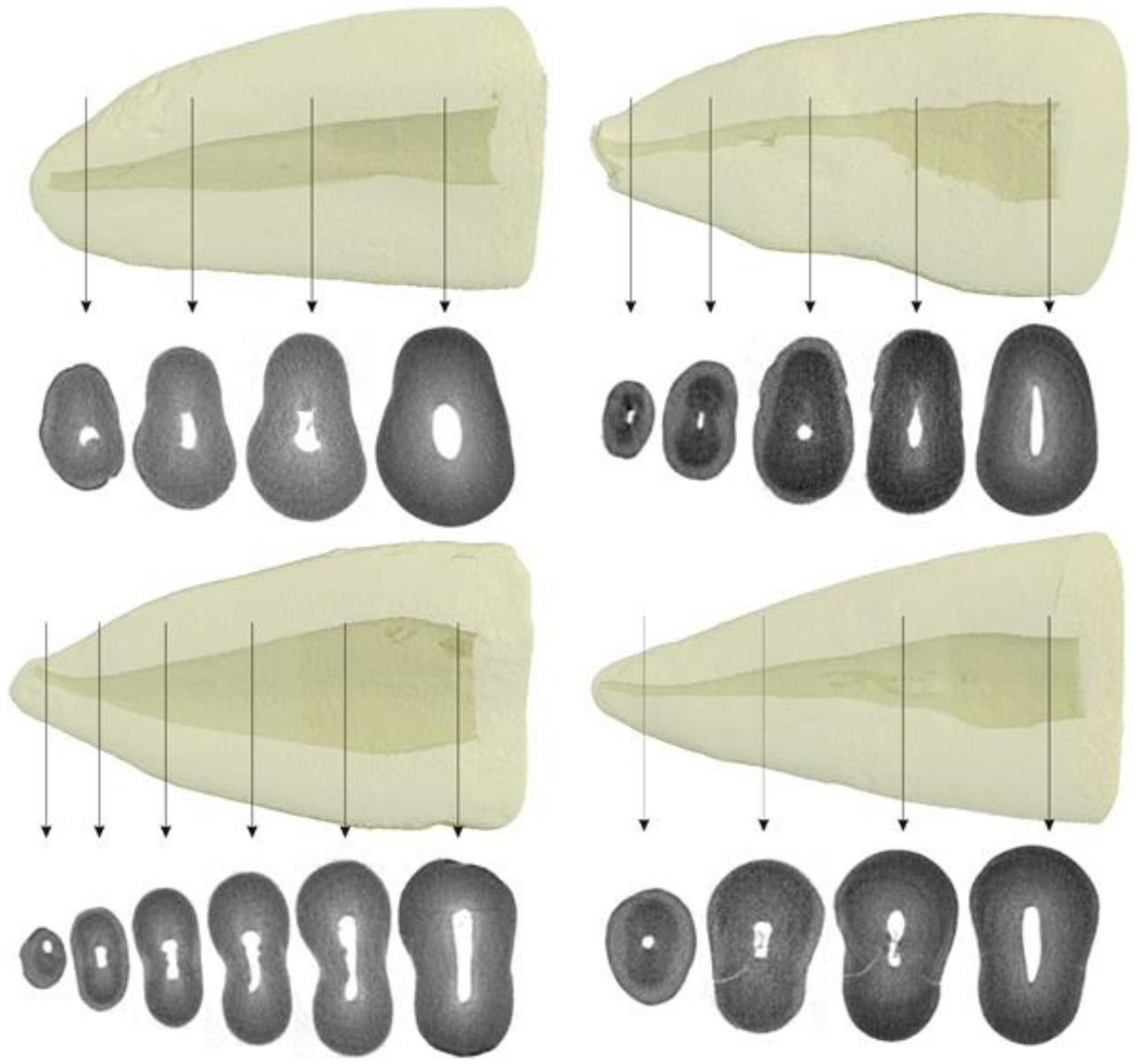
International Endodontic Journal

doi:10.1111/iej.12061

# Microcomputed tomography analysis of the root canal morphology of single-rooted mandibular canines

**M. A. Versiani, J. D. Pécora & M. D. Sousa-Neto**

Department of Restorative Dentistry, Faculty of Dentistry, University of São Paulo, Ribeirão Preto, Brazil



0099-2399/97/2302-0101$03.00/0
JOURNAL OF ENDODONTICS

Printed in U.S.A.
VOL. 23, NO. 2, FEBRUARY 1997

# 3D Reconstruction of Two C-Shape Mandibular Molars

**Kleoniki Lyroudia, Georgios Samakovitis, Ioannis Pitas, Theodoros Lambrianidis, Ioannis Molyvdas, and Georgios Mikrogeorgis**

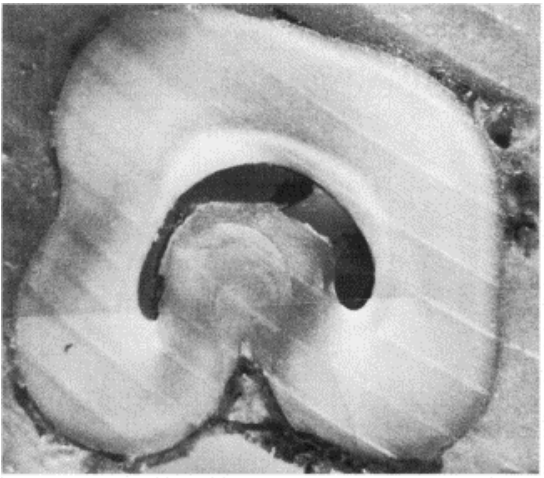
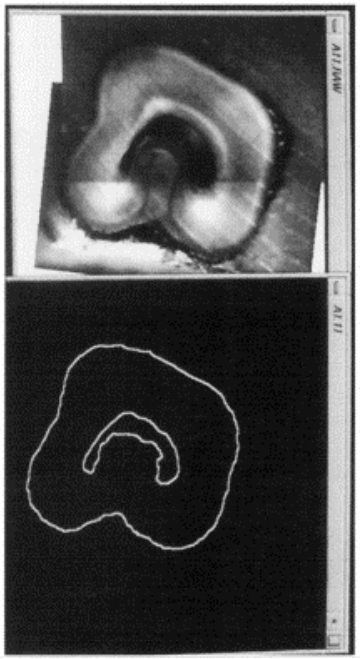


FIG 1. Cross sections of a mandibular second molar. Both the root and the root canal have a C-shape. The dentin of the two roots is separated and connected by cementum.



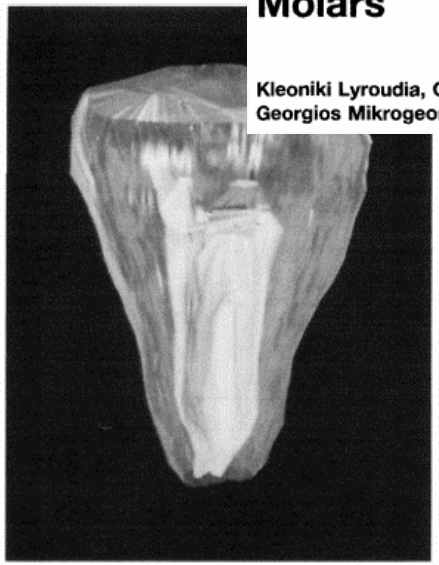


FIG 3. 3D reconstruction of the same mandibular second molar. The structure and the double apical foramen are clearly seen.

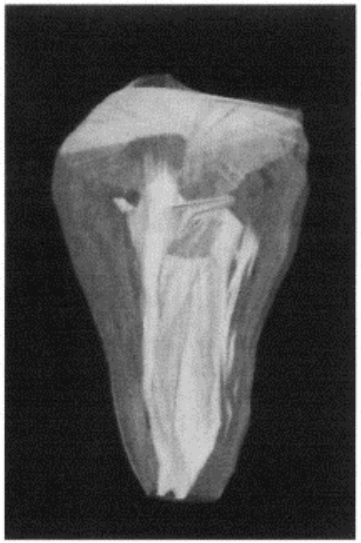
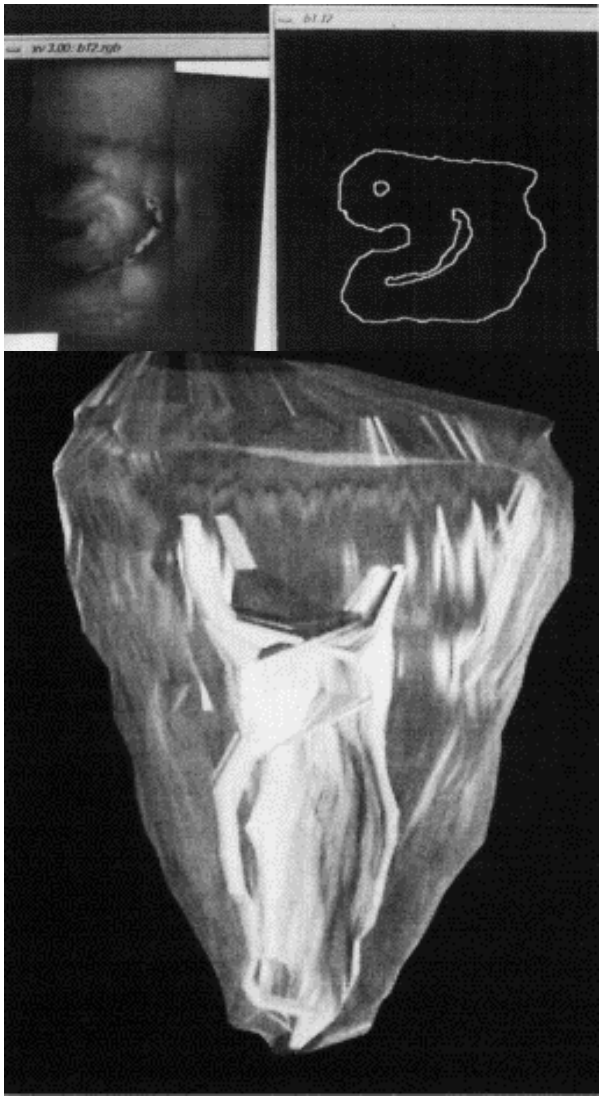


FIG 4. 3D reconstruction of the same tooth seen from another point of view.



## Volume ($mm^3$)

Volume of binarized root canal within the volume of interest

## Surface Area (mm2)

Total area that the surface of the canal occupies within the volume of interest

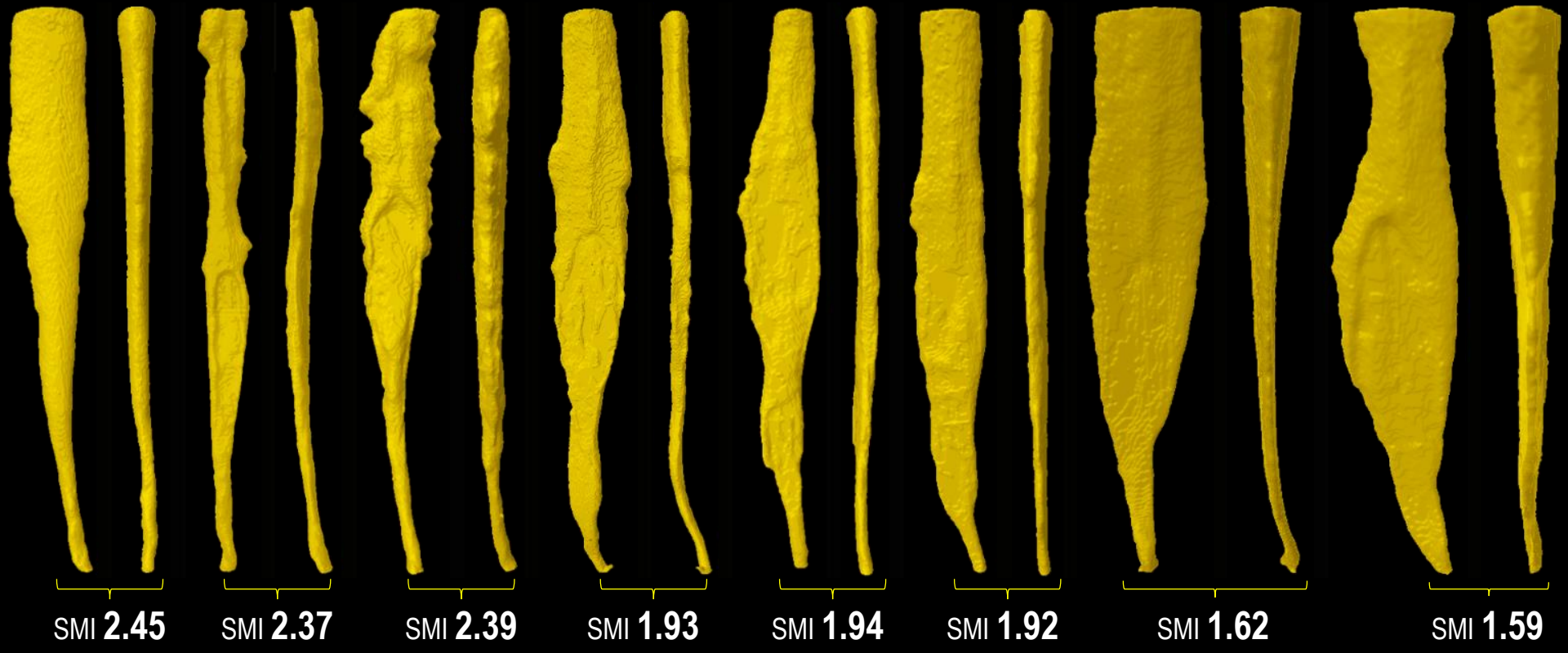
# Changes in Root Canal Geometry after Preparation Assessed by High-Resolution Computed Tomography

Ove A. Peters, Dr. med dent, Andres Laib, Dr. sc. tech., Till N. Göhring, Dr. med dent, and Fred Barbakow, BDS, HDD, MSc

Under the conditions of this study, variations in canal geometry before preparation had more influence on the changes during preparation than the techniques themselves.

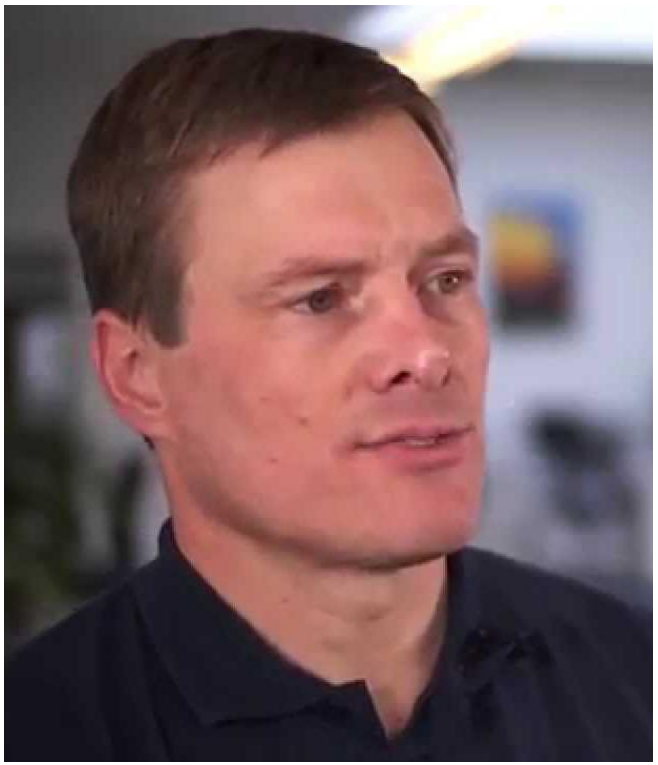
# 3D Shape of Root Canal

## Structure Model Index (SMI)



# The un-shape 3D morphometric indices

$$uRi = \frac{S \times Th}{4V}$$

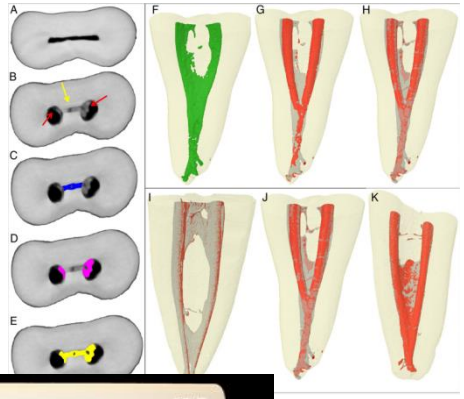


Dr. Phil Salmon

Dr. Marco Versiani

## Assessing Accumulated Hard-tissue Debris Using Micro–computed Tomography and Free Software for Image Processing and Analysis

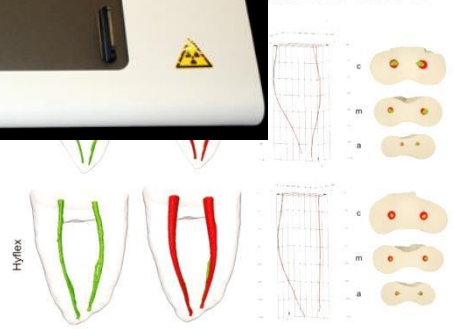
*Gustavo De-Deus, DDS, MSc, PhD,* Juliana Marins, DDS, MSc, PhD,† Aline de Almeida Neves, DDS, MSc, PhD,* Claudia Reis, DDS, MSc, PhD,‡ Sandra Fidel, PhD,† Marco A. Versiani, DDS, MSc, PhD,‡ Haimon Alves, MSc,|| Ricardo Tadeu Lopes, MSc, DSc,|| and Sidnei Paciornik, MSc, PhD†*





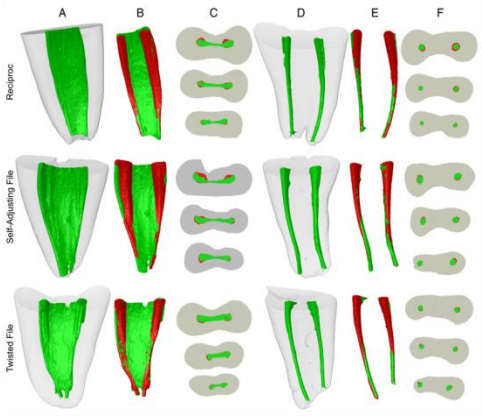
doi:10.1111/iej.12412

## ...ciprocating and ...ystems: a micro-CT



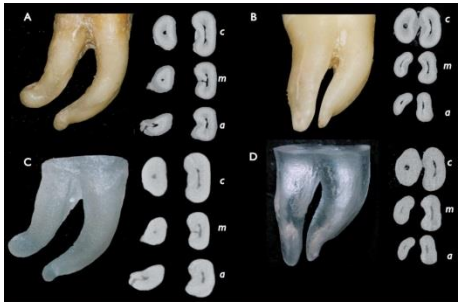

## Correlative Bacteriologic and Micro–Computed Tomographic Analysis of Mandibular Molar Mesial Canals Prepared by Self-Adjusting File, Reciproc, and Twisted File Systems

*José F. Siqueira, Jr, PhD,* Flávio R.F. Alves, PhD,* Marco A. Versiani, PhD,† Isabela N. Rôças, PhD,* Bernardo M. Almeida, MS,* Mônica A.S. Neves, PhD,* and Manoel D. Sousa-Neto, PhD†*



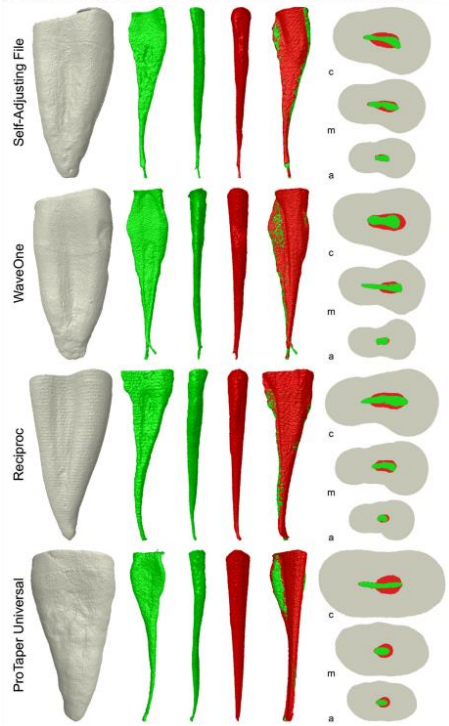

## Shaping ability of Reciproc and TF Adaptive systems in severely curved canals of rapid microCT-based prototyping molar replicas

Ronald ORDINOLA-ZAPATA[1], Clovis Monteiro BRAMANTE[1], Marco Antonio Hungaro DUARTE[1], Bruno Cavalini CAVENAGO[1], David JARAMILLO[2], Marco Aurélio VERSIANI[1]




## Micro–computed Tomography Study of Oval-shaped Canals Prepared with the Self-adjusting File, Reciproc, WaveOne, and ProTaper Universal Systems

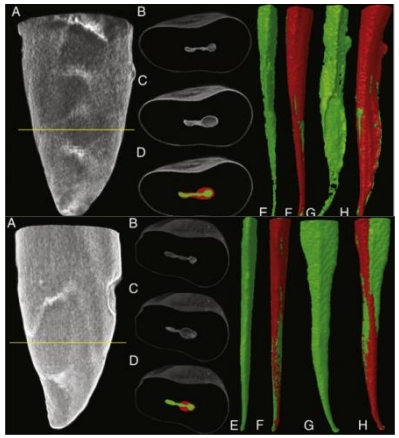
*Marco Aurélio Versiani, DDS, MSc, PhD,* Graziela Bianchi Leoni, DDS, MSc,* Lívia Steier, De med dent,† Gustavo De-Deus, DDS, MSc, PhD,‡ Simone Tassani, PhD,† Jesus Djalma Pécora, DDS, MSc, PhD,* and Manoel Damião de Sousa-Neto, DDS, MSc, PhD**




## Flat-Oval Root Canal Preparation with Self-Adjusting File Instrument: A Micro–Computed Tomography Study

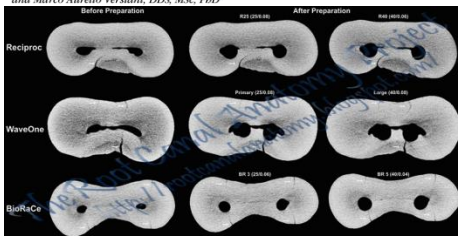
*Marco Aurélio Versiani, MS, Jesus Djalma Pécora, PhD, and Manoel Damião de Sousa-Neto, PhD*

*JOE* — Volume 37, Number 7, July 2011



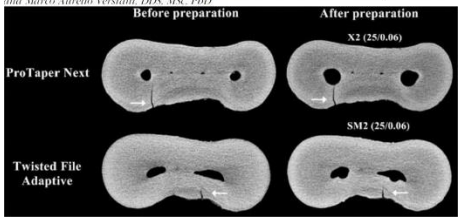

## Lack of Causal Relationship between Dentinal Microcracks and Root Canal Preparation with Reciprocation Systems

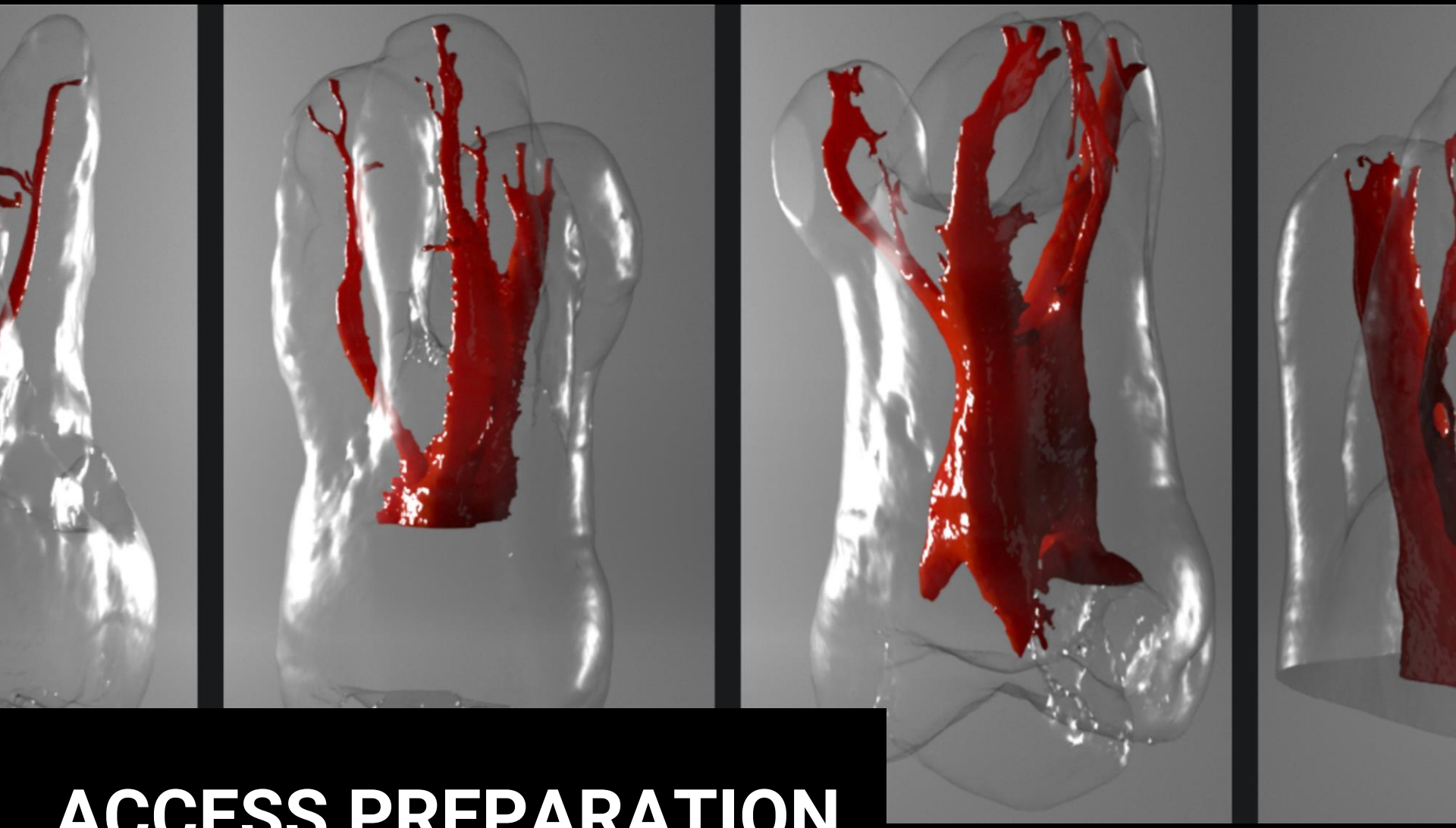
*Gustavo De-Deus, DDS, MSc, PhD,* Emmanuel João Nogueira Leal Silva, DDS, MSc, PhD,* Juliana Marins, DDS, MSc, PhD,† Erick Souza, DDS, MSc, PhD,‡ Aline de Almeida Neves, DDS, MSc, PhD,* Felipe Gonçalves Belladonna, DDS, MSc,† Haimon Alves, MSc,‡ Ricardo Tadeu Lopes, MSc, DSc,‡ and Marco Aurélio Versiani, DDS, MSc, PhD†*



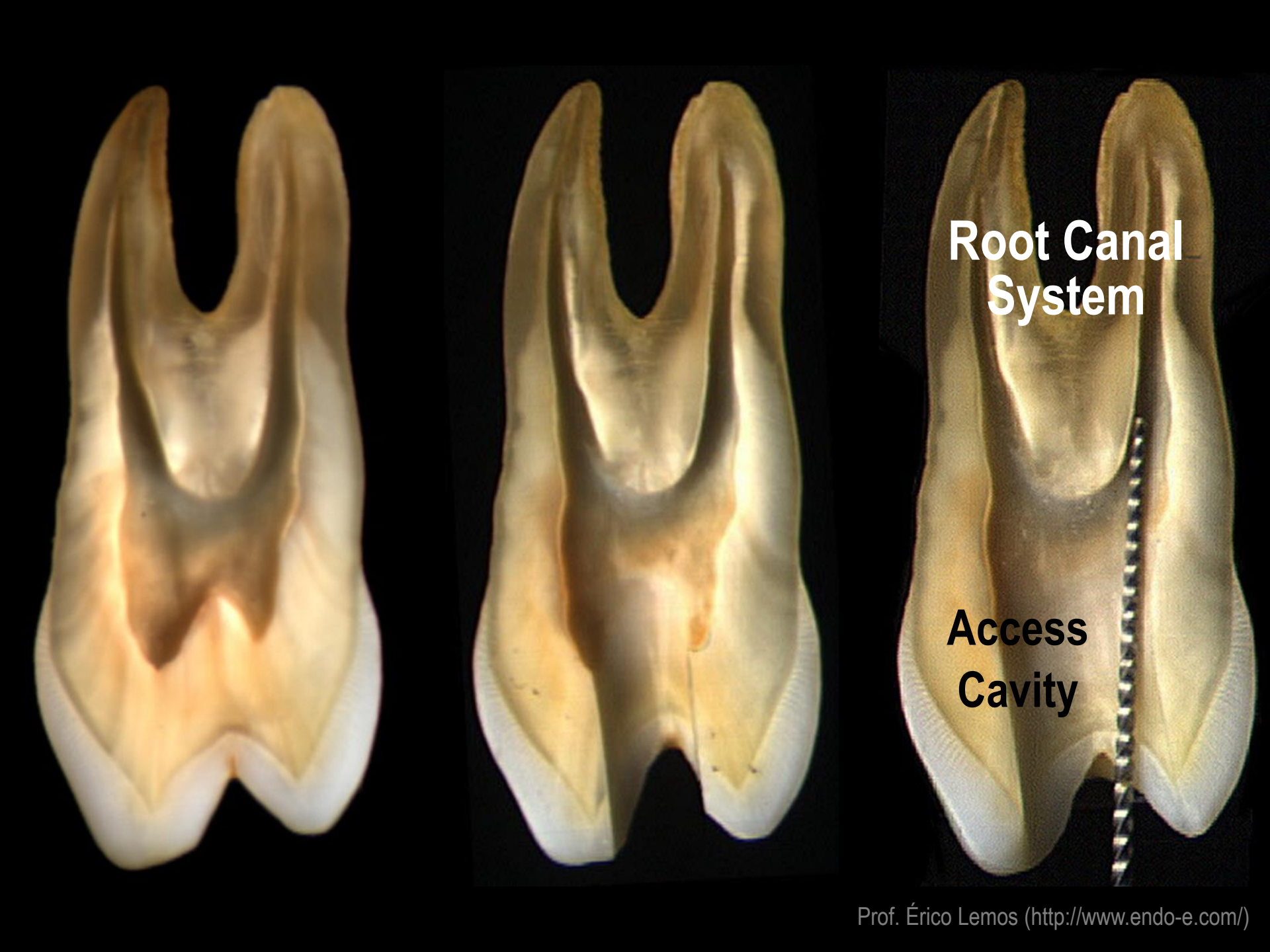

## Micro–computed Tomographic Assessment on the Effect of ProTaper Next and Twisted File Adaptive Systems on Dentinal Cracks

*Gustavo De-Deus, DDS, MSc, PhD,* Felipe Gonçalves Belladonna, DDS, MSc,† Erick Miranda Souza, DDS, MSc, PhD,† Emmanuel João Nogueira Leal Silva, DDS, MSc, PhD,* Aline de Almeida Neves, DDS, MSc, PhD,† Haimon Alves, MSc,† Ricardo Tadeu Lopes, MSc, DSc,‡ and Marco Aurélio Versiani, DDS, MSc, PhD†*



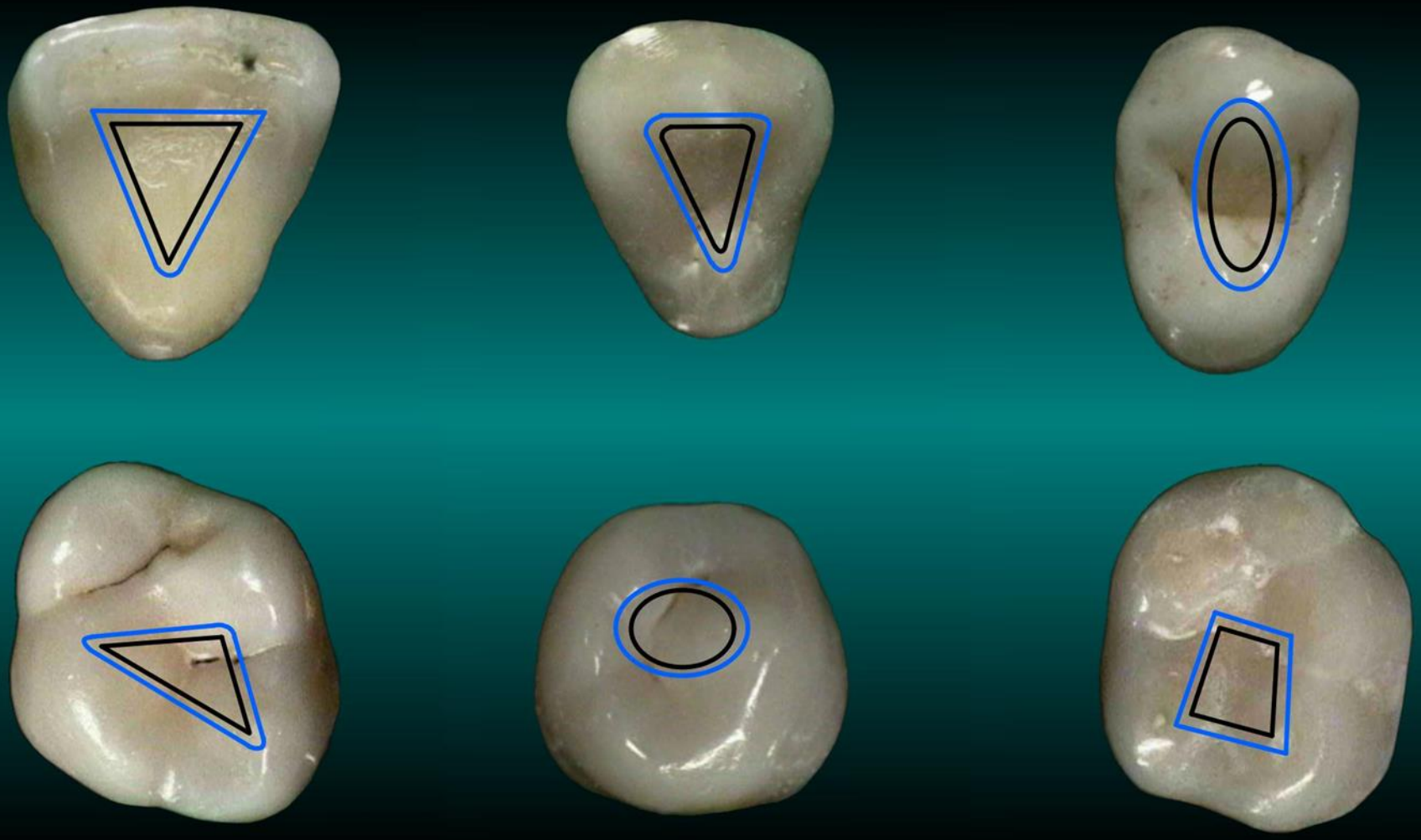


# ACCESS PREPARATION



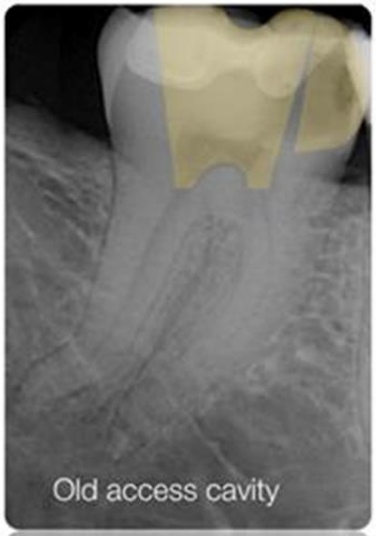

Prof. Érico Lemos (http://www.endo-e.com/)

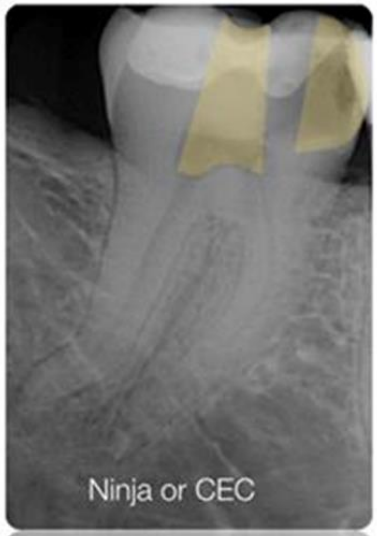
# Traditional Access Preparation



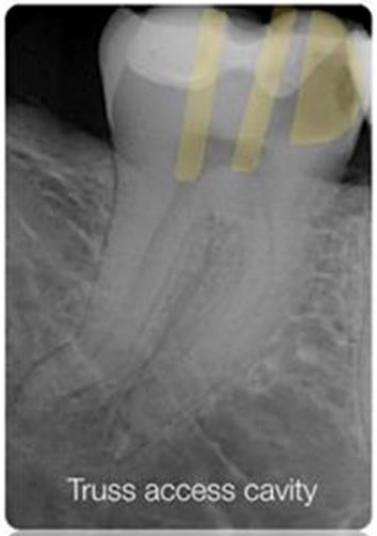
Pascon et al.

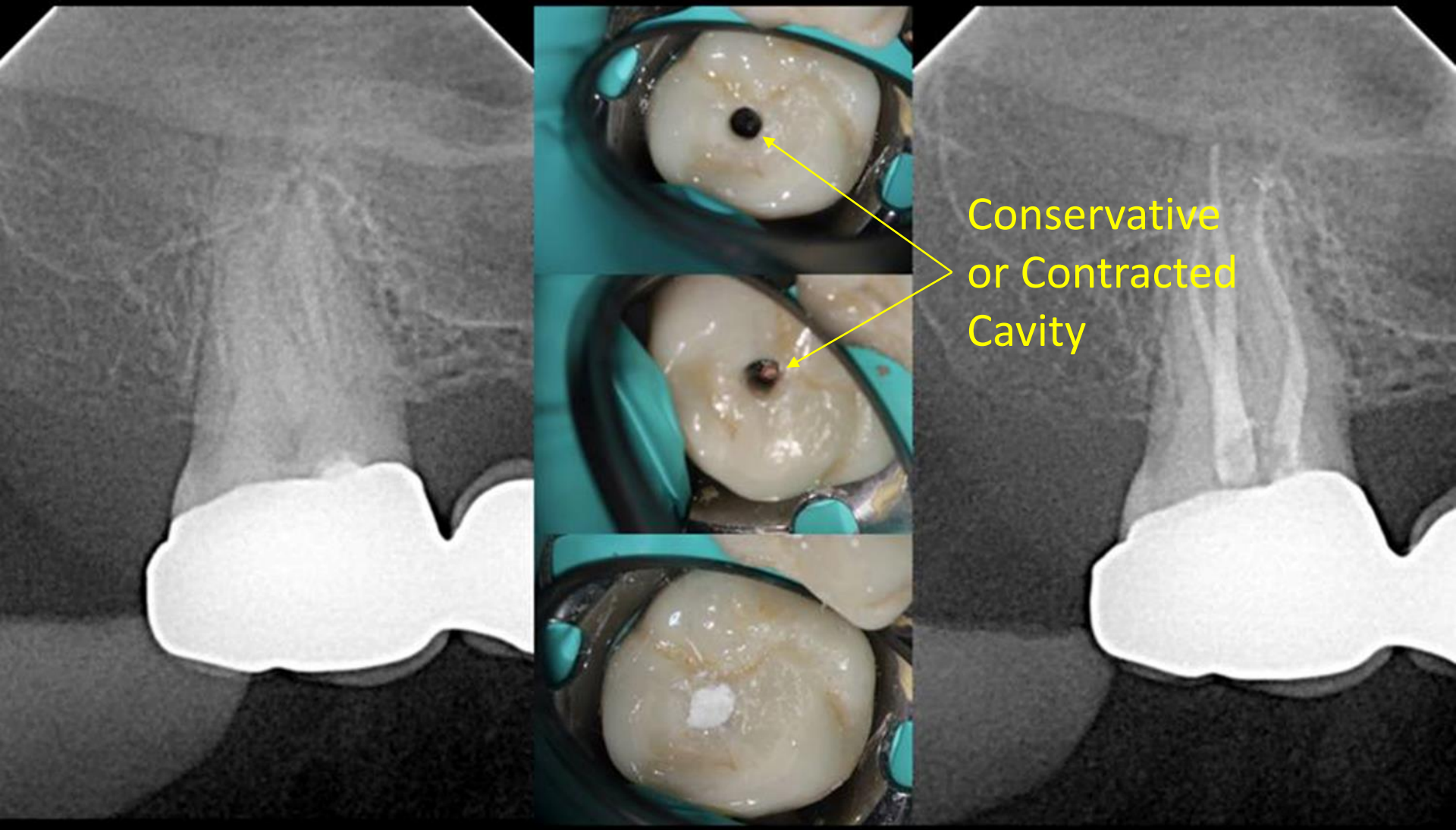
# What Kind of Access?



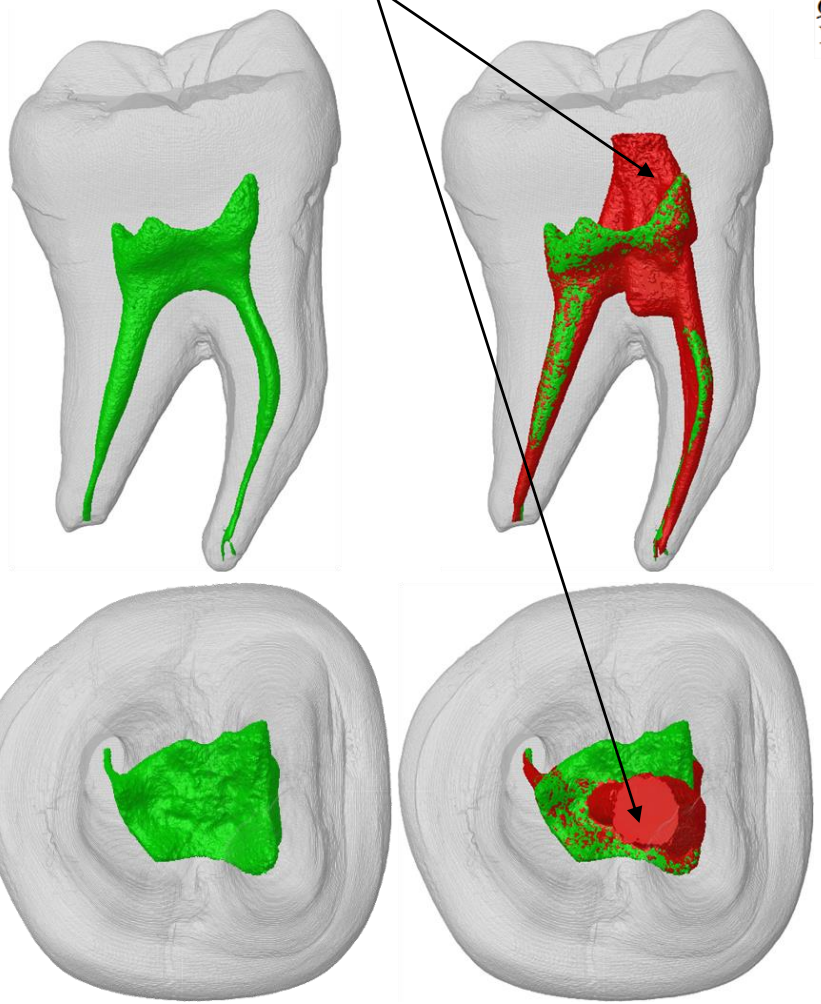




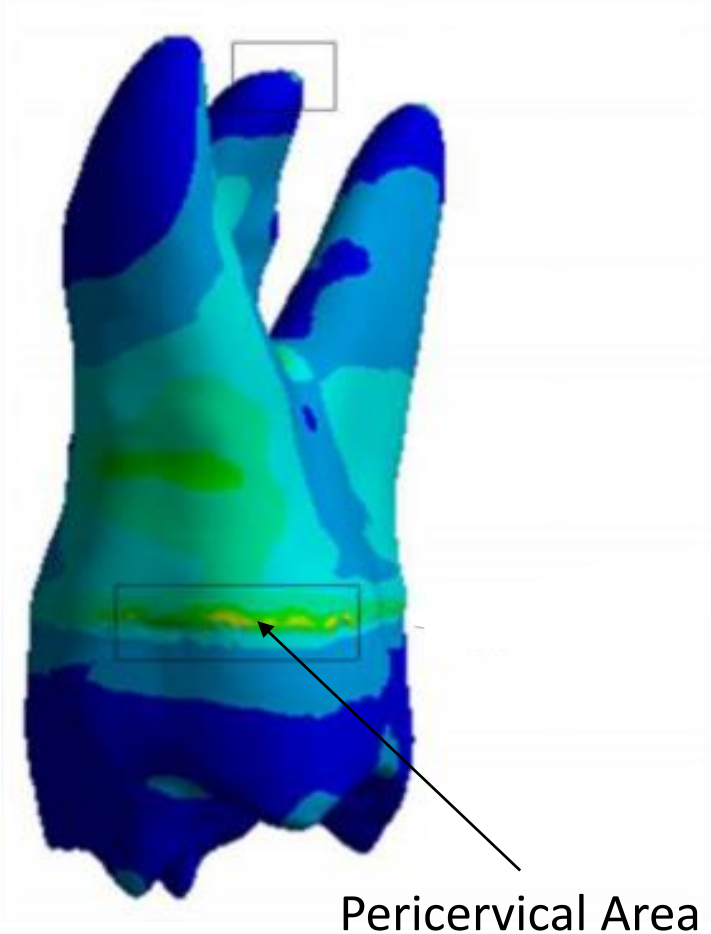

Clinical case by
Dr. Alberto Lorenzo

Conservative Access Cavity



## Biomechanical Properties of First Maxillary Molars with Different Endodontic Cavities: A Finite Element Analysis

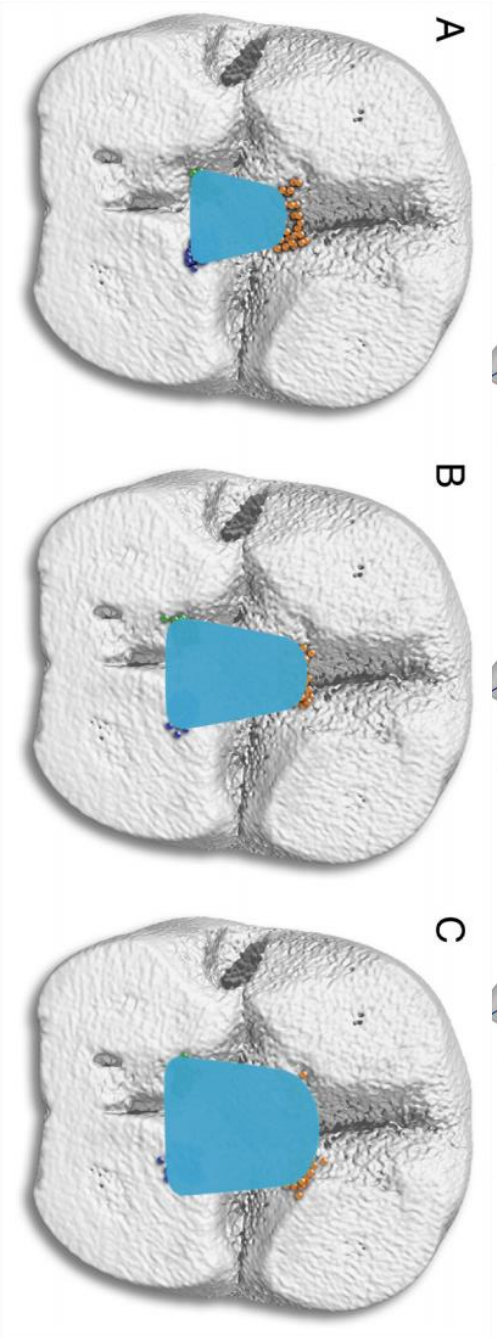
*Qianzhou Jiang, PhD, DDS, Yuting Huang, DDS, XinRan Tu, DDS, Zhengmao Li, DDS, Ying He, DDS, and Xuechao Yang, PhD, DDS*

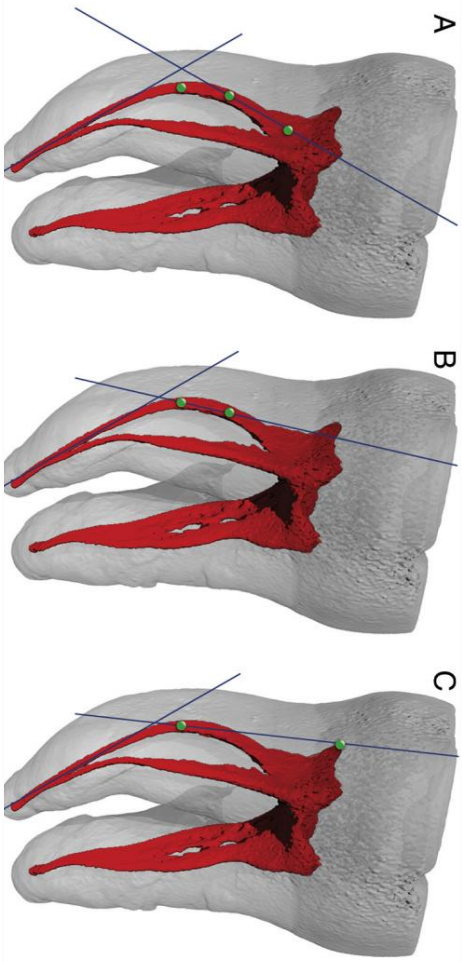


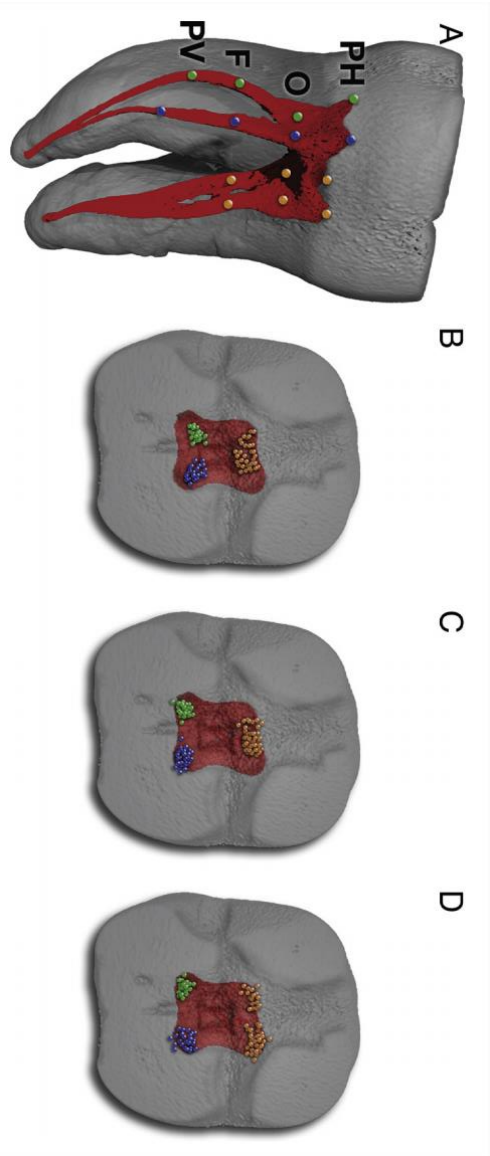
Pericervical Area [Stress Concentration]

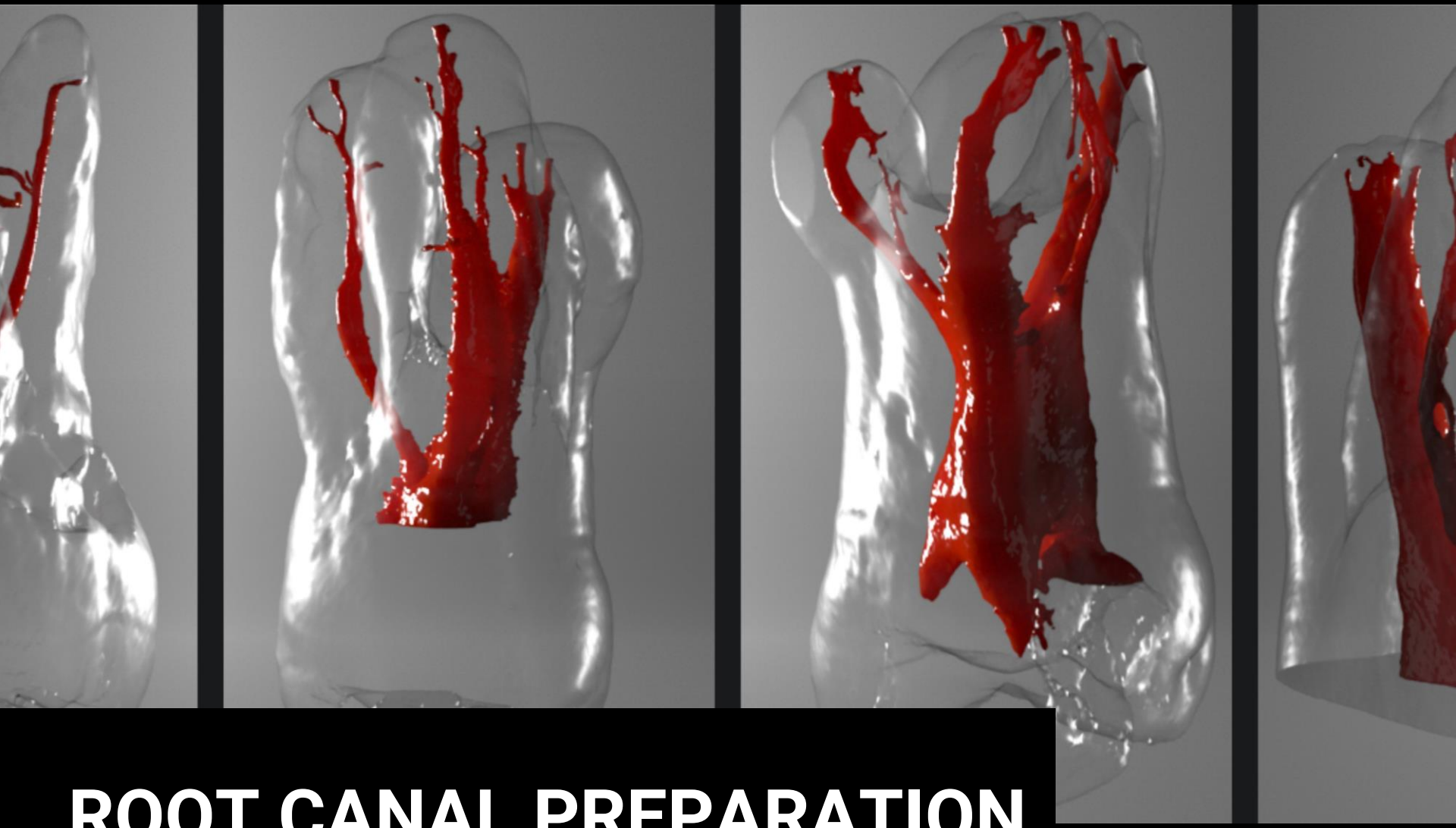
# Micro–computed Tomographic Evaluation of the Influence of Root Canal System Landmarks on Access Outline Forms and Canal Curvatures in Mandibular Molars

*James A. Eaton, DDS, David J. Clement, DDS, Adam Lloyd, BDS MS, and Melissa A. Marchesan, DDS MS PhD*

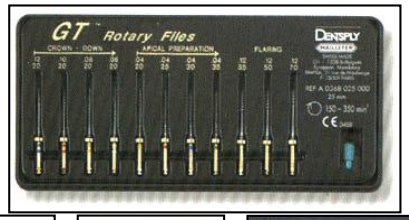




# ROOT CANAL PREPARATION

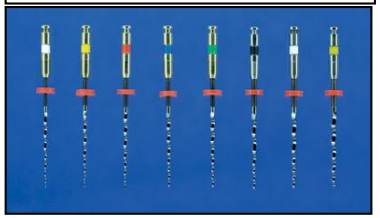





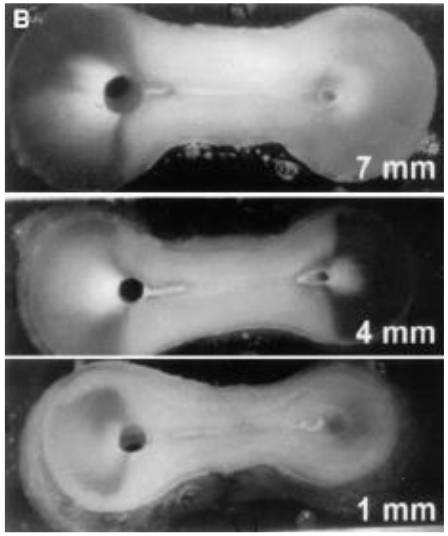




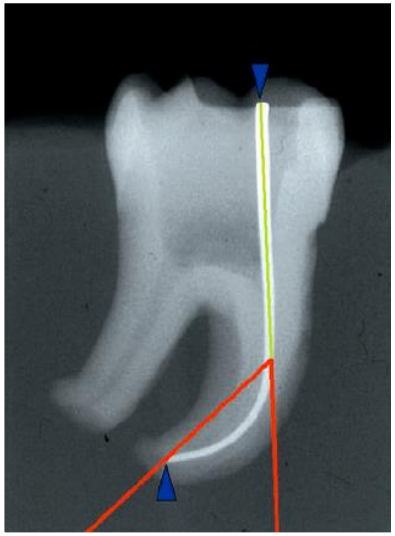




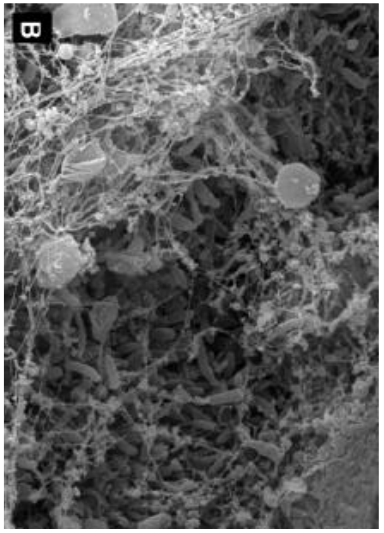
Video from Dentsply



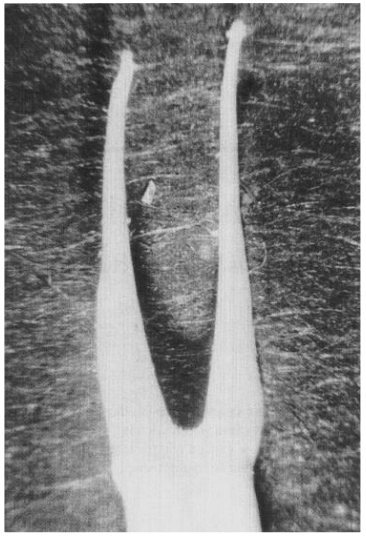

Sectioning



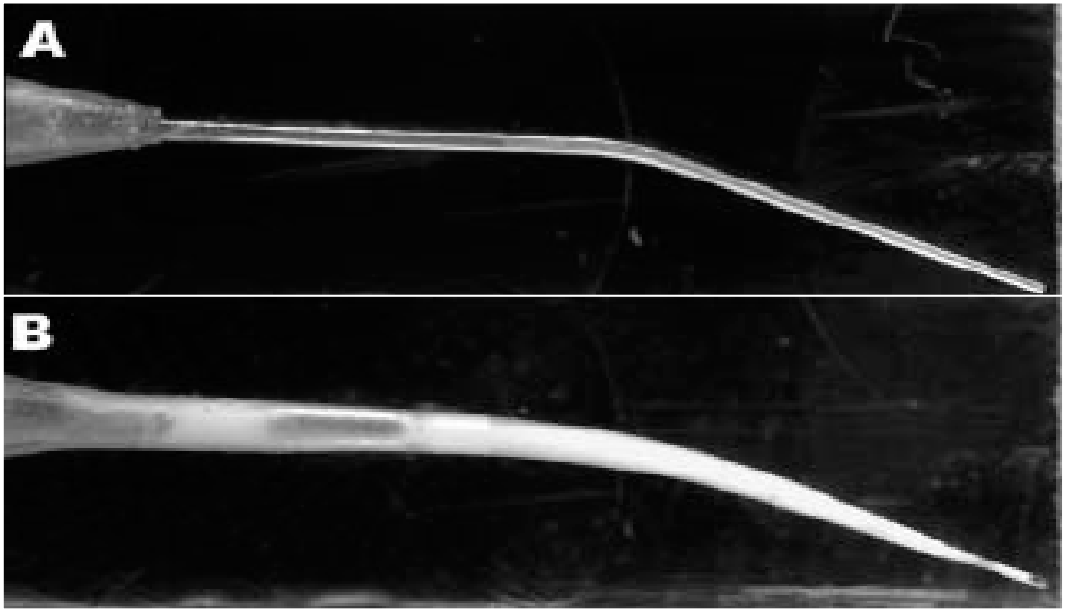
Radiography



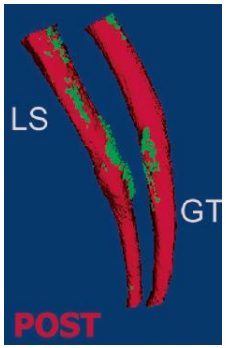

SEM



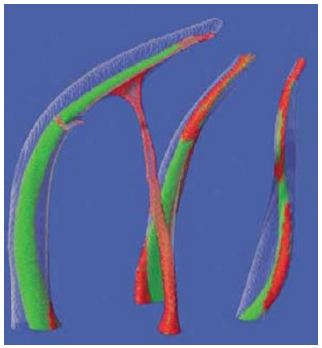
Silicon Impression




Artificial Canals in Resin

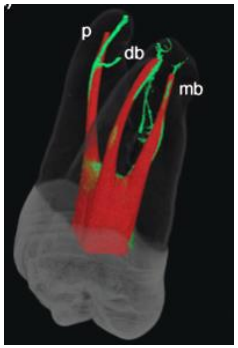


Bergmans et al. 2002

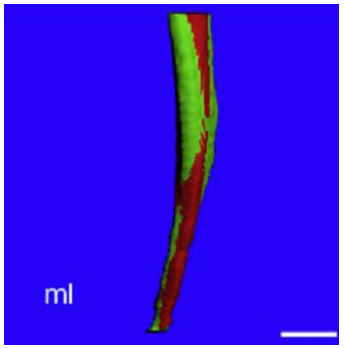

Peters et al. 2003


Bergmans et al. 2003

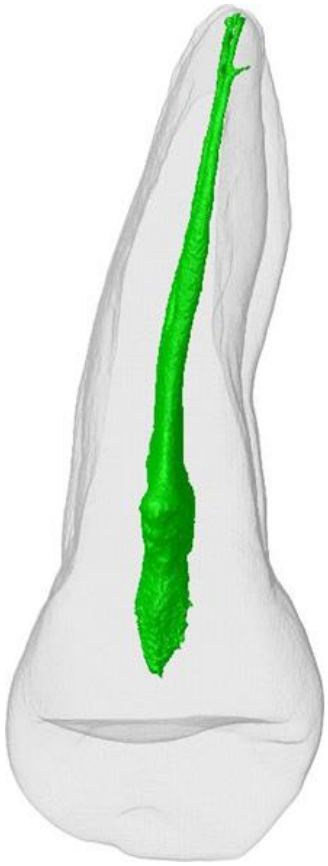
Hübscher et al. 2005

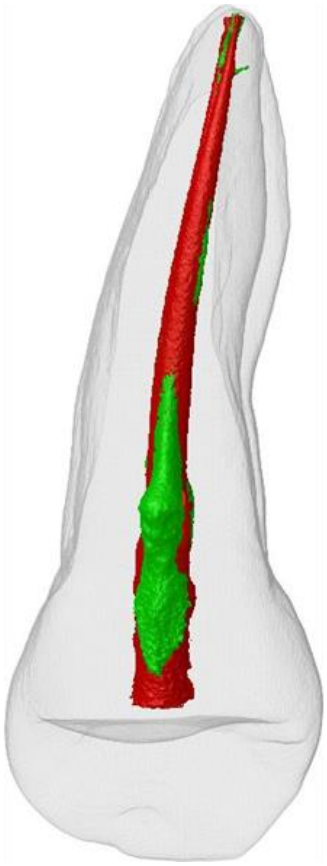


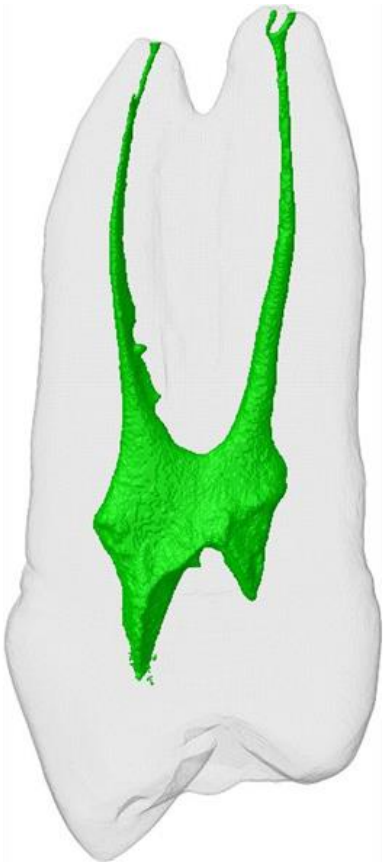
Paqué et al. 2005

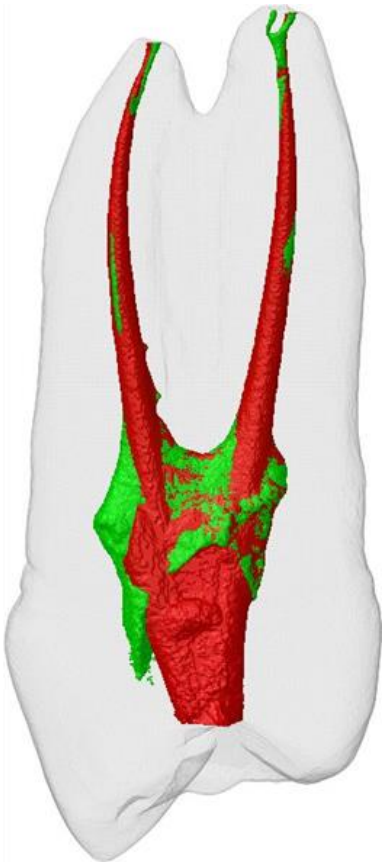


Gekelman et al. 2009



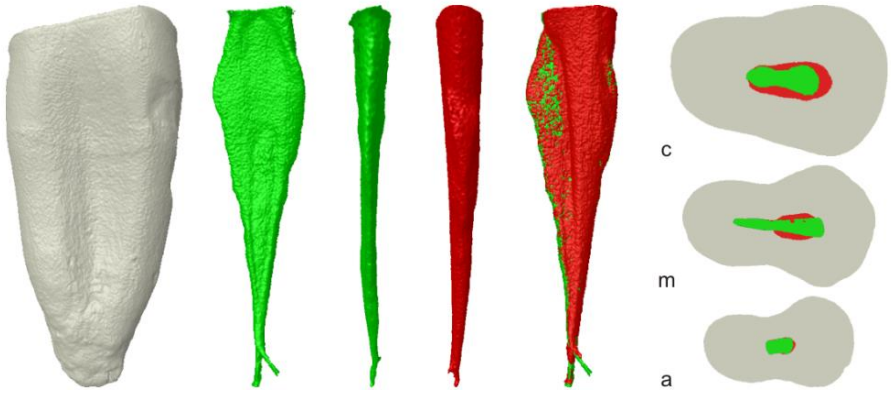




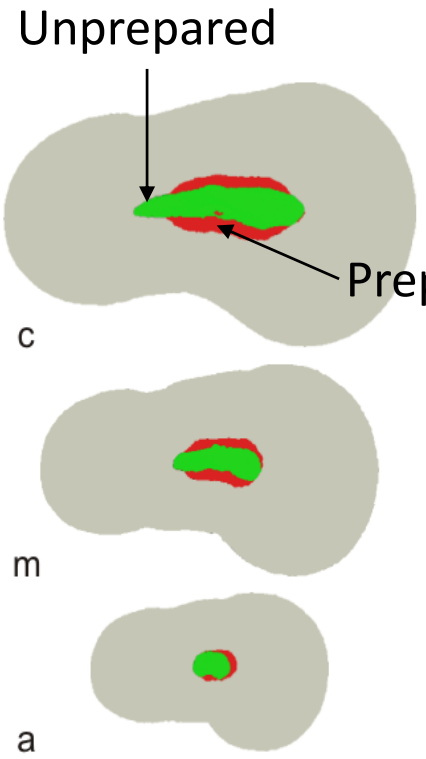


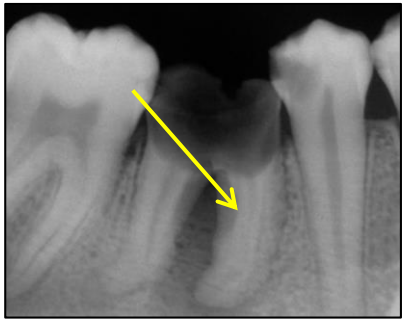
# Micro–computed Tomography Study of Oval-shaped Canals Prepared with the Self-adjusting File, Reciproc, WaveOne, and ProTaper Universal Systems

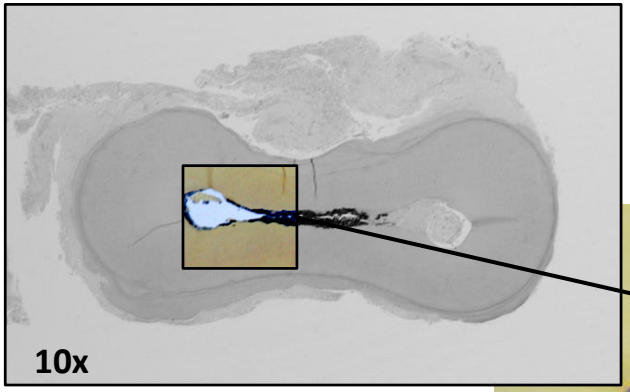
*Marco Aurélio Versiani, DDS, MSc, PhD,* Graziela Bianchi Leoni, DDS, MSc,**
*Liviu Steier, Dr med dent,† Gustavo De-Deus, DDS, MSc, PhD,‡ Simone Tassani, PhD,§*
*Jesus Djalma Pécora, DDS, MSc, PhD,* and Manoel Damião de Sousa-Neto, DDS, MSc, PhD**

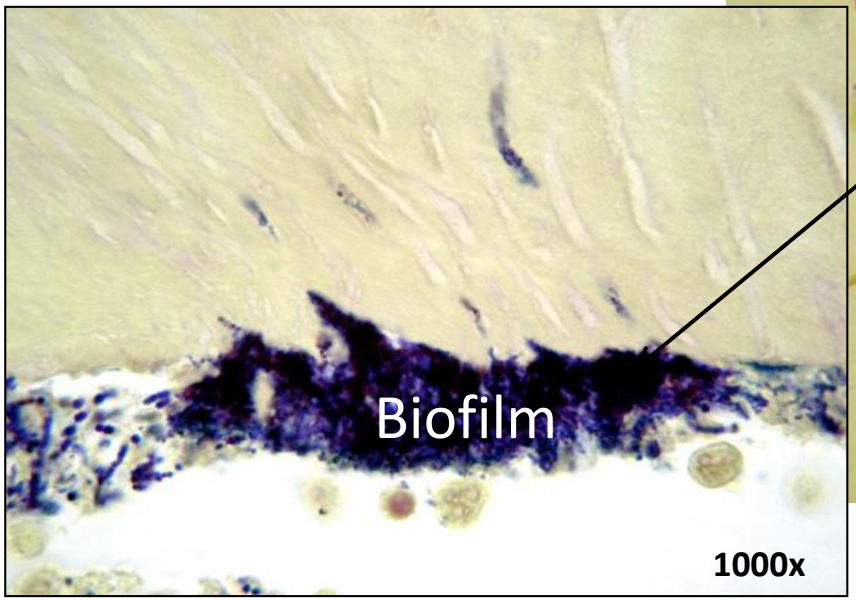



| | Experimental groups | | | |
|---|---|---|---|---|
| | SAF ($n$ = 18) | WaveOne ($n$ = 18) | Reciproc ($n$ = 18) | ProTaper ($n$ = 18) |
| Working length (mm) | 15.50 ± 1.32 | 15.67 ± 1.13 | 15.68 ± 1.18 | 15.61 ± 1.18 |
| Area ($mm^2$) (initial) | 0.84 ± 0.26 | 0.86 ± 0.36 | 0.86 ± 0.17 | 0.86 ± 0.37 |
| After preparation | 1.01 ± 0.26 | 1.23 ± 0.33 | 1.16 ± 0.18 | 1.21 ± 0.26 |
| Δ | $0.17 \pm 0.07^{A}$ | $0.38 \pm 0.11^{B}$ | $0.30 \pm 0.10^{B}$ | $0.35 \pm 0.21^{B}$ |
| Perimeter (mm) (initial) | **3.78 ± 0.63** | 3.48 ± 0.78 | 3.79 ± 0.71 | 3.68 ± 0.85 |
| After preparation | **3.84 ± 0.58** | 4.04 ± 0.64 | 4.08 ± 0.66 | 4.09 ± 0.62 |
| Δ | $0.06 \pm 0.17^{A}$ | $0.56 \pm 0.26^{C}$ | $0.29 \pm 0.20^{B}$ | $0.40 \pm 0.39^{C}$ |
| Roundness (initial) | 0.56 ± 0.10 | 0.60 ± 0.11 | 0.58 ± 0.11 | 0.61 ± 0.09 |
| After preparation | 0.63 ± 0.09 | 0.82 ± 0.04 | 0.78 ± 0.08 | 0.82 ± 0.04 |
| Δ | $0.07 \pm 0.10^{A}$ | $0.21 \pm 0.08^{B}$ | $0.20 \pm 0.06^{B}$ | $0.21 \pm 0.06^{B}$ |
| Major diameter (mm) (initial) | 1.41 ± 0.23 | 1.28 ± 0.34 | 1.41 ± 0.34 | 1.33 ± 0.32 |
| After preparation | 1.44 ± 0.24 | 1.43 ± 0.29 | 1.50 ± 0.32 | 1.47 ± 0.29 |
| Δ | $0.04 \pm 0.03^{A}$ | $0.15 \pm 0.09^{B}$ | $0.09 \pm 0.04^{C}$ | $0.15 \pm 0.06^{B}$ |
| Minor diameter (mm) (initial) | 0.70 ± 0.14 | 0.73 ± 0.15 | 0.72 ± 0.09 | 0.73 ± 0.16 |
| After preparation | 0.80 ± 0.12 | 1.01 ± 0.08 | 1.03 ± 0.21 | 0.95 ± 0.08 |
| Δ | $0.10 \pm 0.06^{A}$ | $0.28 \pm 0.11^{B}$ | $0.31 \pm 0.23^{B}$ | $0.22 \pm 0.09^{B}$ |
| Volume ($mm^3$) (initial) | 13.17 ± 4.48 | 13.56 ± 6.96 | 13.85 ± 3.02 | 12.99 ± 4.85 |
| After preparation | 15.76 ± 4.81 | 19.29 ± 5.75 | 18.15 ± 3.14 | 18.97 ± 4.60 |
| Δ | $2.58 \pm 1.33^{A}$ | $5.73 \pm 1.42^{B}$ | $4.31 \pm 1.54^{C}$ | $5.98 \pm 1.51^{B}$ |
| Surface area ($mm^2$) (initial) | 63.86 ± 13.32 | 60.80 ± 15.34 | 65.40 ± 12.63 | 62.85 ± 14.56 |
| After preparation | 66.69 ± 13.81 | 70.11 ± 13.16 | 70.78 ± 11.41 | 71.15 ± 12.65 |
| Δ | $2.83 \pm 2.01^{A}$ | $9.31 \pm 4.71^{B}$ | $5.38 \pm 2.57^{C}$ | $8.31 \pm 3.63^{B}$ |
| SMI (initial) | 2.21 ± 0.45 | 2.58 ± 0.32 | 2.34 ± 0.57 | 2.27 ± 0.55 |
| After preparation | 2.64 ± 0.29 | 2.88 ± 0.13 | 2.73 ± 0.34 | 2.80 ± 0.29 |
| Δ | 0.43 ± 0.31 | 0.30 ± 0.24 | 0.39 ± 0.44 | 0.53 ± 0.48 |



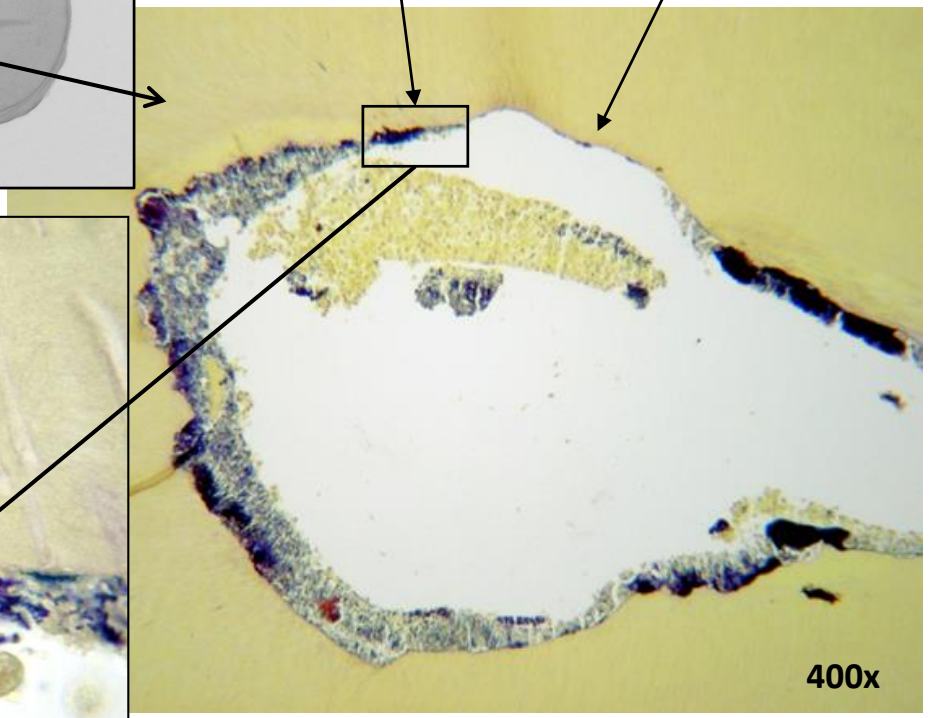





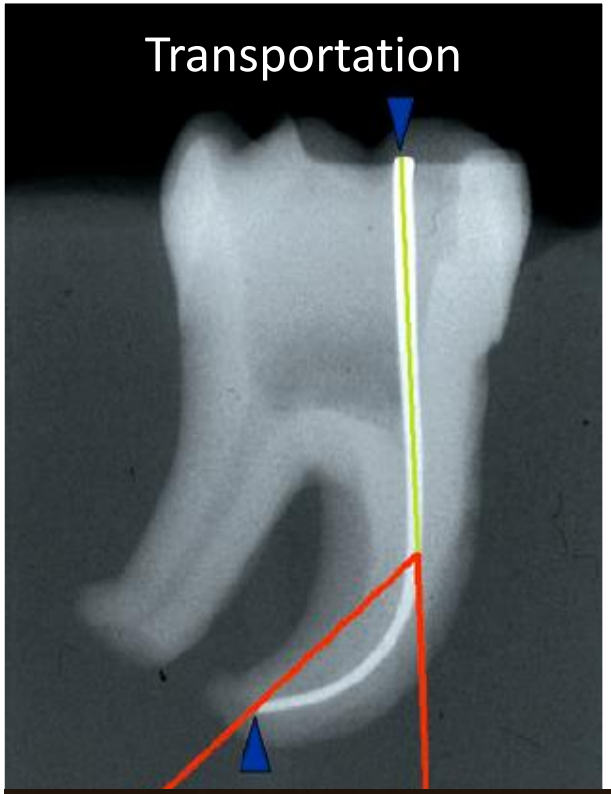

Unprepared Area

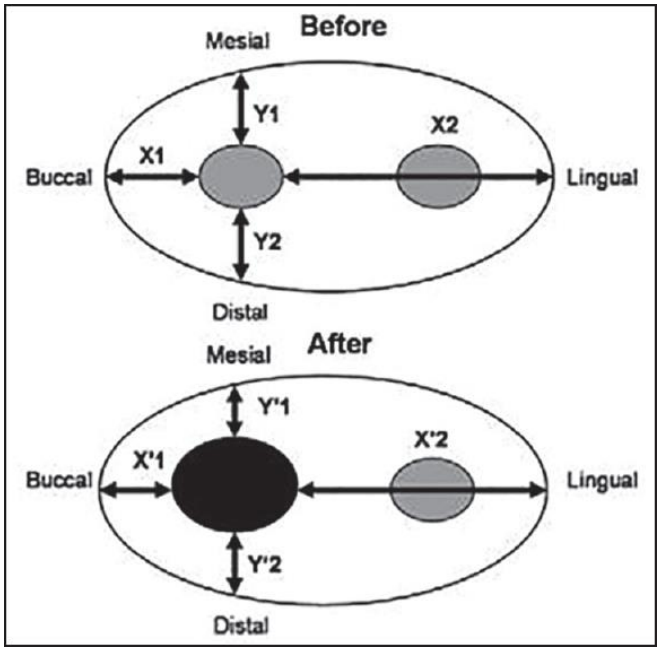
Prepared Area

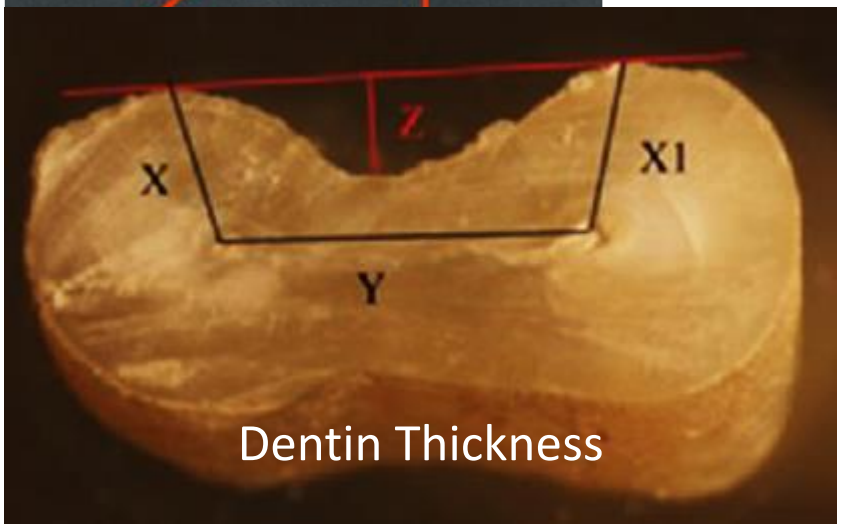


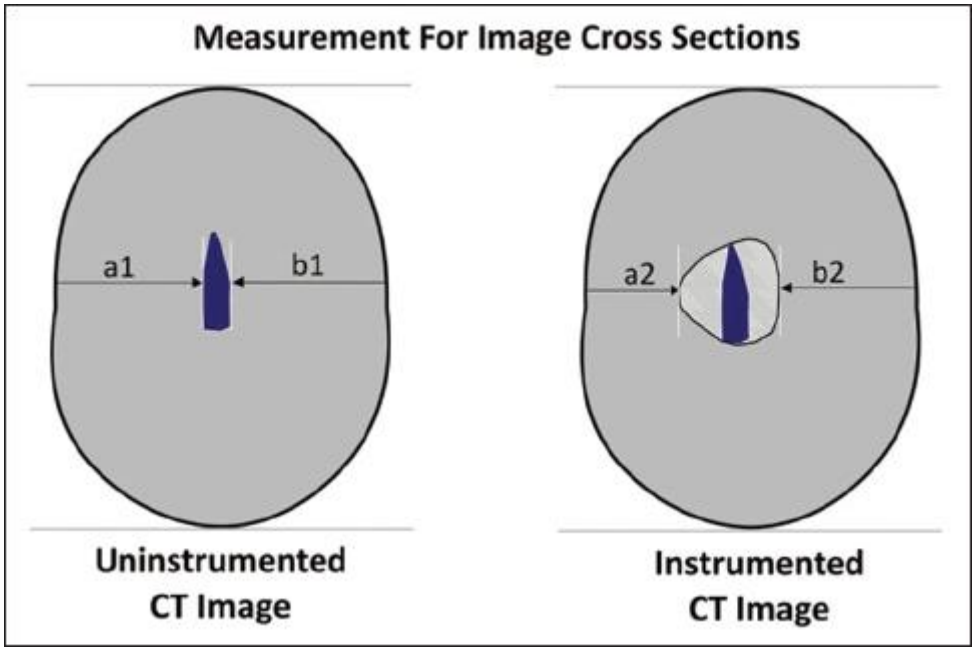

Courtesy: Ricucci

# Conventional Methods

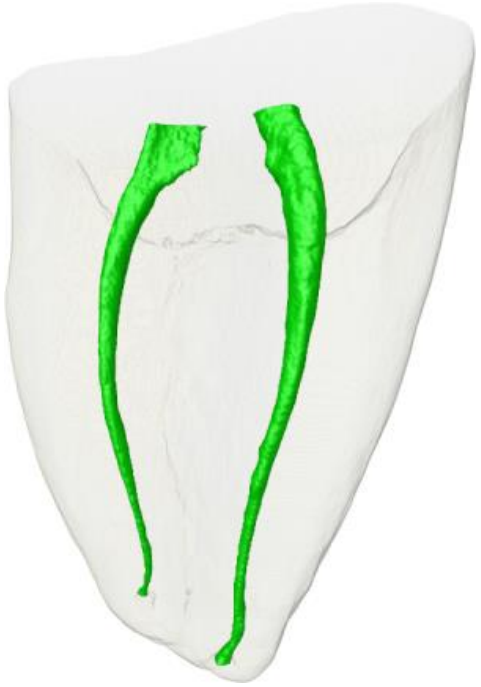


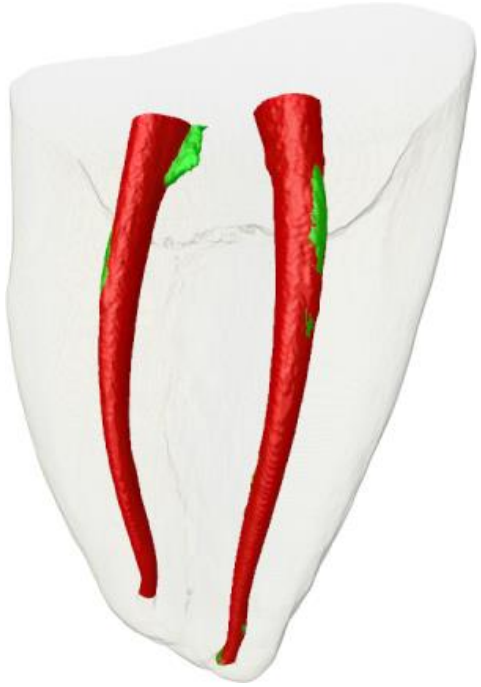



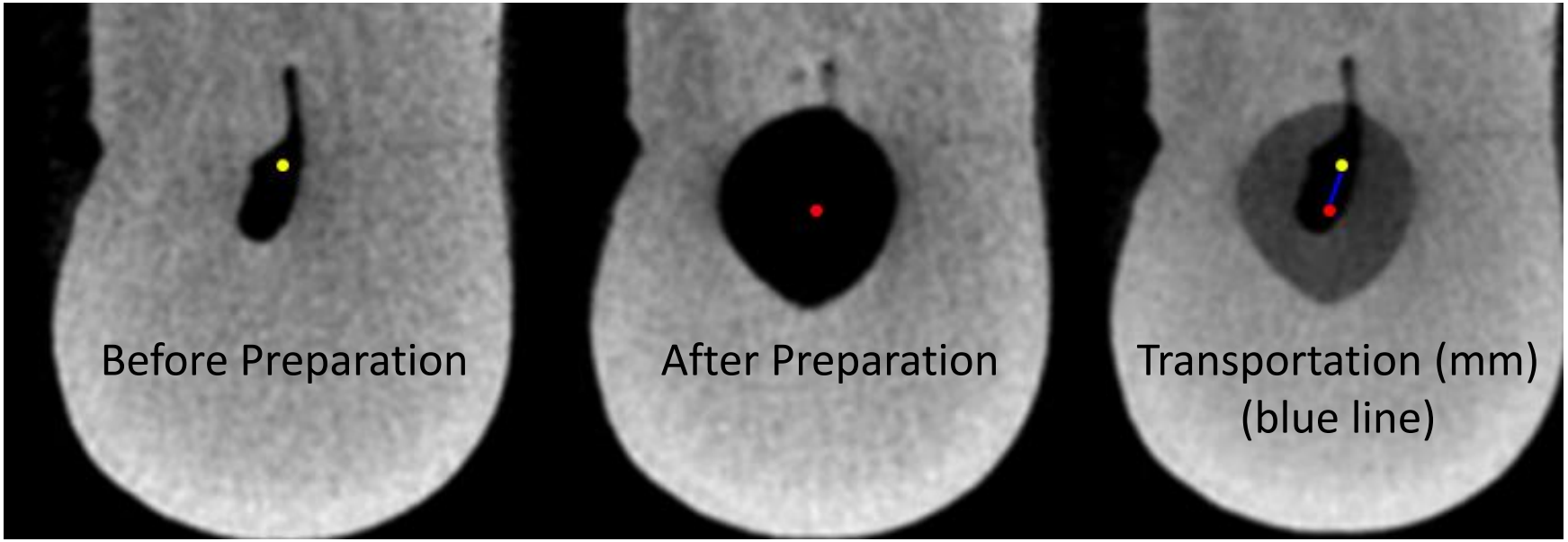
Before Preparation

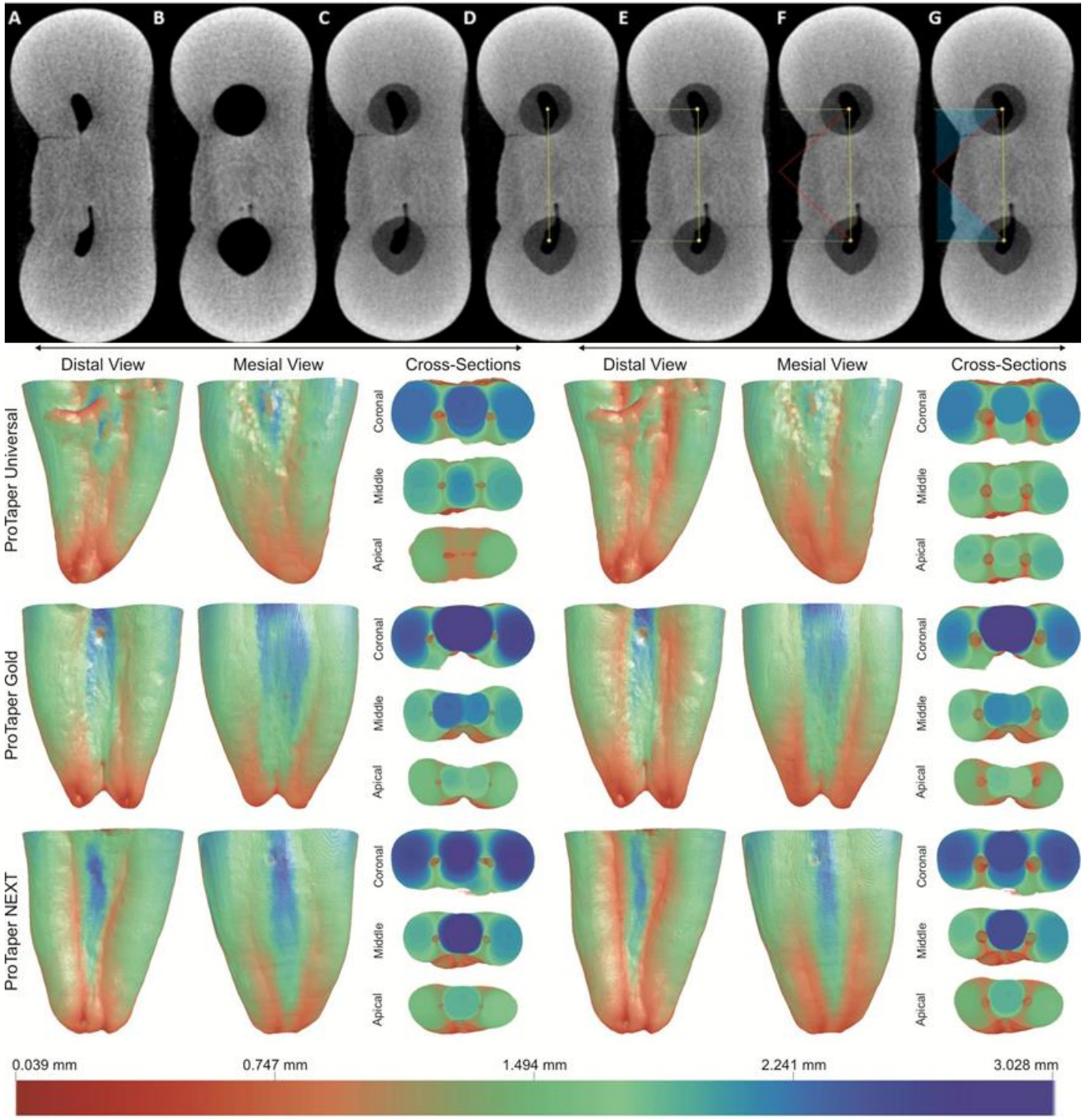


After Preparation

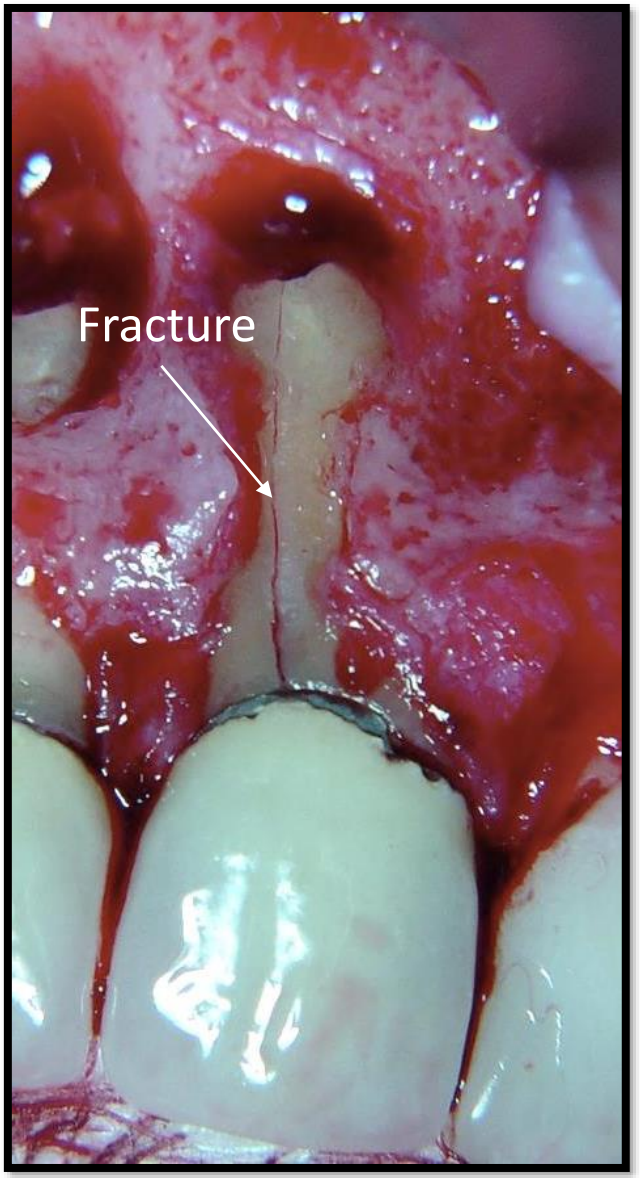


Graphic (Centers of Gravity)


A
B
C
D
E
F
G
Distal View
Mesial View
Cross-Sections
Distal View
Mesial View
Cross-Sections
ProTaper Universal
ProTaper Gold
ProTaper NEXT
Coronal
Middle
Apical
Coronal
Middle
Apical
Coronal
Middle
Apical
Coronal
Middle
Apical
Coronal
Middle
Apical
Coronal
Middle
Apical
0.039 mm
0.747 mm
1.494 mm
2.241 mm
3.028 mm


From: Endos Colima Source: Internet



1960 — 1970 — 1980 — 1990 — 2000 — 2009 — 2017

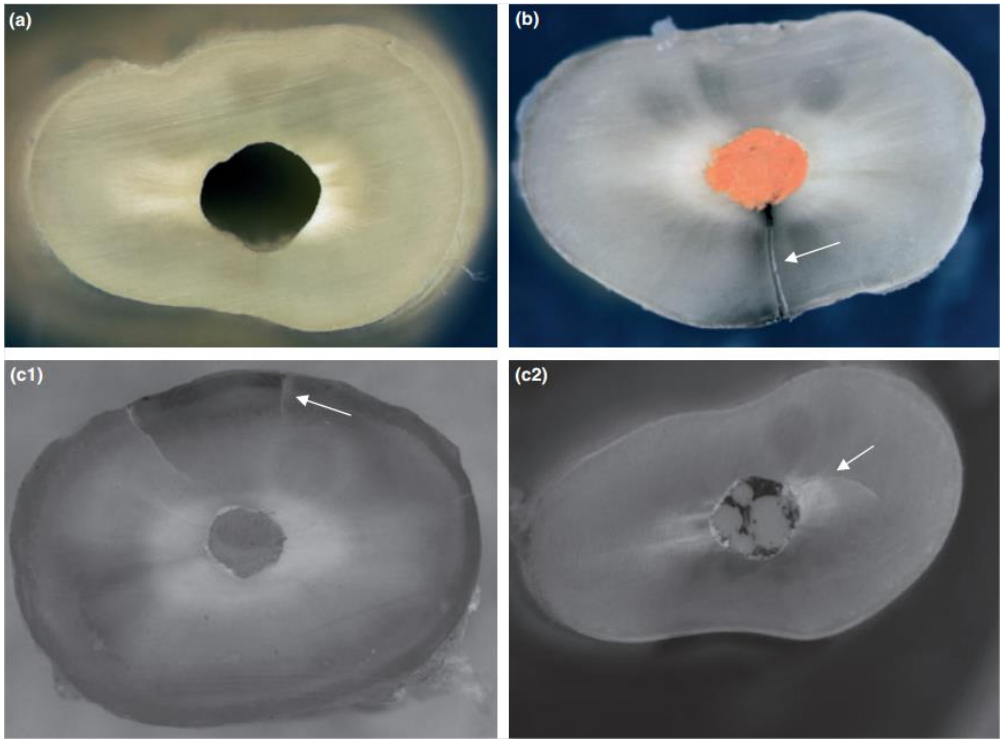
## The effects of canal preparation and filling on the incidence of dentinal defects

H. Shemesh[1], C. A. S. Bier[2], M.-K. Wu[1], M. Tanomaru-Filho[2] & P. R. Wesselink[1]

[1]Department of Cariology, Endodontology, Pedodontology, Academic Centre of Dentistry Amsterdam, Amsterdam, The Netherlands; and [2]Department of Restorative Dentistry, Araraquara Dental School, São Paulo State University, UNESP, Araraquara, SP, Brazil

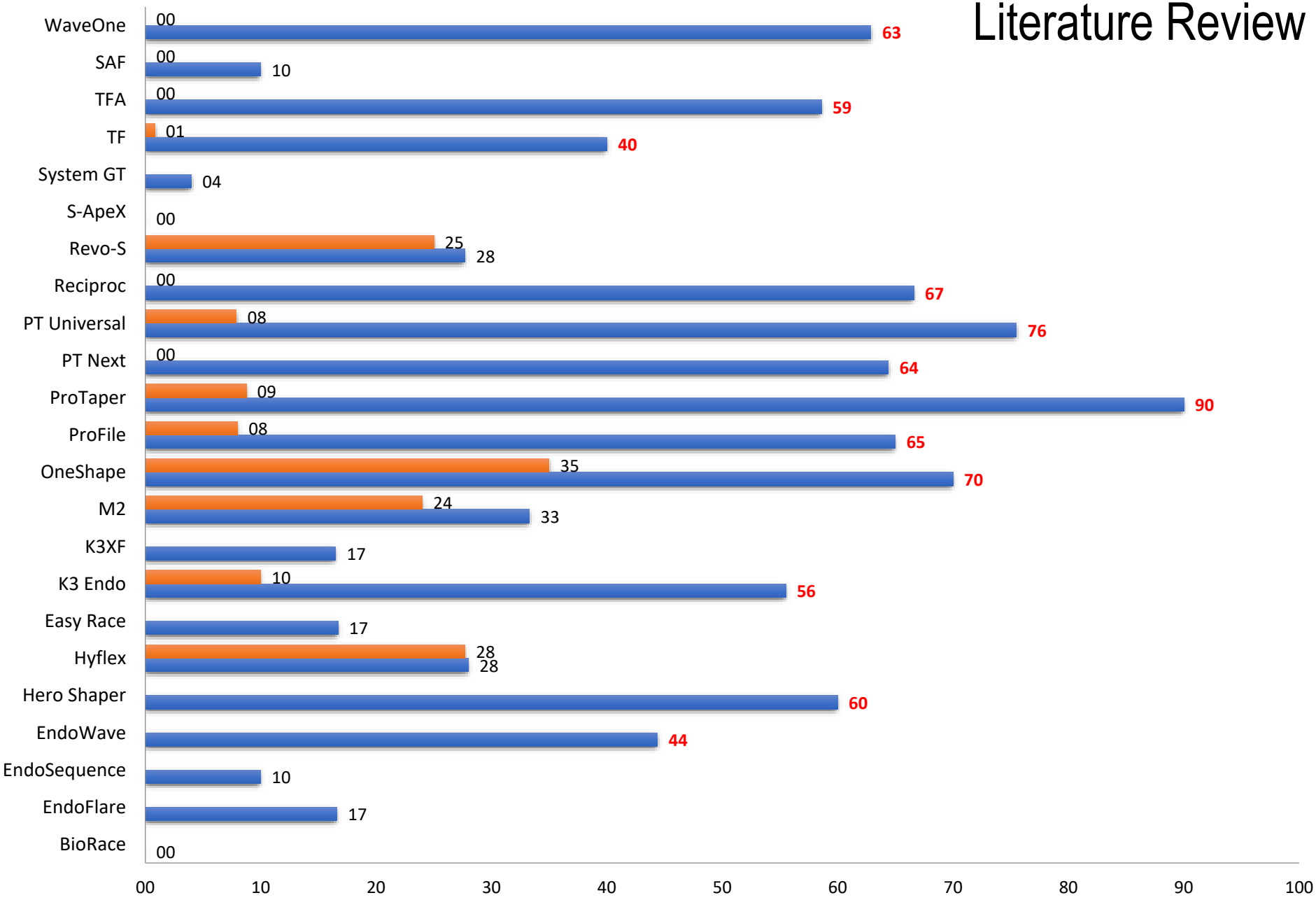
## The Ability of Different Nickel-Titanium Rotary Instruments To Induce Dentinal Damage During Canal Preparation

*Carlos Alexandre Souza Bier, DMD,* Hagay Shemesh, DMD,† Mário Tanomaru-Filho, DDS, MSc, PhD,* Paul R. Wesselink, DDS, PhD,† and Min-Kai Wu, MD, MSD, PhD‡*



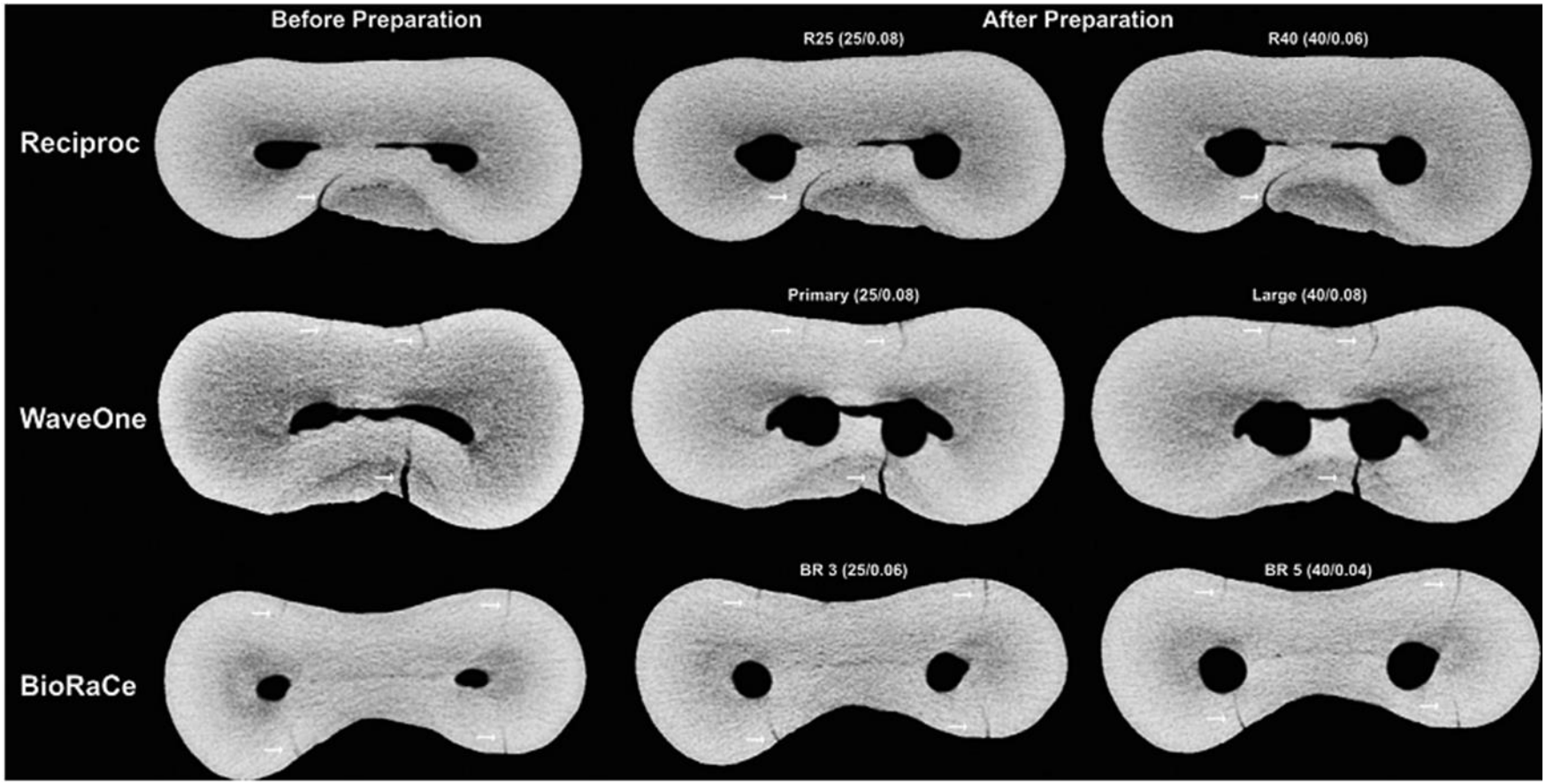
# Percentage range (%) of Dentinal Microcracks

## Literature Review



# Lack of Causal Relationship between Dentinal Microcracks and Root Canal Preparation with Reciprocation Systems

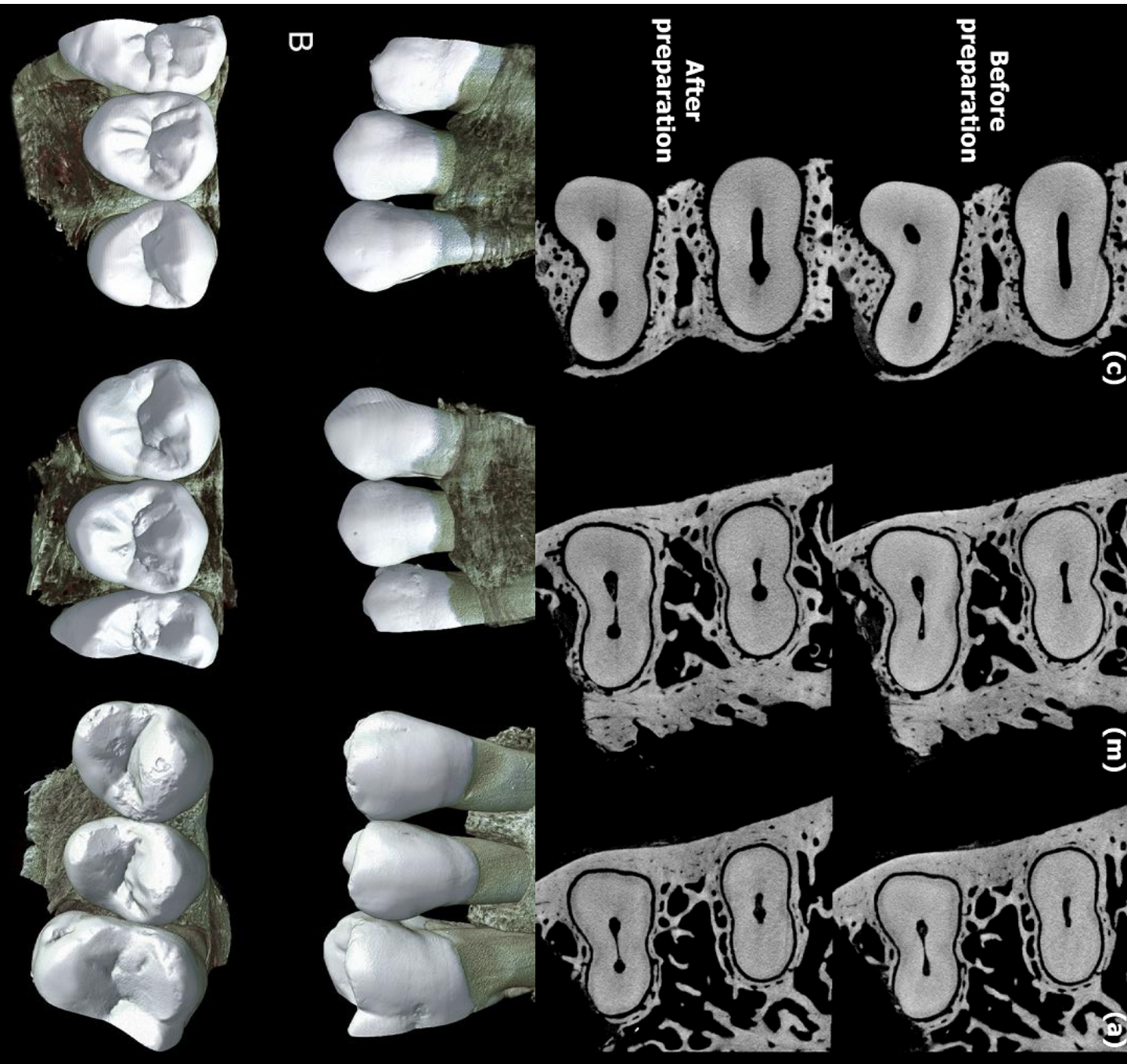
*Gustavo De-Deus, DDS, MSc, PhD,[*] Emmanuel João Nogueira Leal Silva, DDS, MSc, PhD,[*] Juliana Marins, DDS, MSc, PhD,[†] Erick Souza, DDS, MSc, PhD,[‡] Aline de Almeida Neves, DDS, MSc, PhD,[*] Felipe Gonçalves Belladonna, DDS, MSc,[†] Haimon Alves, MSc,[§] Ricardo Tadeu Lopes, MSc, DSc,[§] and Marco Aurélio Versiani, DDS, MSc, PhD[‖]*



# Dentinal Microcrack Development after Canal Preparation: A Longitudinal *in Situ* Micro–computed Tomography Study Using a Cadaver Model

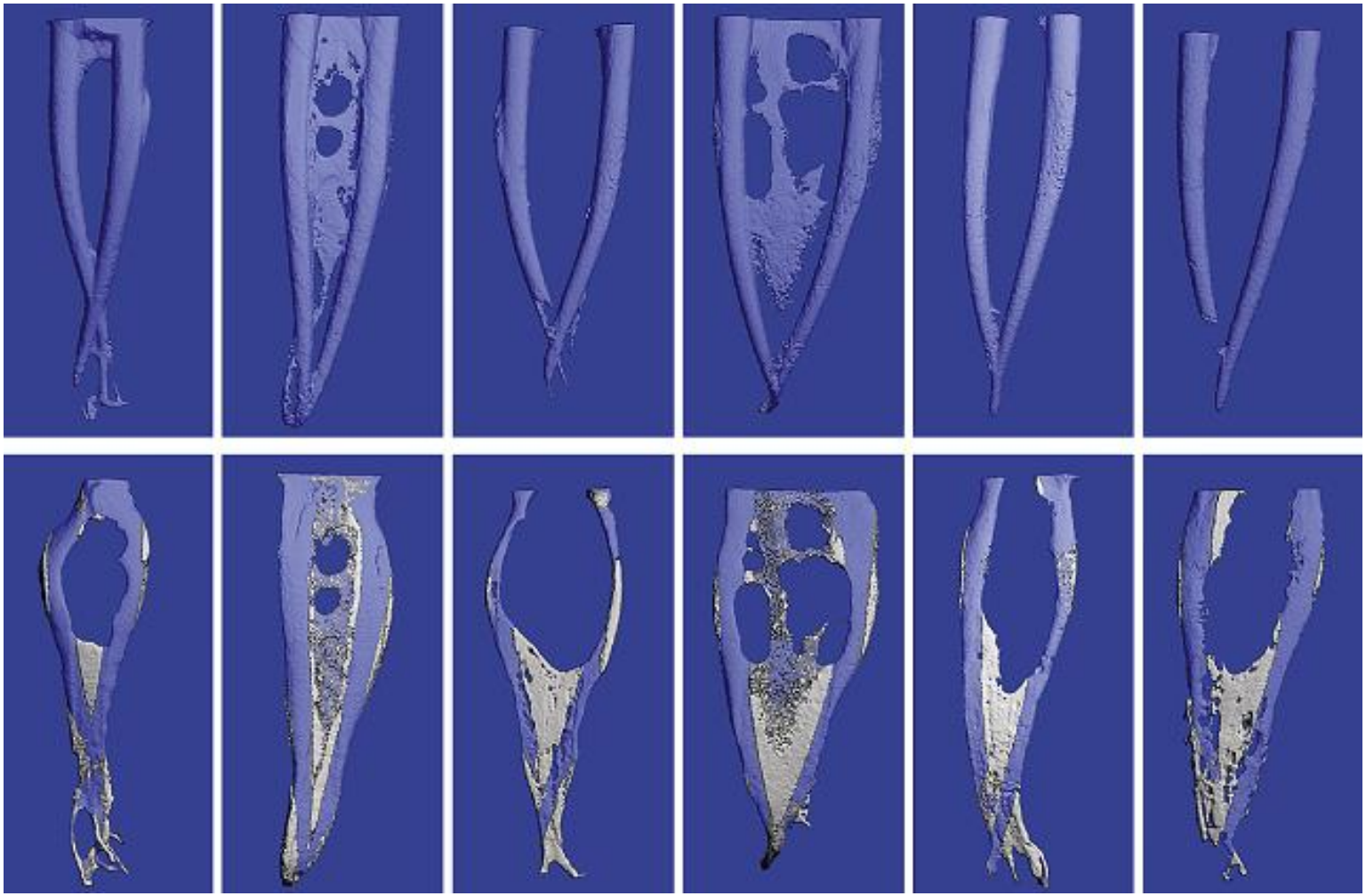
*(J Endod 2017;43:1553–1558)*

*Gustavo De-Deus, DDS, MSc, PhD,[*] Júlio César de Azevedo Carvalhal, DDS, MSc, PhD,[†] Felipe Gonçalves Belladonna, DDS, MSc,[*] Emmanuel João Nogueira Leal Silva, DDS, MSc, PhD,[‡] Ricardo Tadeu Lopes, DDS, MSc, PhD,[§] Renato Evando Moreira Filho, MD, MSc, PhD,[‖] Erick Miranda Souza, DDS, MSc, PhD,[¶] José Claudio Provenzano, DDS, MSc, PhD,[†] and Marco Aurélio Versiani, DDS, MSc, PhD[#]*

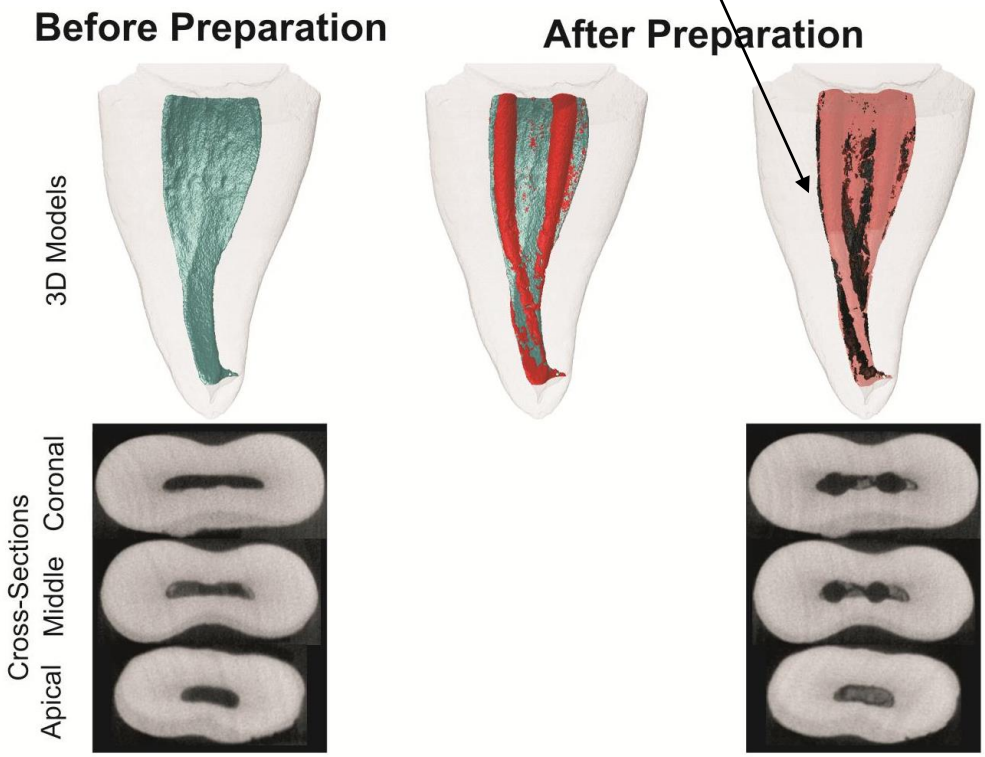


# Hard-Tissue Debris Accumulation Analysis by High-Resolution Computed Tomography Scans

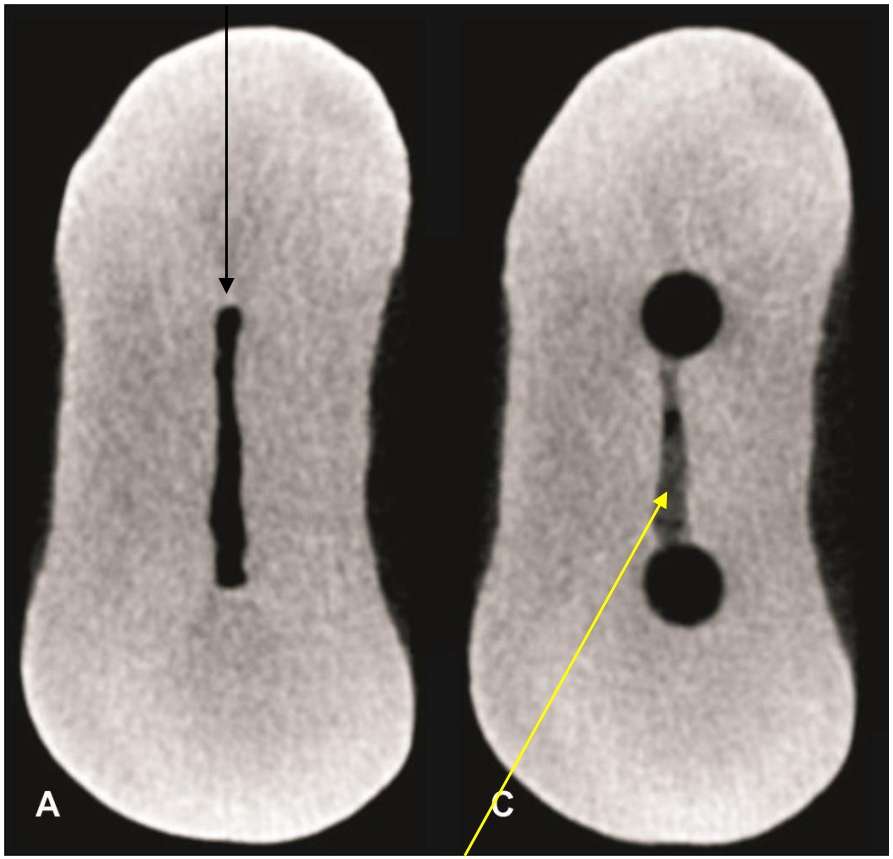
*Frank Paqué, Dr med dent,* Andres Laib, Dr sc nat,† Hanspeter Gautschi,‡ and Matthias Zehnder, PD, Dr med dent, PhD**



Tissue Debris Packed in Isthmus Area (in black)



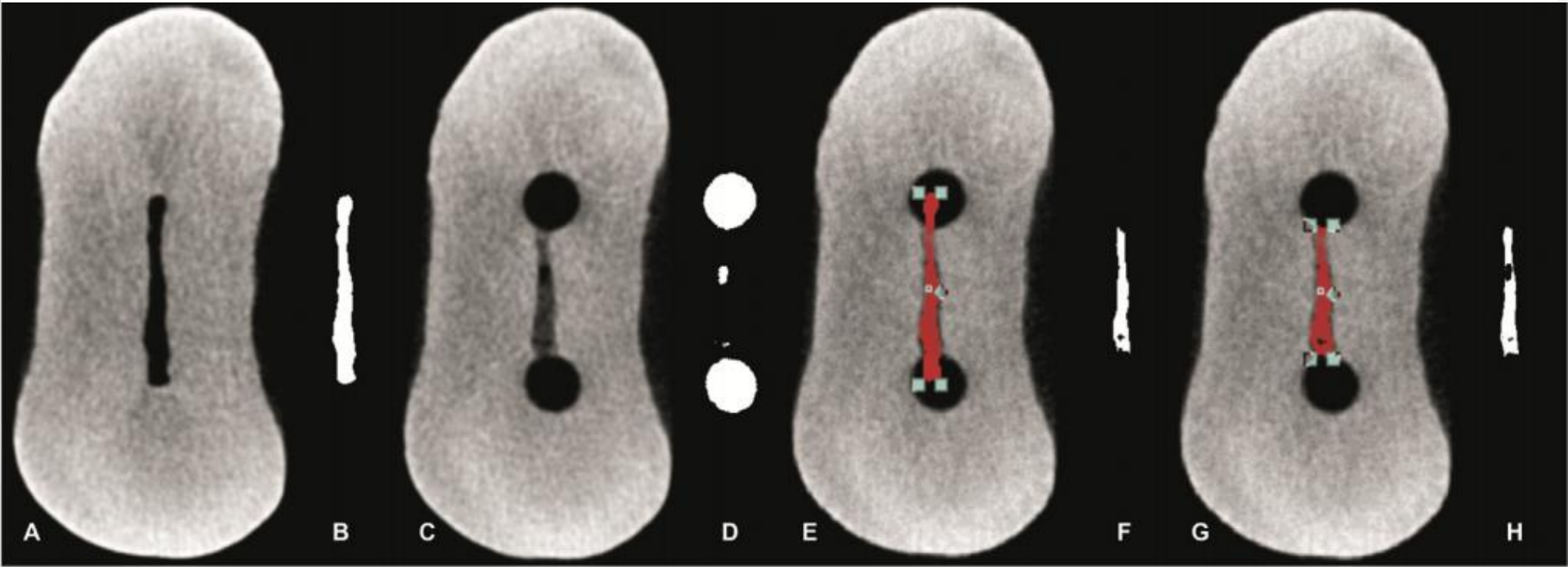

Complex Anatomy (Isthmus)




Hard Tissue Debris Packed in Isthmus Area After Preparation

# Supplementary Steps for Removing Hard Tissue Debris from Isthmus-containing Canal Systems

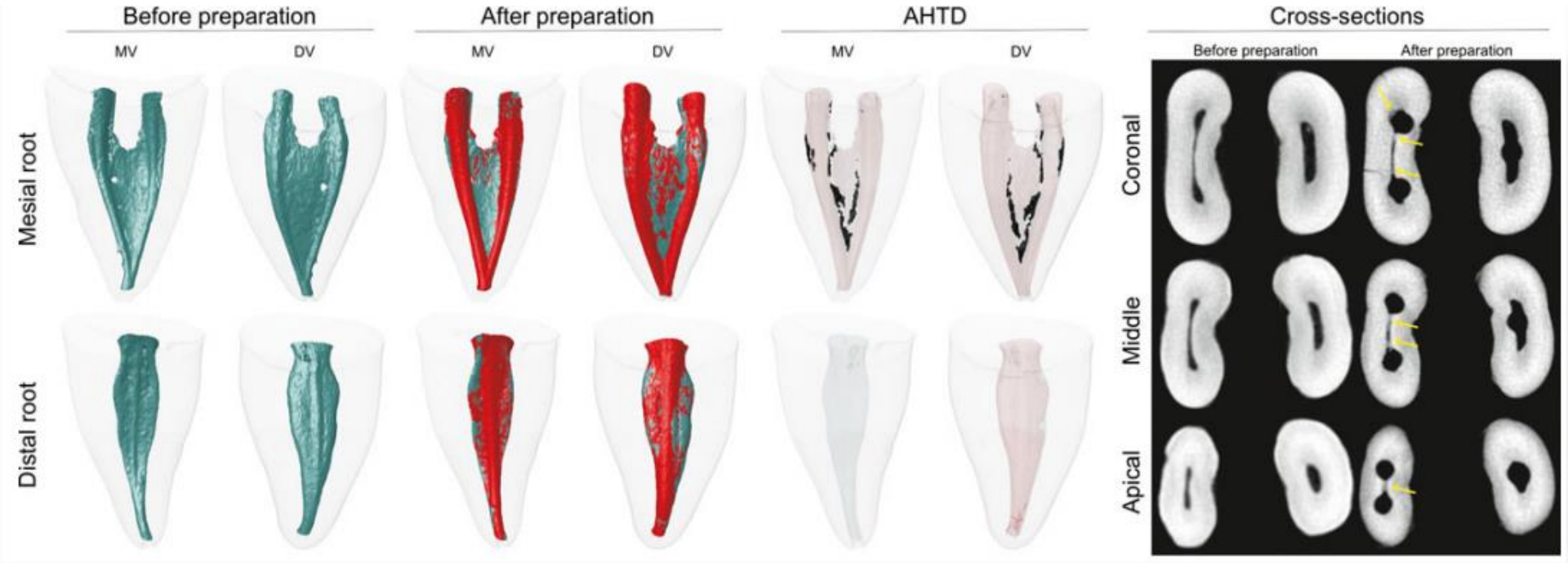
*Ali Keleş, PhD,* Hatice Alçin, PhD,† Manoel D. Sousa-Neto, PhD,‡ and Marco A. Versiani, PhD‡*




(A) Mesial root canal before preparation
(B) Segmentation of the root canal system in A
(C) Root canals after preparation (presence of debris in the isthmus area)
(D) Segmentation of areas without debris after canal preparation
(E) Superimposition of the segmented canal before preparation over the prepared canal
(F) Segmentation of the isthmus area
(G) Superimposition of the segmented area over the isthmus
(H) Segmentation of the hard tissue debris in the isthmus area.

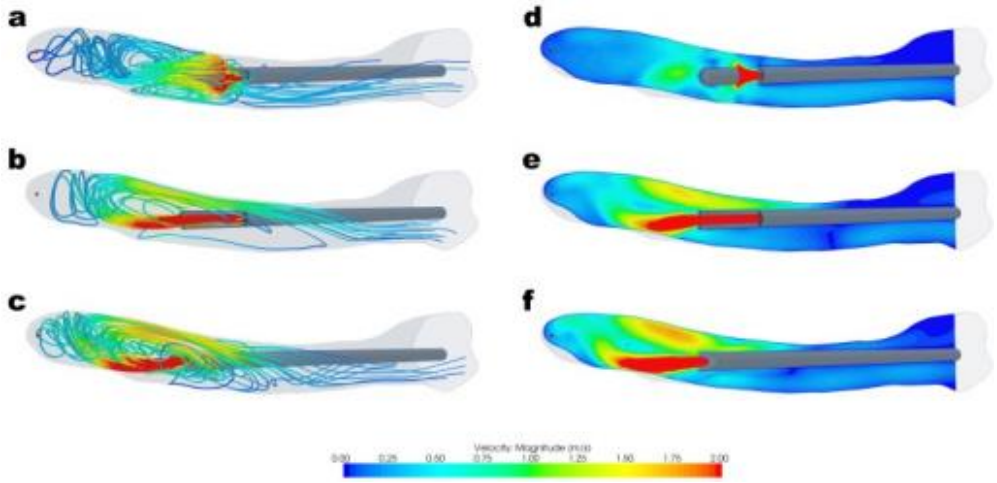
# Micro-CT evaluation of the efficacy of hard-tissue removal from the root canal and isthmus area by positive and negative pressure irrigation systems

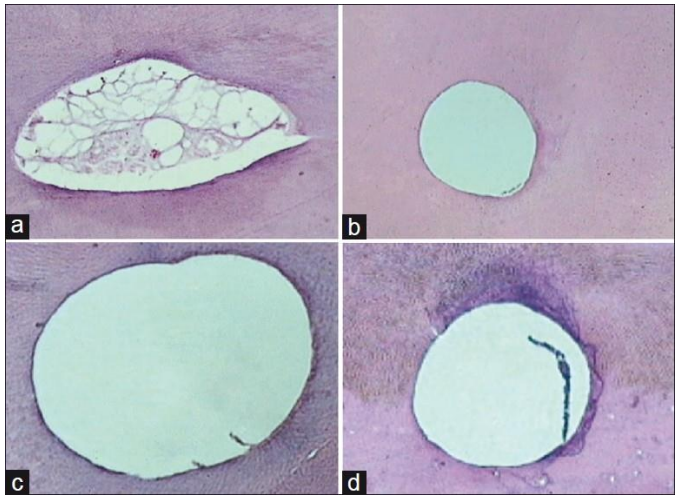
M. A. Versiani[1], F. R. F. Alves[2], C. V. Andrade-Junior[3], M. F. Marceliano-Alves[2], J. C. Provenzano[2], I. N. Rôças[2], M. D. Sousa-Neto[1] & J. F. Siqueira Jr[2]

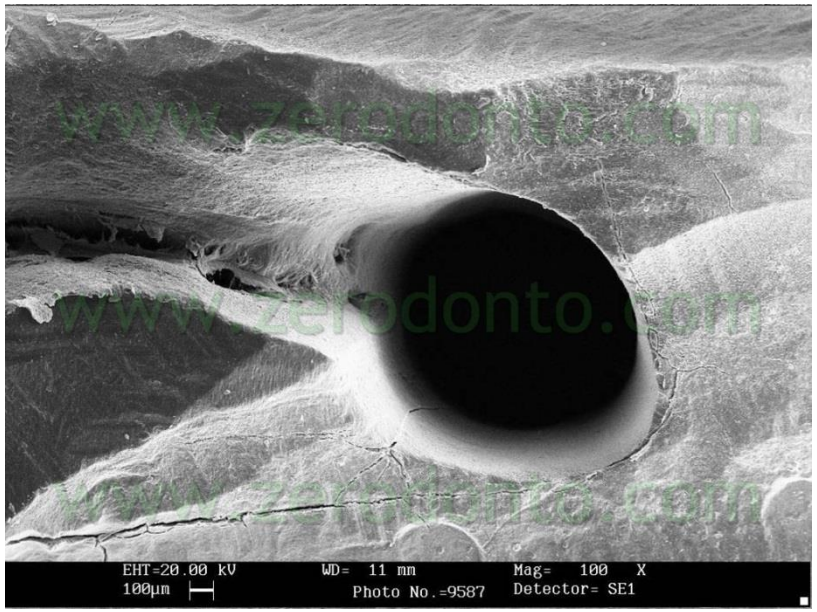


# Root Canal Irrigation

# Root Canal Irrigation – Conventional Methods



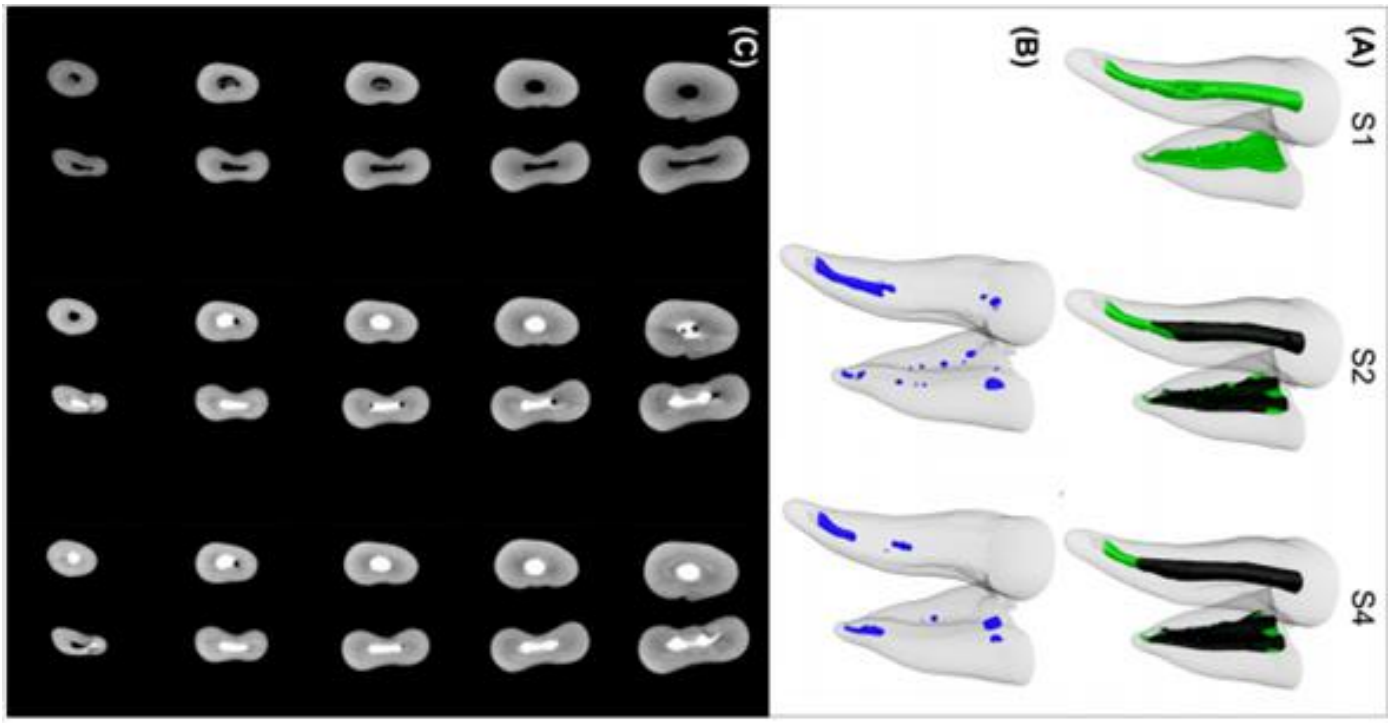

None of them allows a 3D assessment of irrigant spreading

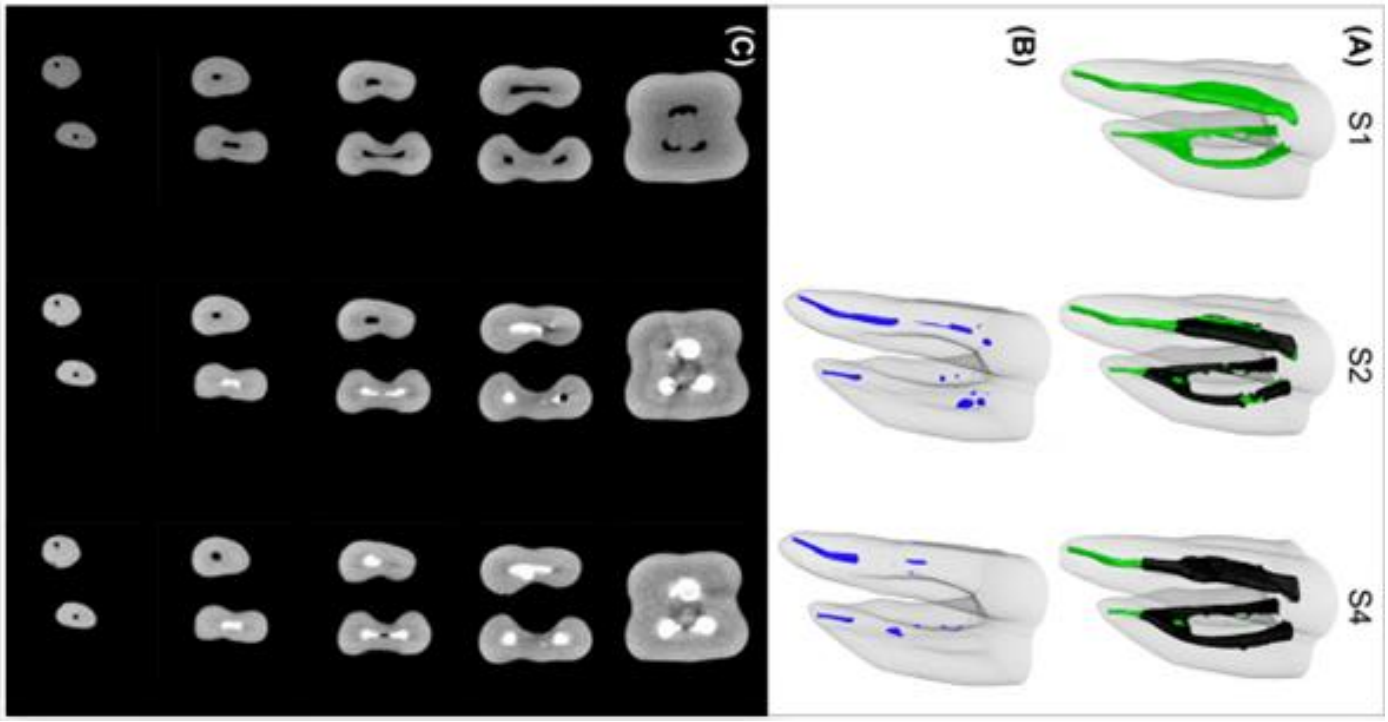
ORIGINAL ARTICLE

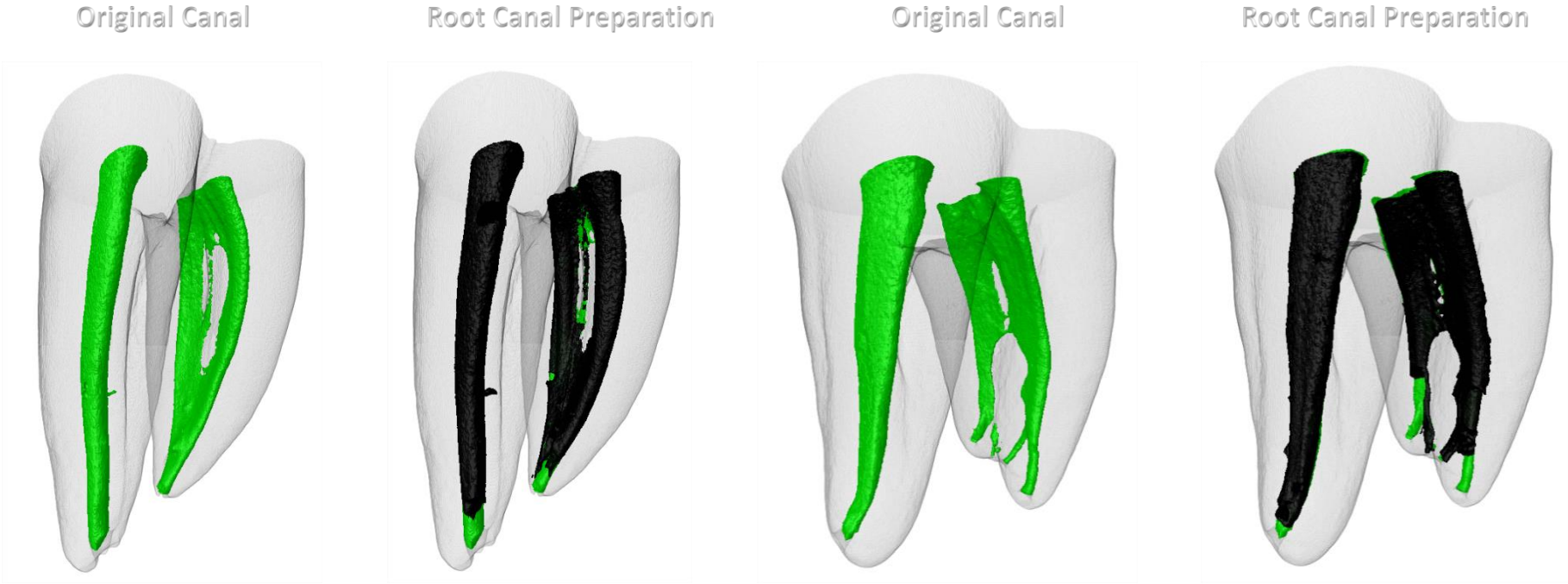
# 3D mapping of the irrigated areas of the root canal space using micro-computed tomography

Marco Aurélio Versiani · Gustavo De-Deus · Jorge Vera · Erick Souza · Liviu Steier · Jesus D. Pécora · Manoel D. Sousa-Neto

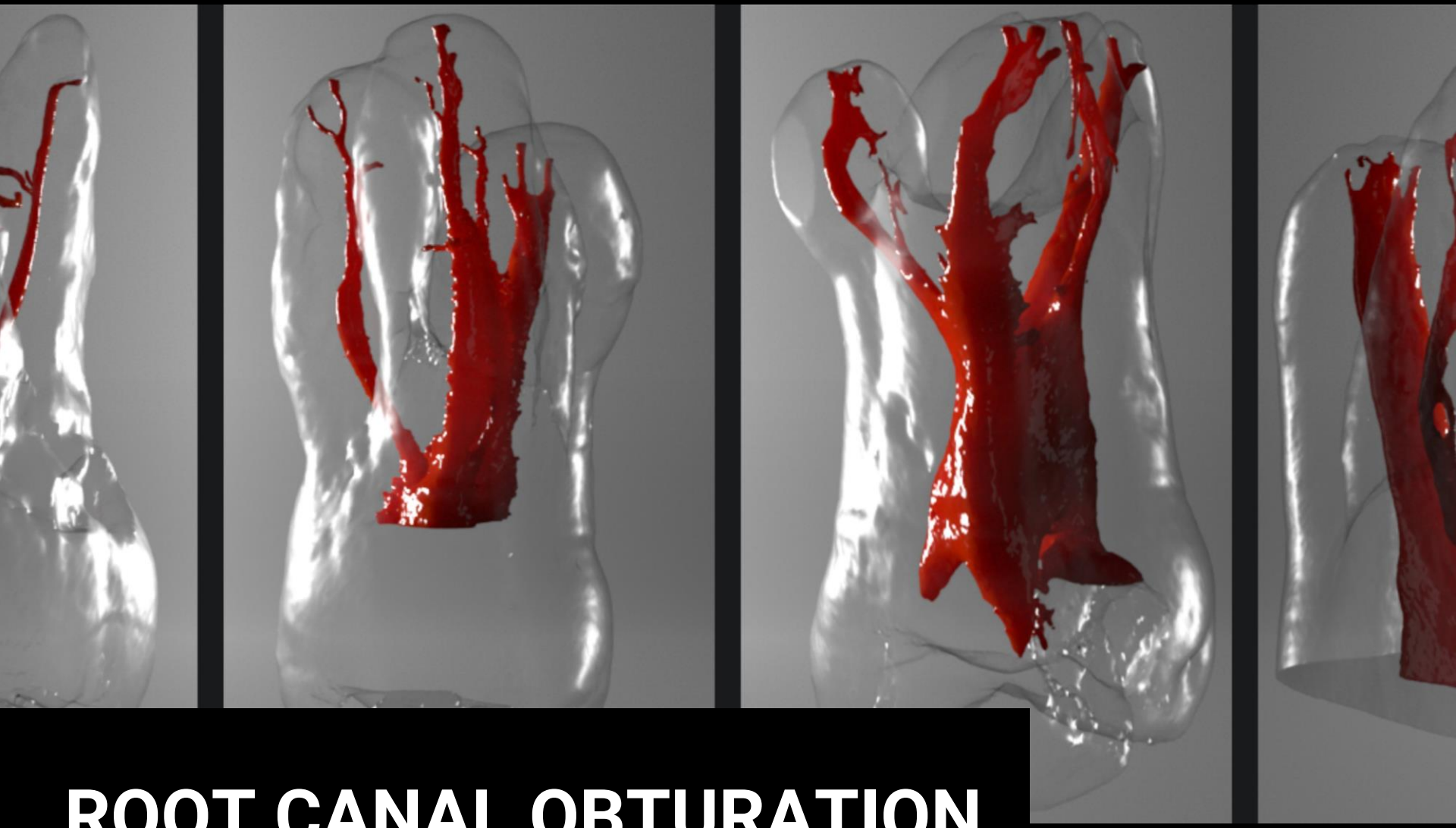
Clin Oral Invest
DOI 10.1007/s00784-014-1311-5



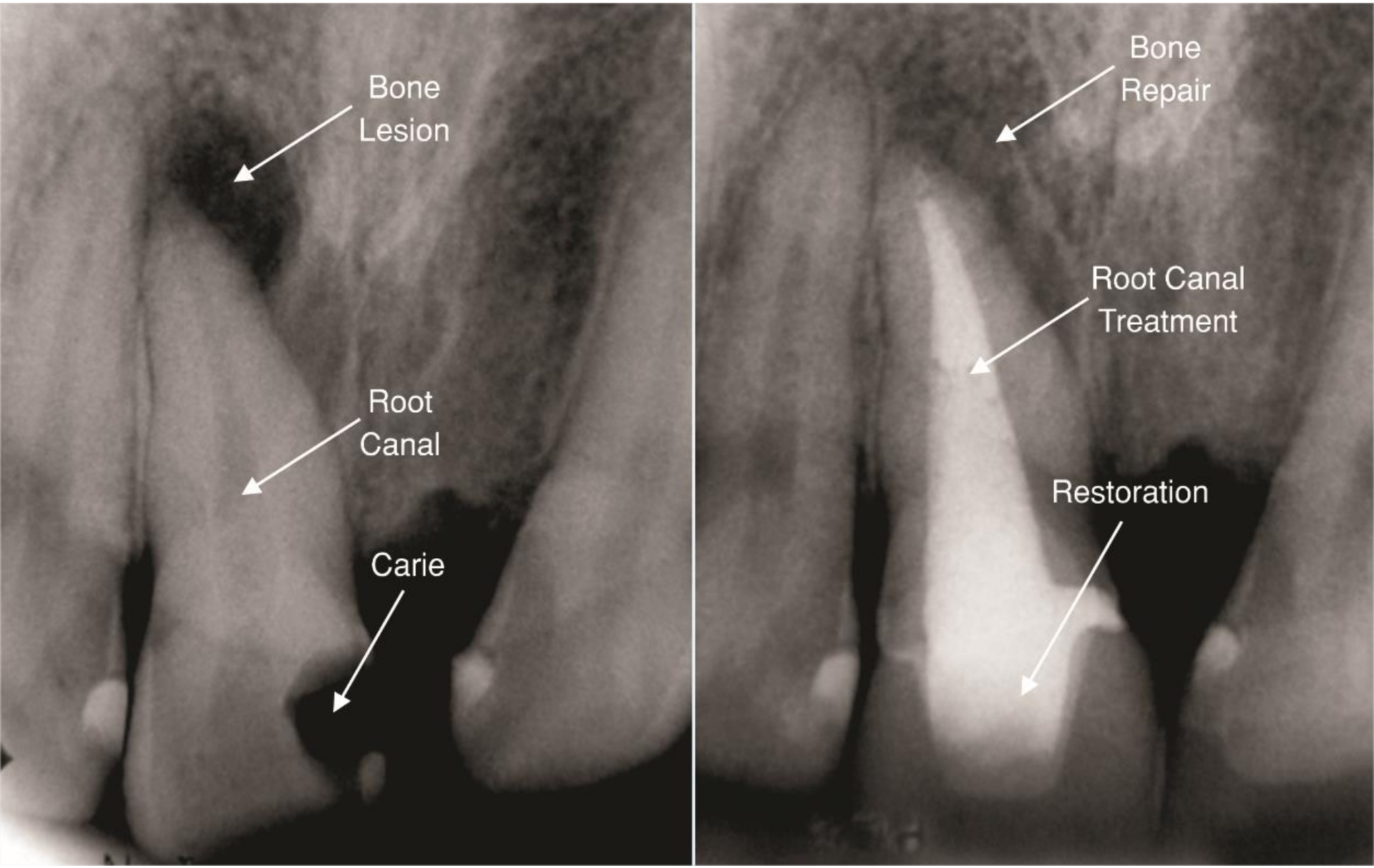



| Volume ($mm^3$) | | | | | Surface area ($mm^2$) | | |
|---|---|---|---|---|---|---|---|
| Scanning steps | | Root canal | Contrast solution | Irrigant-free areas | Root canal | Touched by the contrast solution | Untouched by the contrast solution |
| Mesial root | S1 | 4.65 | – | – | 48.62 | – | – |
| | S2 | 6.76 | 5.63 (83.3 %) | 1.13 (16.7 %) | 59.27 | 52.23 (88.1 %) | 7.04 (11.9 %) |
| | S4 | 9.94 | 8.83 (88.8 %) | 1.11 (11.2 %) | 66.26 | 58.03 (87.6 %) | 8.23 (12.4 %) |
| Distal root | S1 | 5.76 | – | – | 48.30 | – | – |
| | S2 | 7.46 | 5.32 (71.3 %) | 2.14 (28.7 %) | 55.46 | 49.16 (88.6 %) | 6.30 (11.4 %) |
| | S4 | 11.26 | 9.15 (81.3 %) | 2.11 (18.7 %) | 61.84 | 54.94 (88.8 %) | 6.90 (11.2 %) |



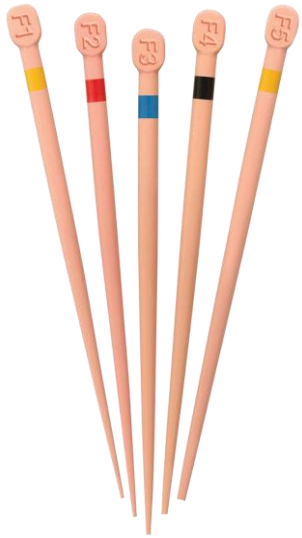
# ROOT CANAL OBTURATION

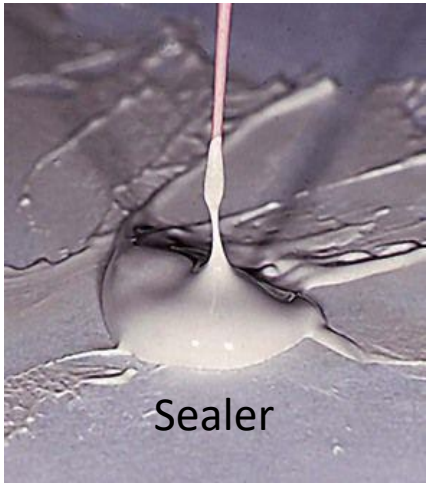
# Root Canal Obturation



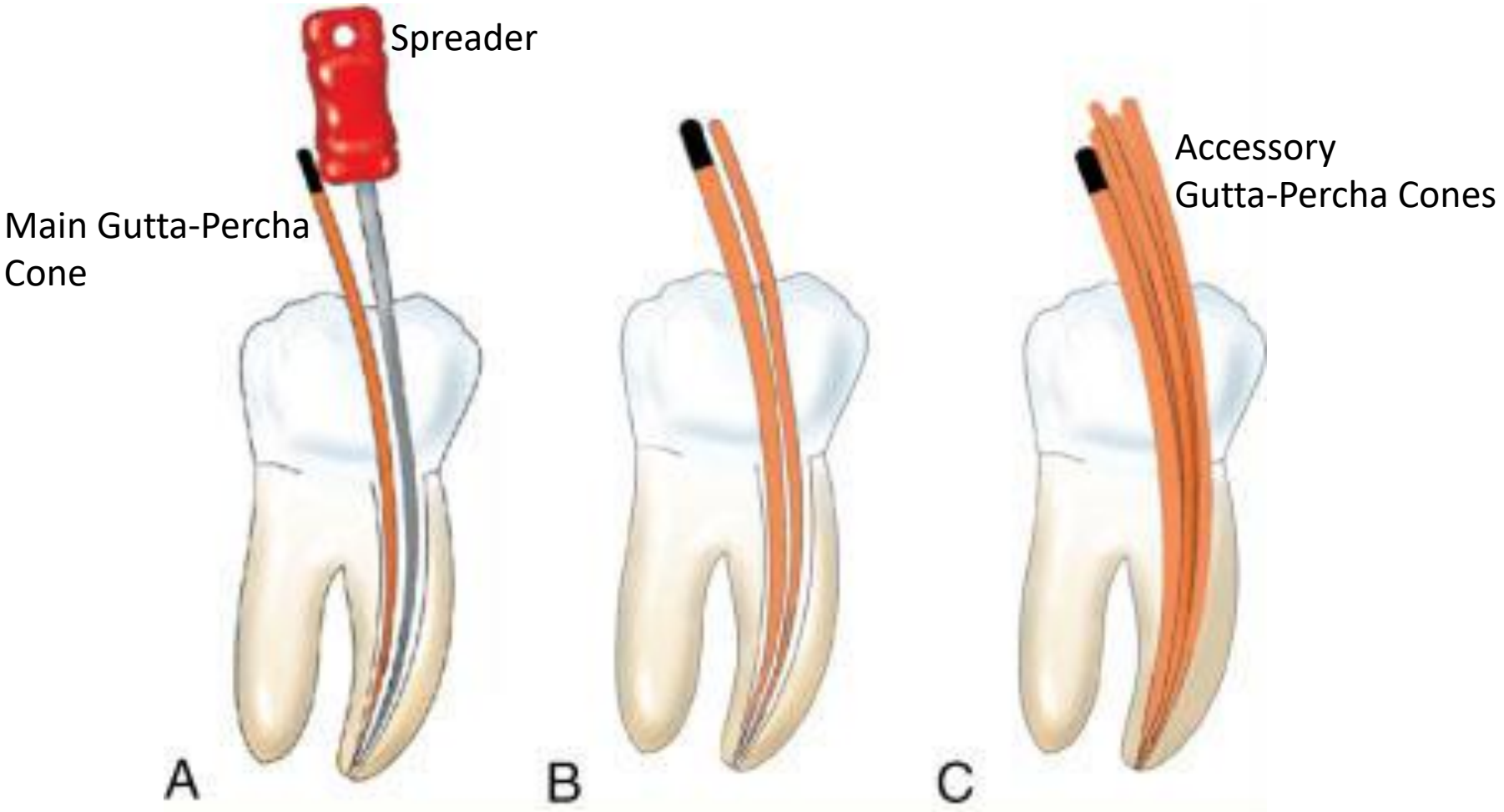

Versiani & Keles 2018

Core
(Gutta-Percha)

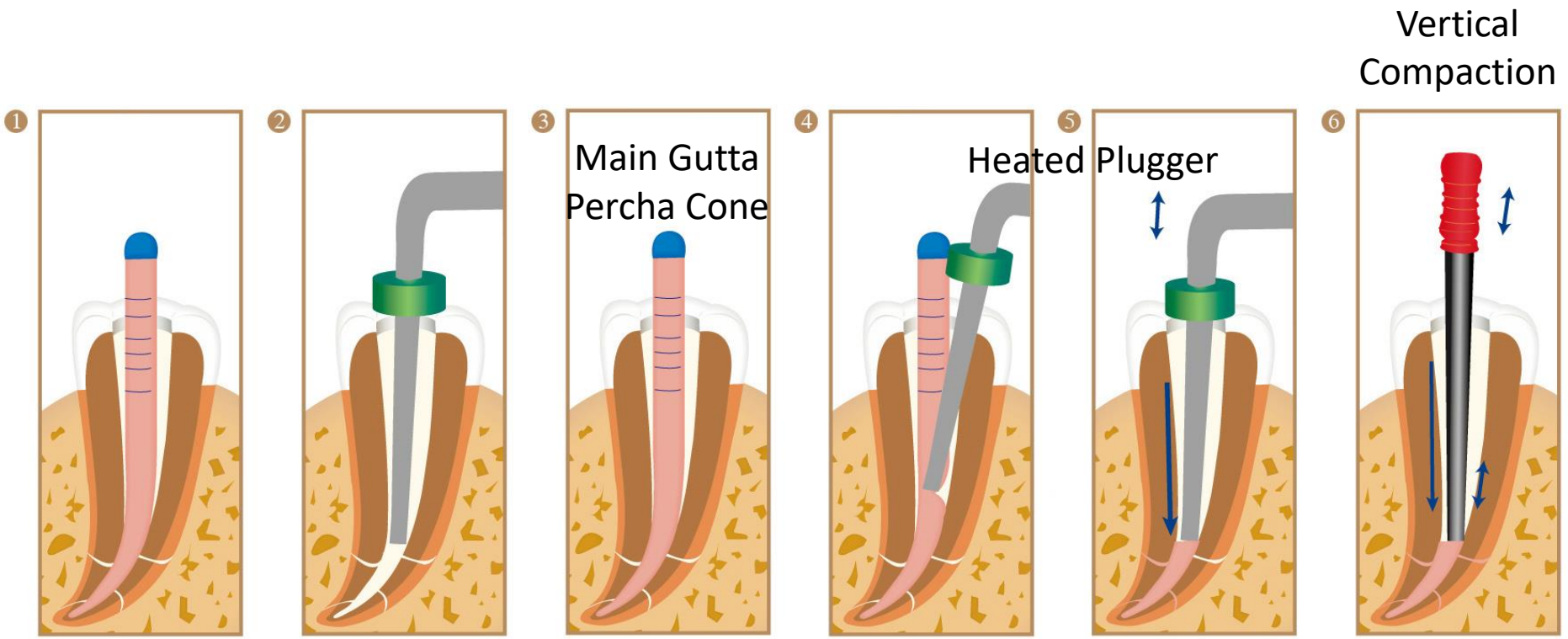


# COLD LATERAL COMPACTION



# WARM VERTICAL COMPACTION



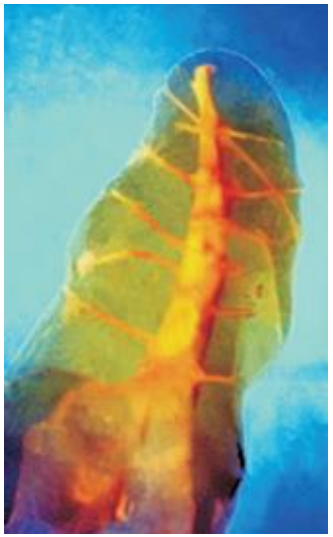
# COLD LATERAL COMPACTION

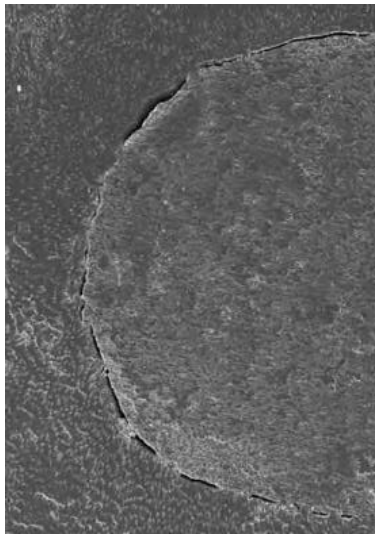
# X

# WARM VERTICAL COMPACTION

Diaphanization

SEM

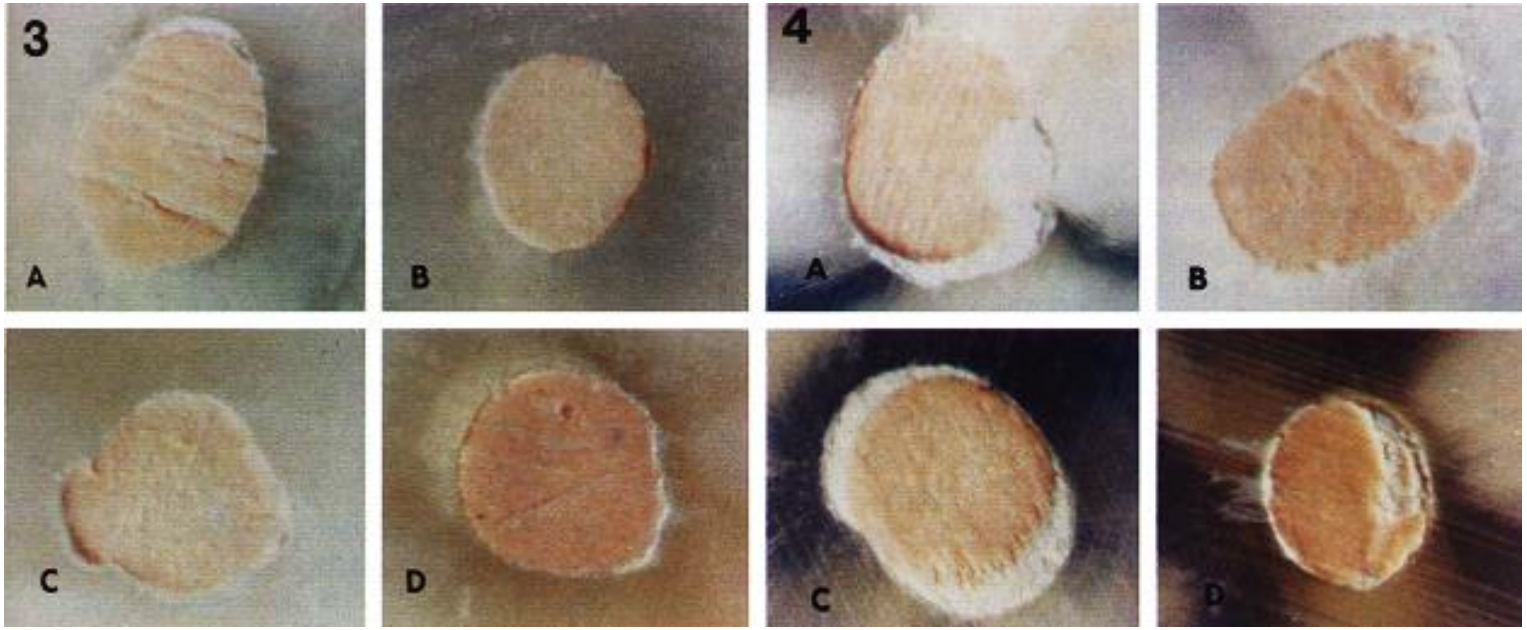




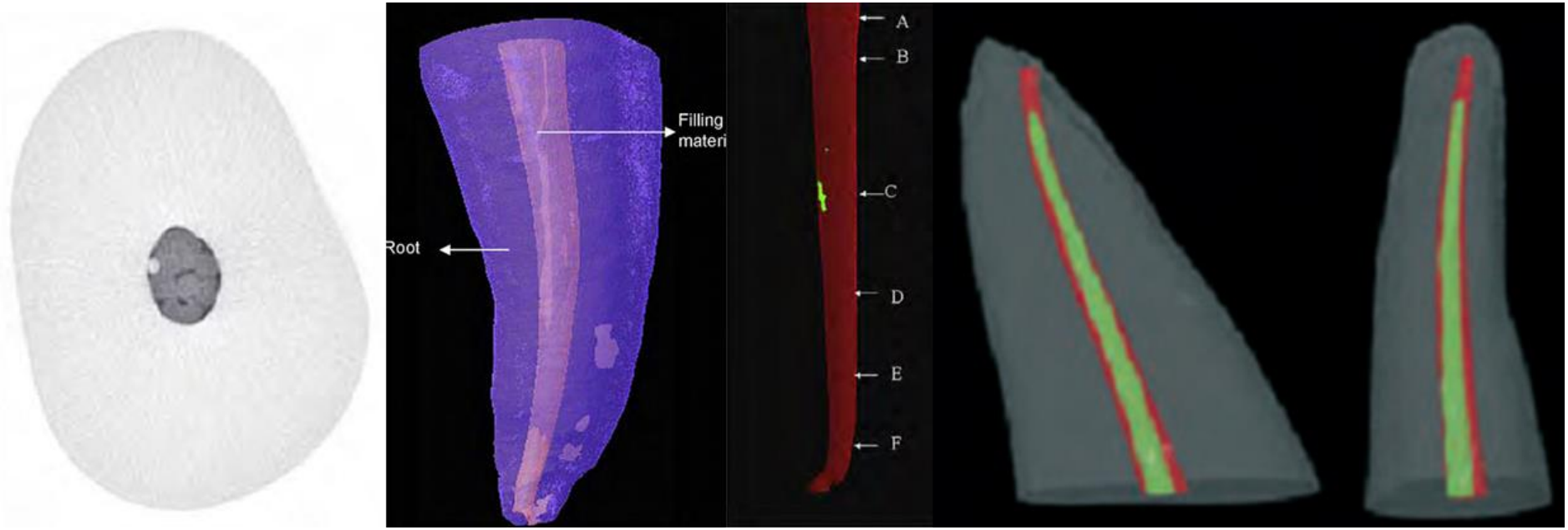
Leakage Test

Radiograph

Sectioning



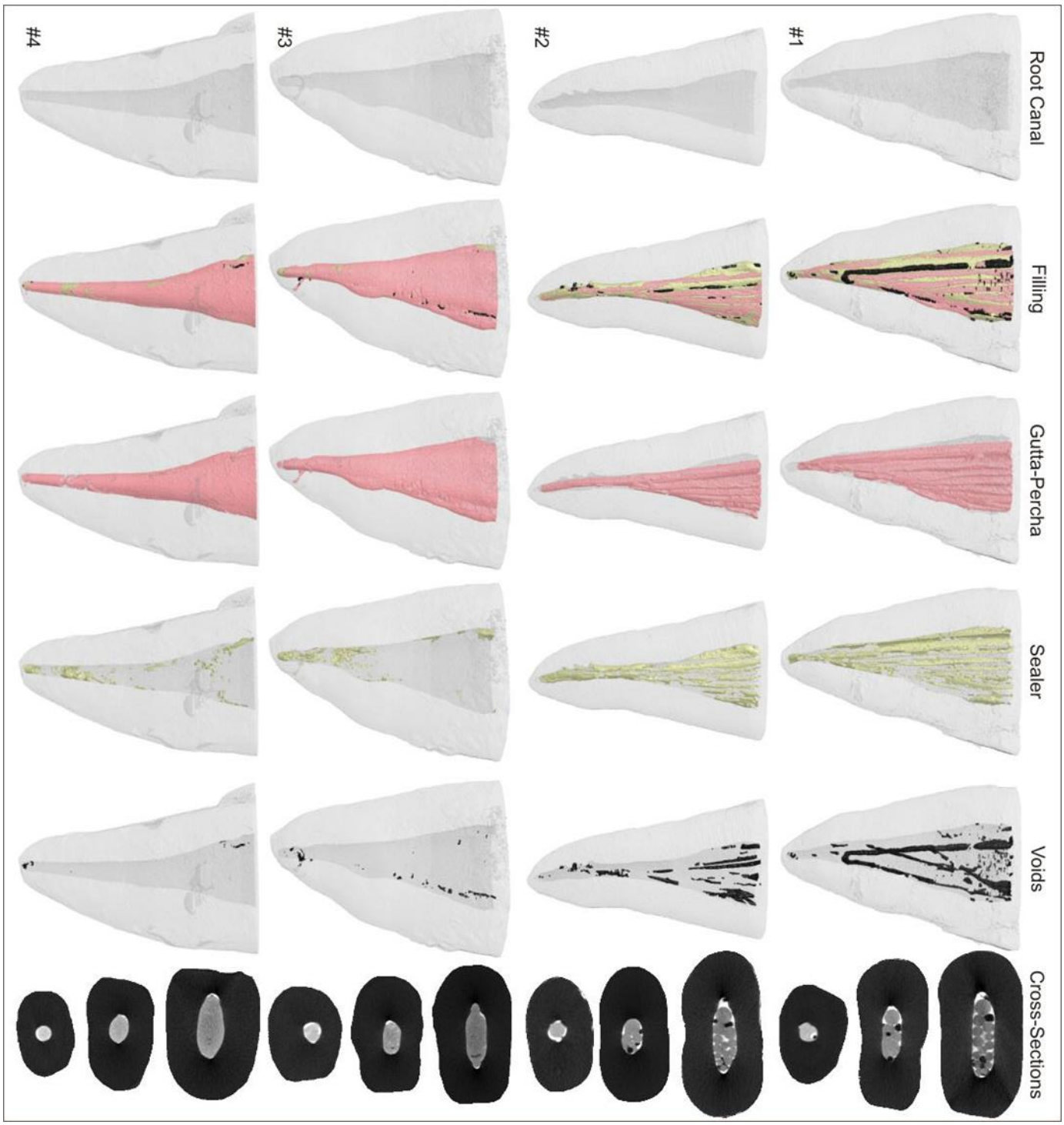
# MICRO-CT AND ROOT CANAL OBTURATION

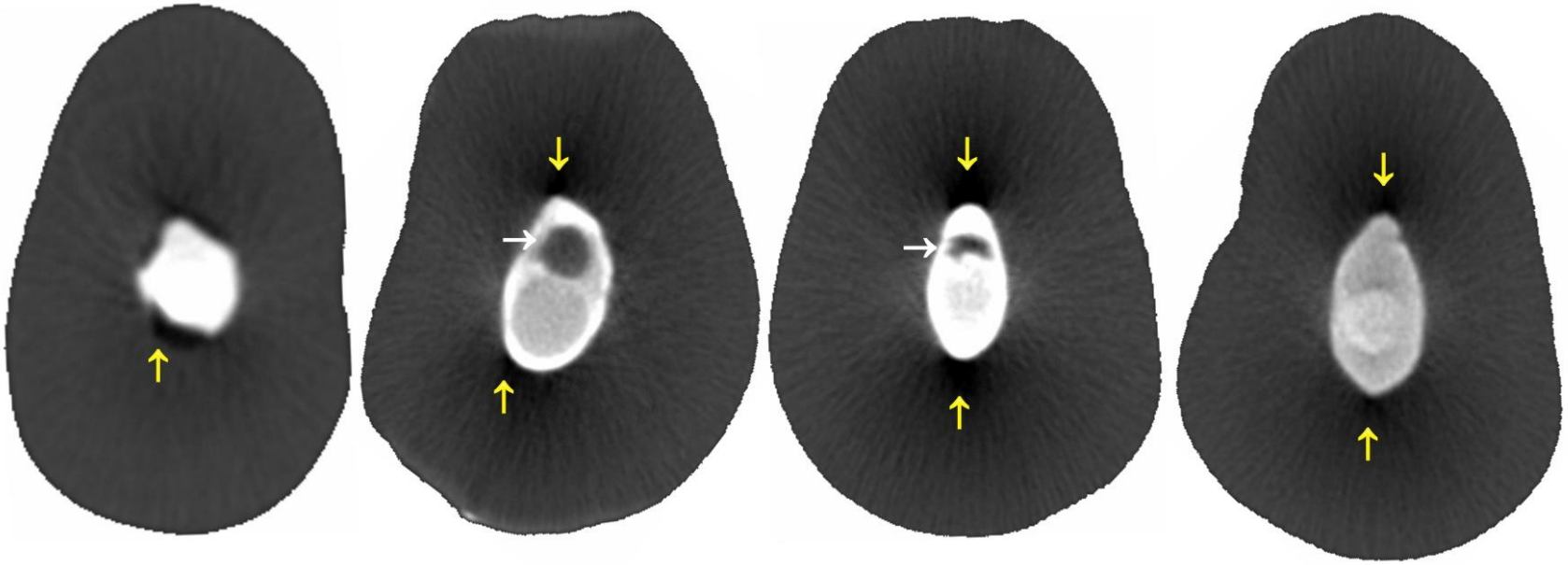



Jung et al., 2005

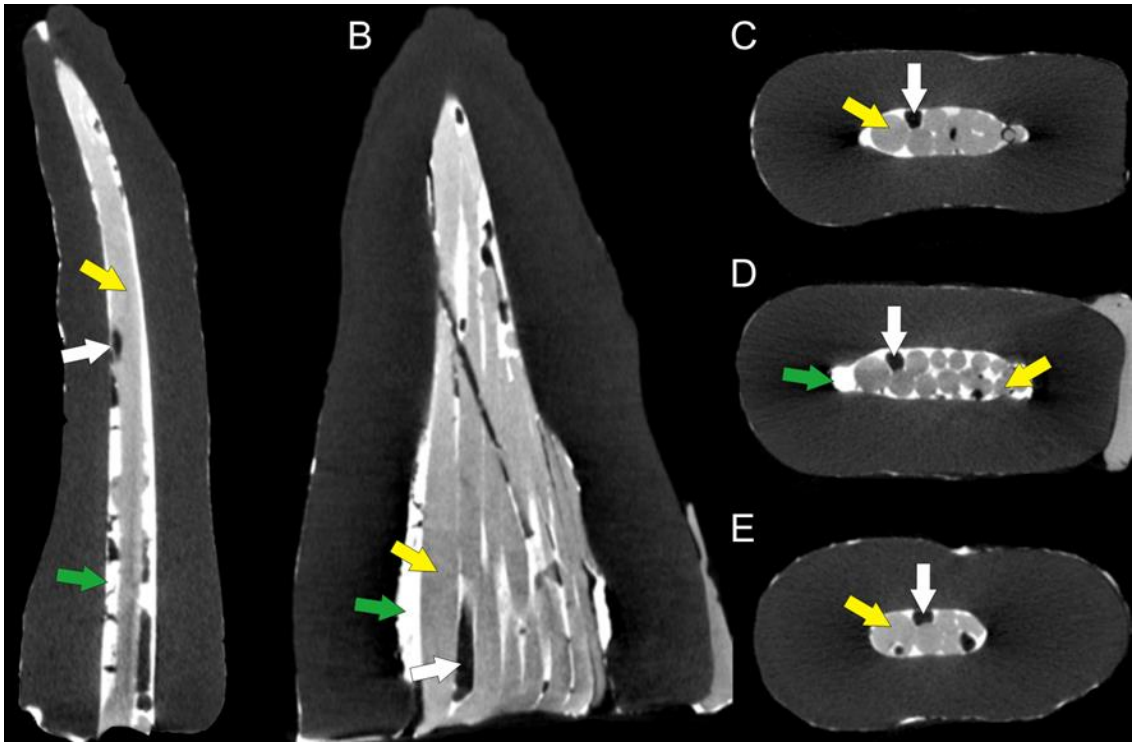
# Micro-CT evaluation of root filling quality in oval-shaped canals

A. Keleş[1], H. Alcin[1], A. Kamalak[1] & M. A. Versiani[2]

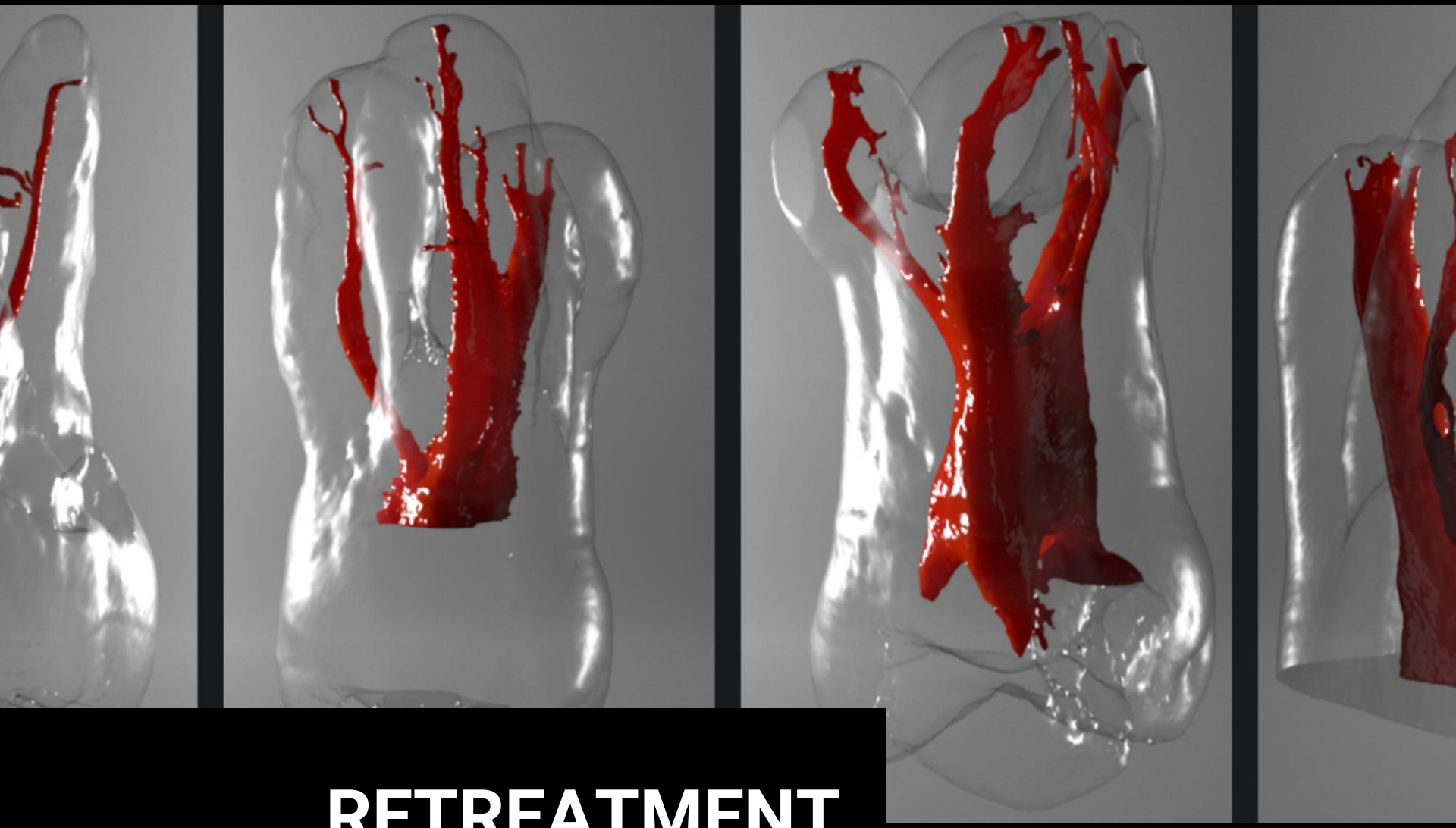




Low Energy Scanning

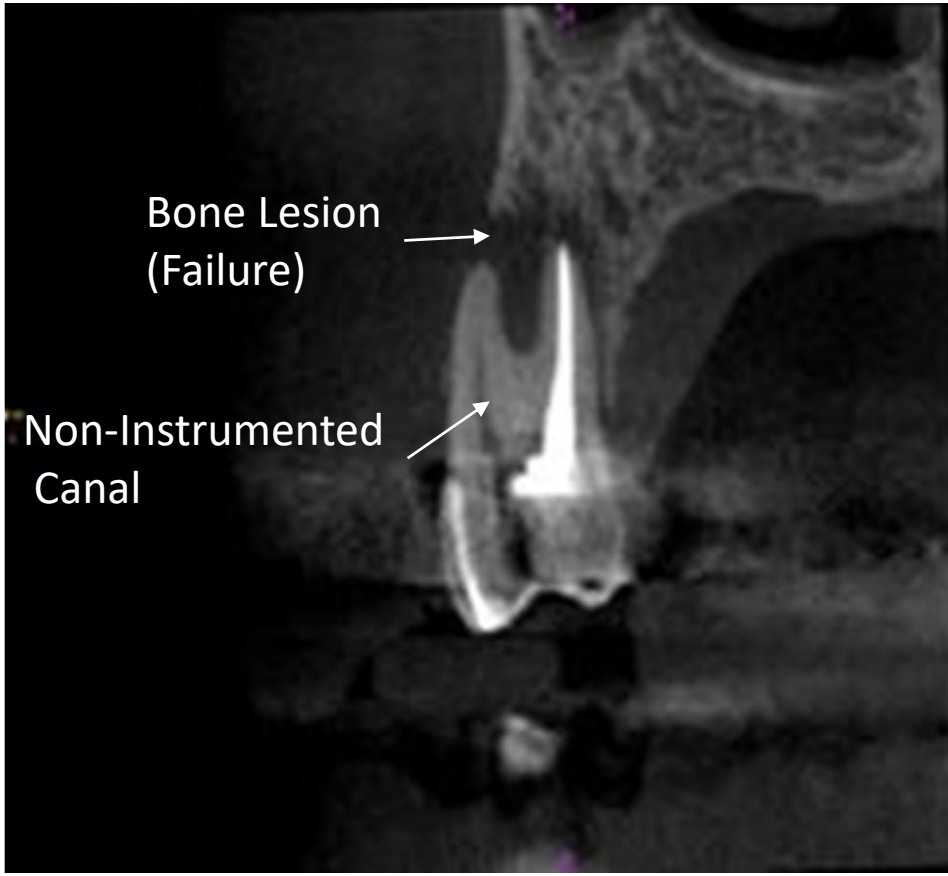



High Energy Scanning



# RETREATMENT

# Root Canal Failure

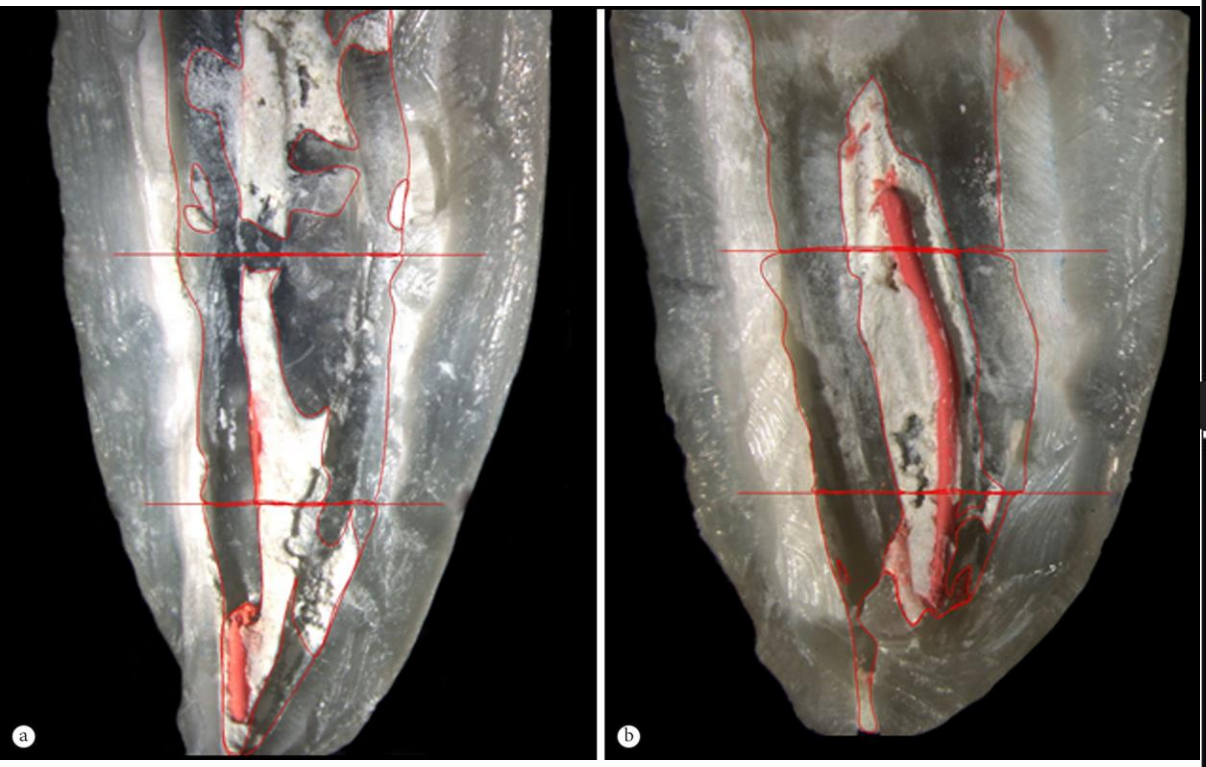



# Non-surgical Retreatment

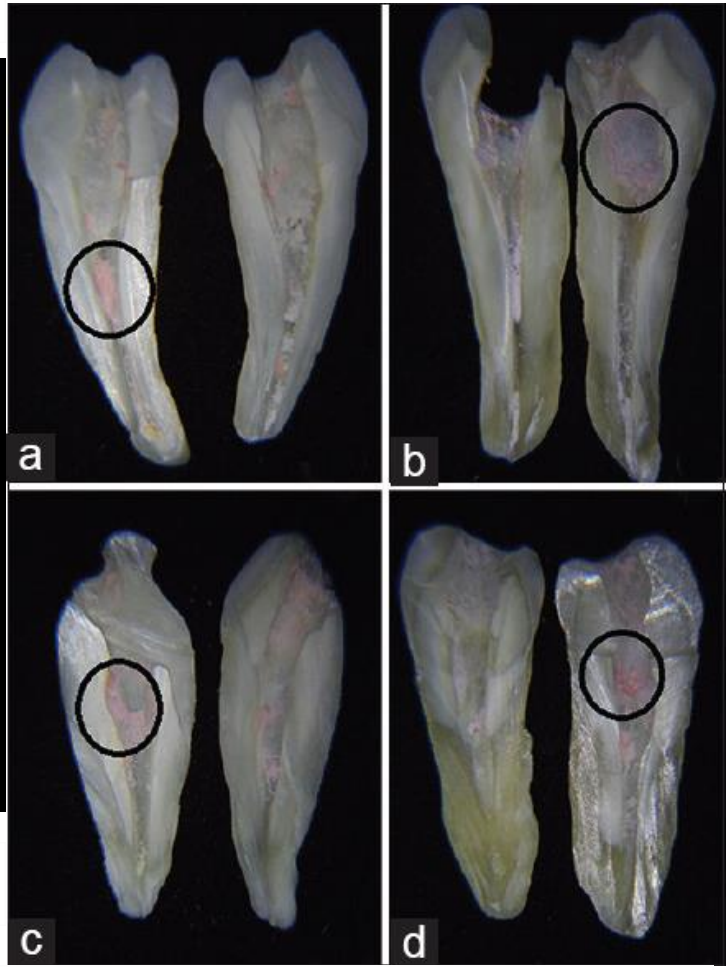
Dr. C. Ruddle
Retreatment Video

# Conventional Methods

## Efficacy of passive ultrasonic irrigation in removing root filling material during endodontic retreatment



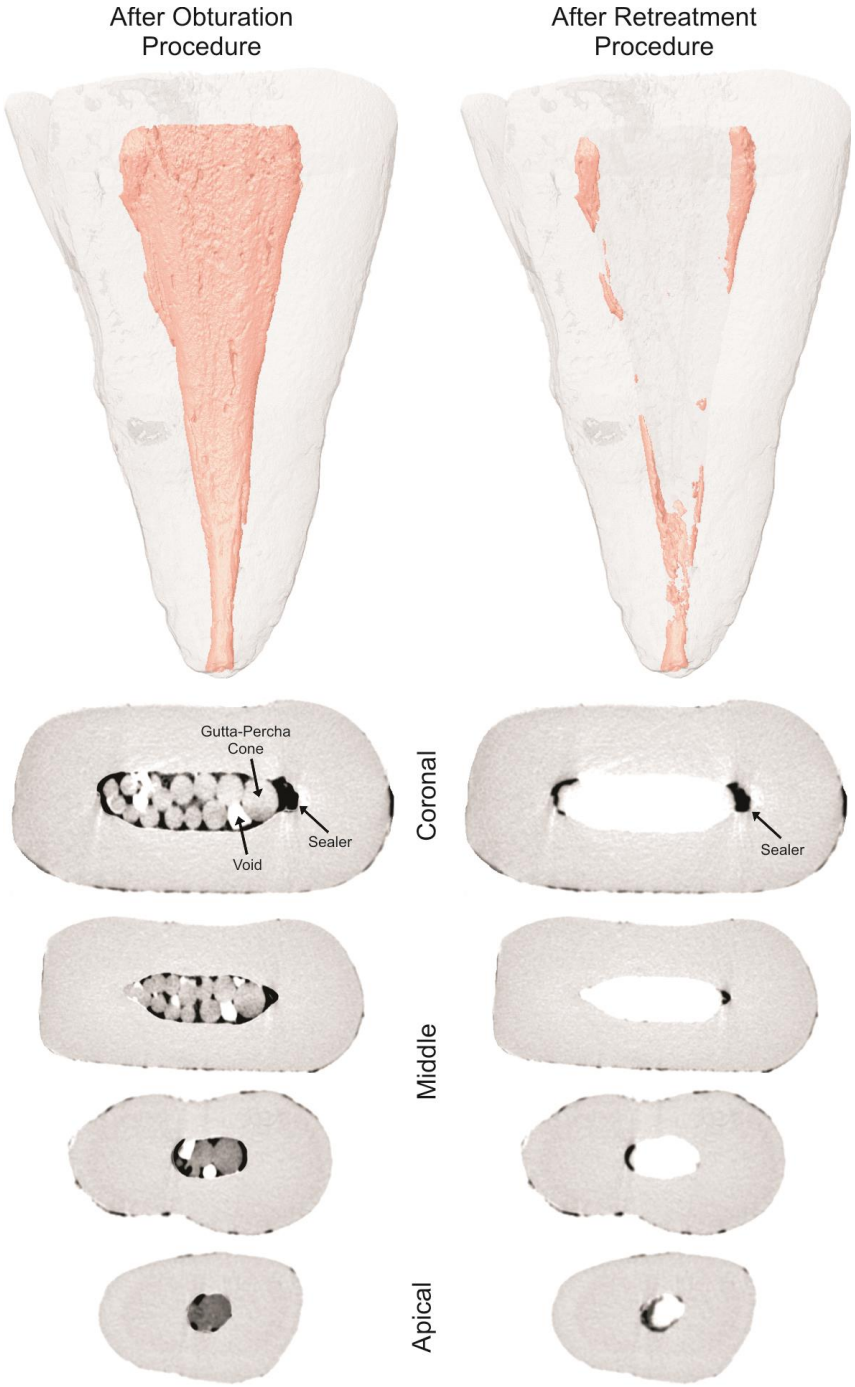

Carina MICHELON[a*], Marina FRIGHETTO[a], Pauline Mastella LANG[a], Mariana De Carlo BELLO[a], Rafael PILLAR[a], Geraldo Fagundes SERPA[a], Carlos Alexandre Souza BIER[a]




**Year** : 2015 | **Volume** : 9 | **Issue** : 2 | **Page** : 234-239

## Root canal retreatment using reciprocating and continuous rotary nickel-titanium instruments

Patricia Fonseca de Souza[1], Leonardo Cantanhede Oliveira Goncalves[1], Andre Augusto Franco Marques[1], Emilio Carlos Sponchiado Junior[2], Lucas da Fonseca Roberti Garcia[3], Fredson Marcio Acris de Carvalho[1]



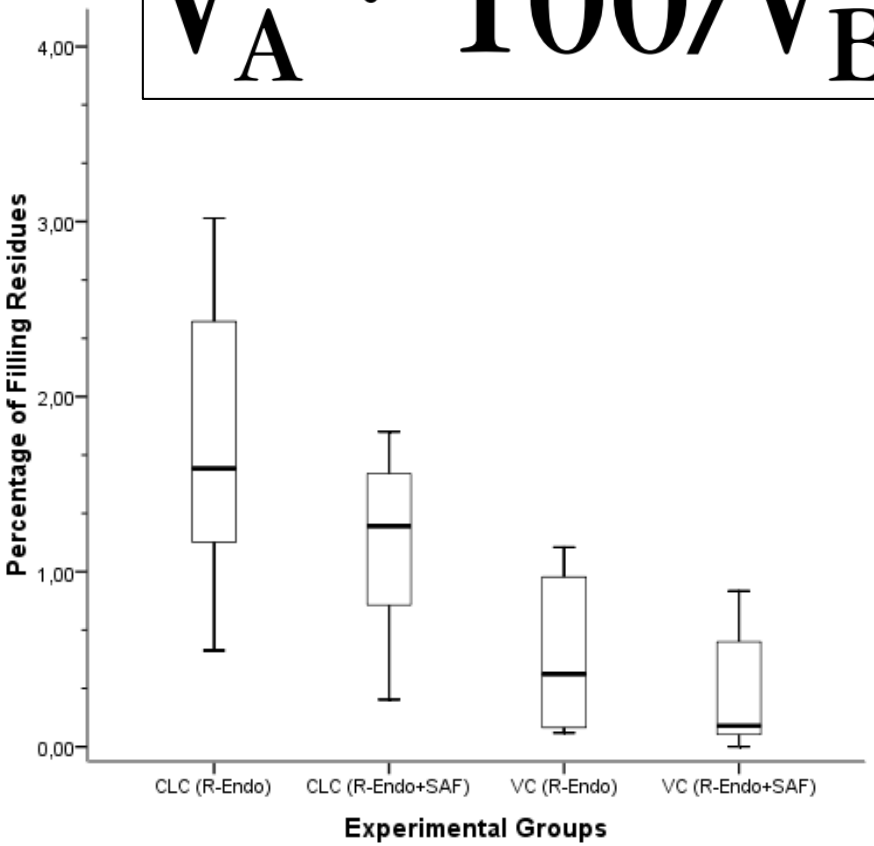

Clin Oral Invest
DOI 10.1007/s00784-013-1086-0

ORIGINAL ARTICLE

# Oval-shaped canal retreatment with self-adjusting file: a micro-computed tomography study

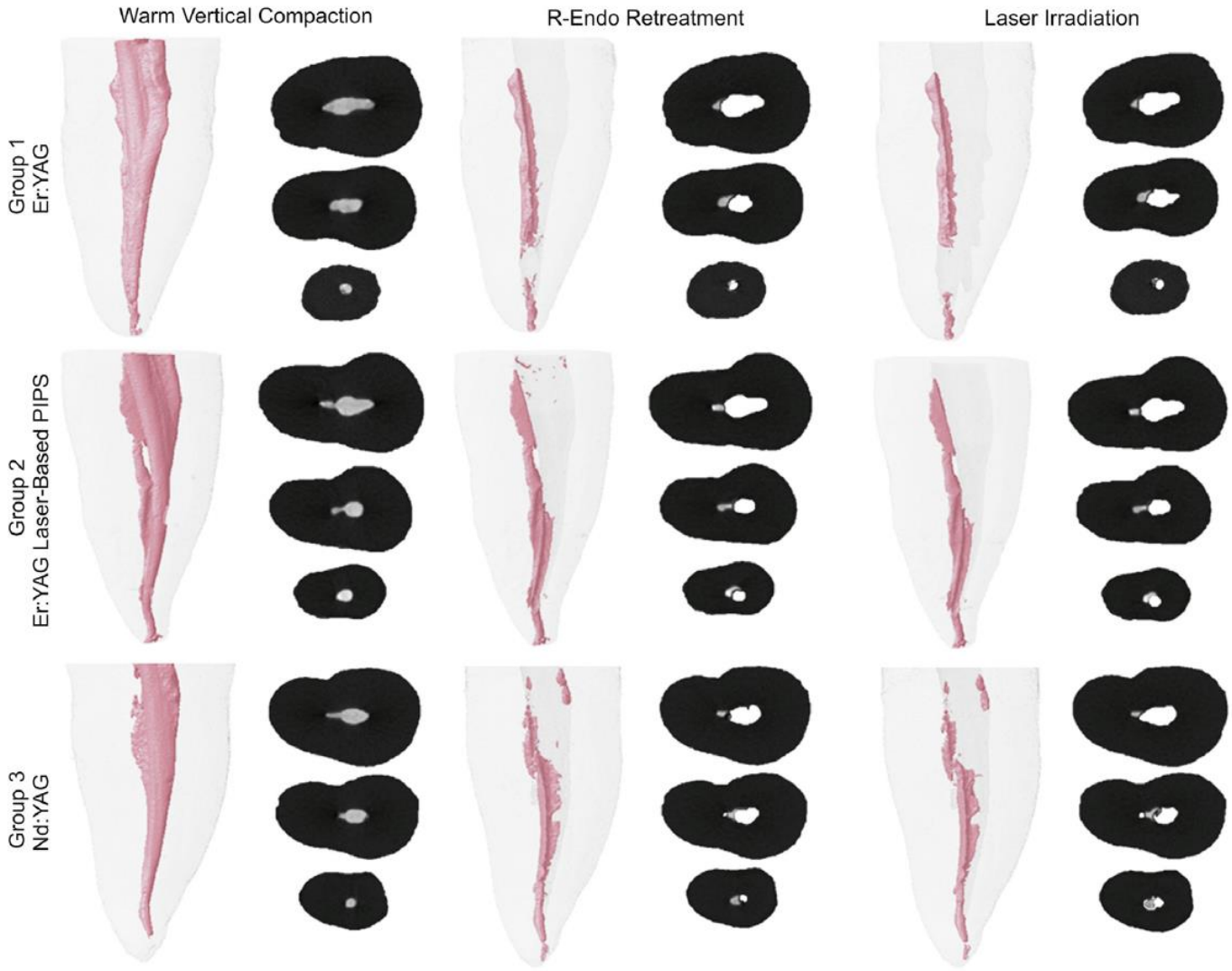
Ali Keleş · Hatice Alcin · Aliye Kamalak · Marco A. Versiani

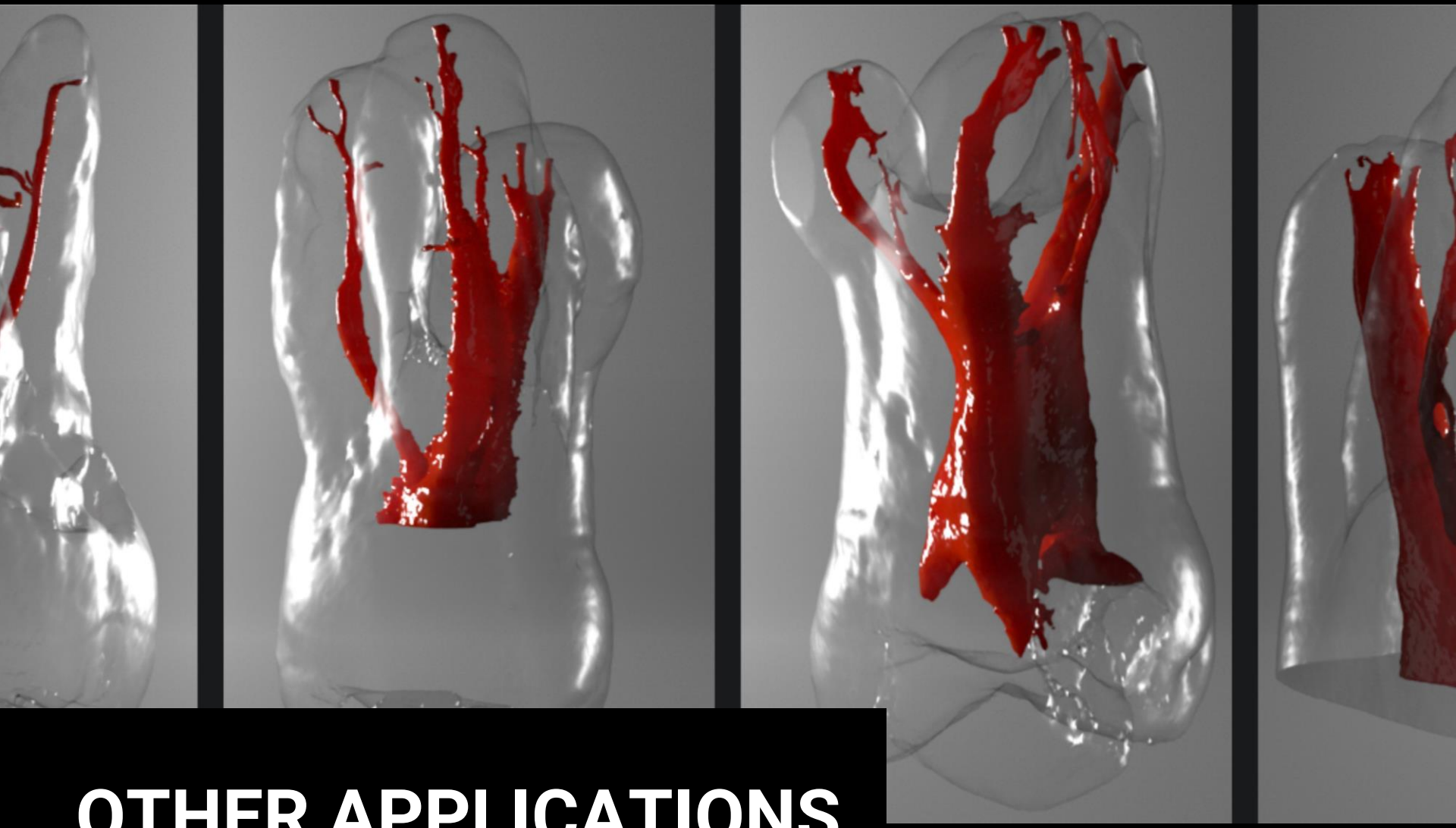
$$V_A * 100 / V_B$$



# Removal of Filling Materials from Oval-shaped Canals Using Laser Irradiation: A Micro–computed Tomographic Study

*Ali Keleş, PhD,[*] Hakan Arslan, PhD,[†] Aliye Kamalak, DDS,[*] Merve Akçay, PhD,[‡] Manoel D. Sousa-Neto, PhD,[§] and Marco Aurélio Versiani, PhD[§]*

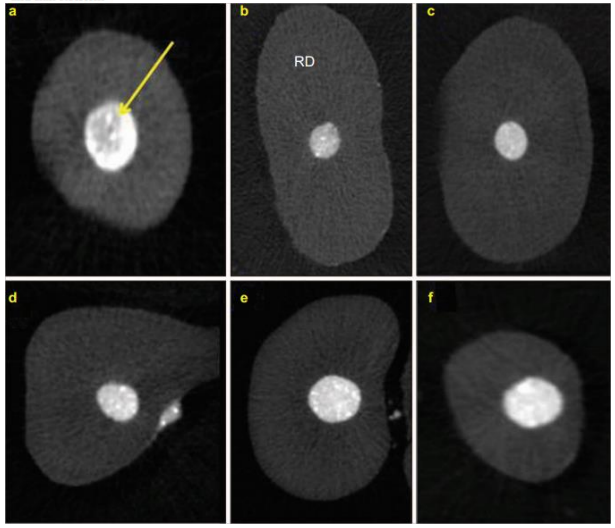




# OTHER APPLICATIONS

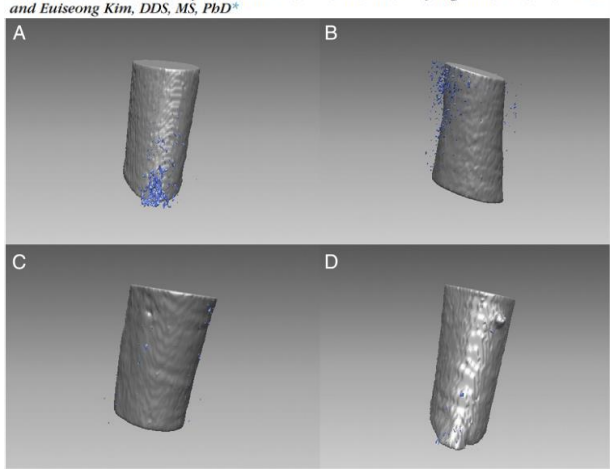
## Effect of acid etching on marginal adaptation of mineral trioxide aggregate to apical dentin: microcomputed tomography and scanning electron microscopy analysis

Khalid Al-Fouzan[1,2], Ziad Al-Garawi[1,3], Khalid Al-Hezaimi[1,4], Fawad Javed[1], Thakib Al-Shalan[1,4] and Ilan Rotstein[5]



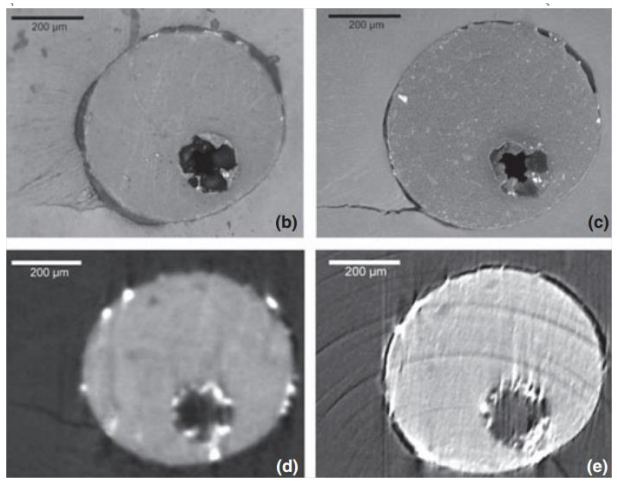

## Comparison of Gap Volume after Retrofilling Using 4 Different Filling Materials: Evaluation by Micro–computed Tomography

*Sue Youn Kim, DDS, MS,* Hyeon-Cheol Kim, DDS, MS, PhD,† Su-Jung Shin, DDS, MS, PhD,* and Euiseong Kim, DDS, MS, PhD**



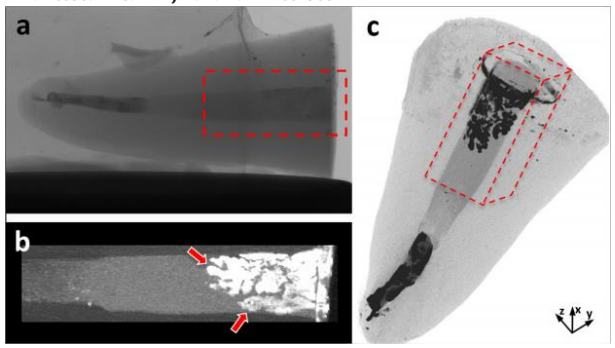

## Identification of root filling interfaces by microscopy and tomography methods

P. Zaslansky[1], P. Fratzl[1], A. Rack[2], M-K. Wu[3], P. R. Wesselink[3] & H. Shemesh[3]



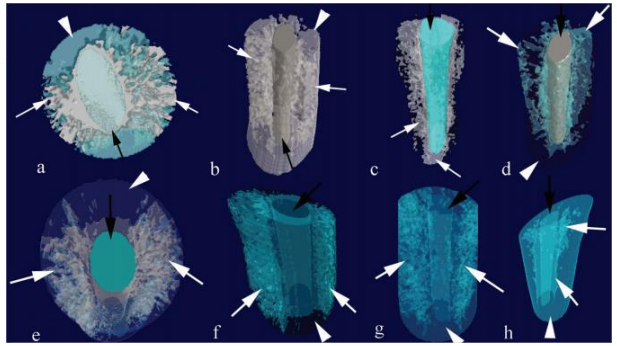

## 3D-microleakage assessment of adhesive interfaces: Exploratory findings by µCT

*Aline A. Neves[a,b,1], Siegfried Jaecques[a,c,1], Annelies Van Ende[a], Marcio Vivan Cardoso[a], Eduardo Coutinho[a,d], Anne-Katrin Lührs[a,e], Francesca Zicari[a,f], Bart Van Meerbeek[a,*]*



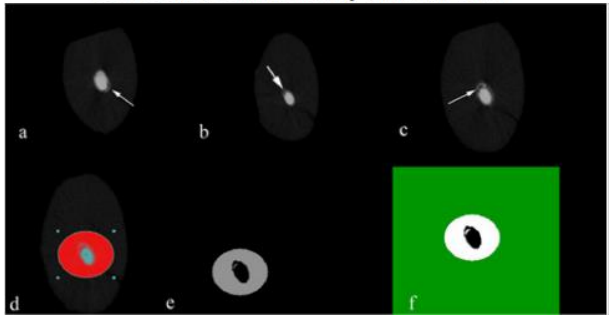

Yan HUANG[1,2]
Kaan ORHAN[3]
Berkan CELIKTEN[4]
Ayşe Işıl ORHAN[5]
Pelin TUFENKCI[6]
Semra SEVIMAY[4]

## Evaluation of the sealing ability of different root canal sealers: a combined SEM and micro-CT study



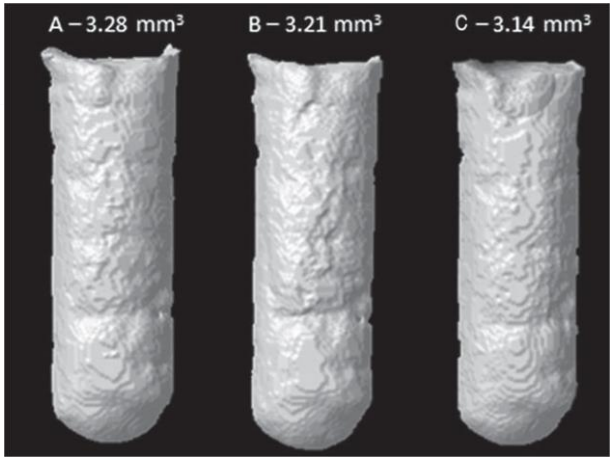

## Micro-CT assessment of the sealing ability of three root canal filling techniques

Berkan Celikten[1)], Ceren F. Uzuntas[2)], Ayse I. Orhan[3)], Pelin Tufenkci[4)], Melis Misirli[5)], Kemal O. Demiralp[6)], and Kaan Orhan[7)]



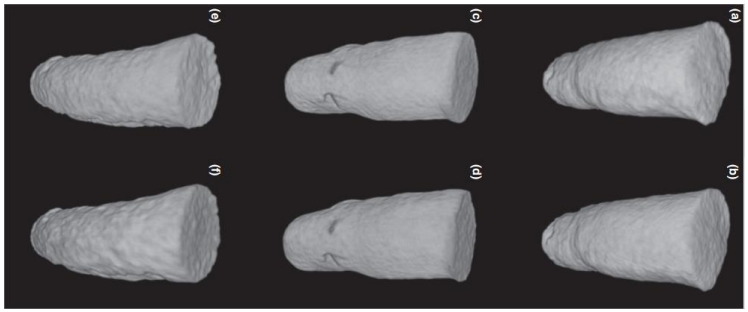
Fernanda Ferrari Esteves TORRES[1]
Roberta BOSSO-MARTELO[2]
Camila Galletti ESPIR[1]
Joni Augusto CIRELLI[3]
Juliane Maria GUERREIRO-TANOMARU[1]
Mario TANOMARU-FILHO[1]

## Evaluation of physicochemical properties of root-end filling materials using conventional and Micro-CT tests



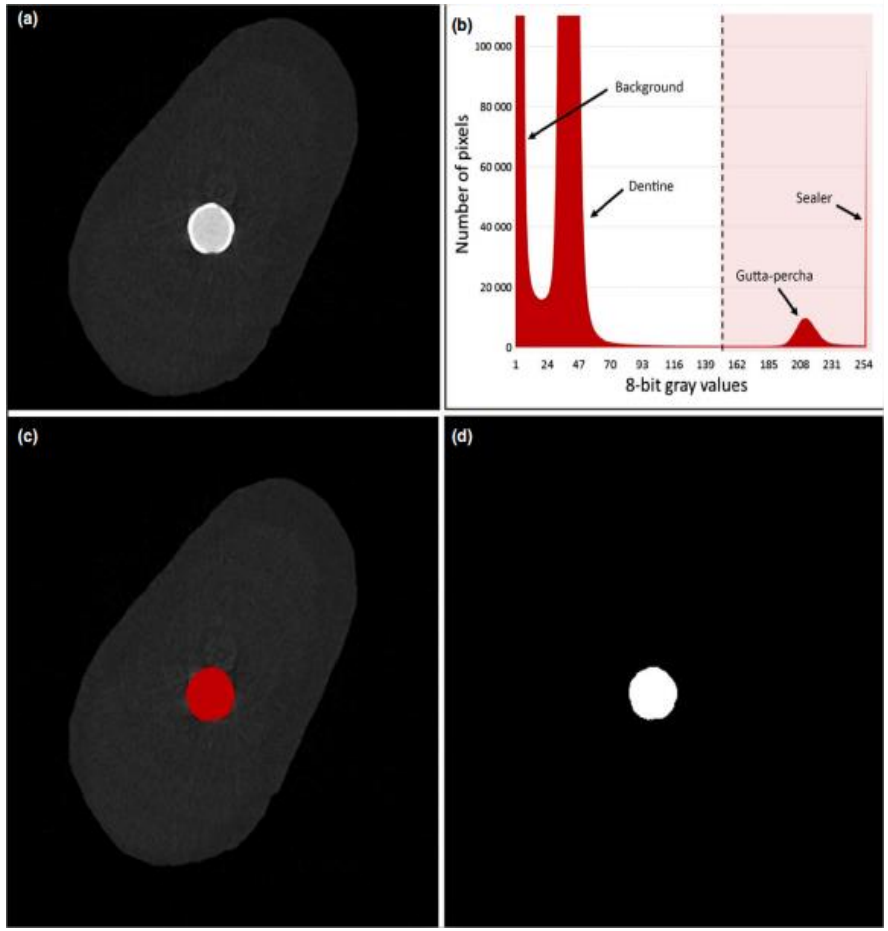

## Influence of powder-to-water ratio on radiopacity, setting time, pH, calcium ion release and a micro-CT volumetric solubility of white mineral trioxide aggregate

B. C. Cavenago, T. C. Pereira, M. A. H. Duarte, R. Ordinola-Zapata, M. A. Marciano, C. M. Bramante & N. Bernardineli



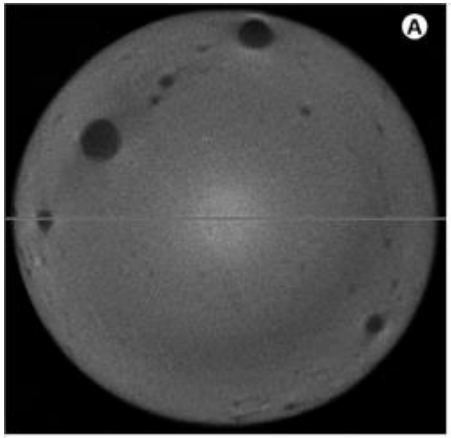
## Dissolution, dislocation and dimensional changes of endodontic sealers after a solubility challenge: a micro-CT approach

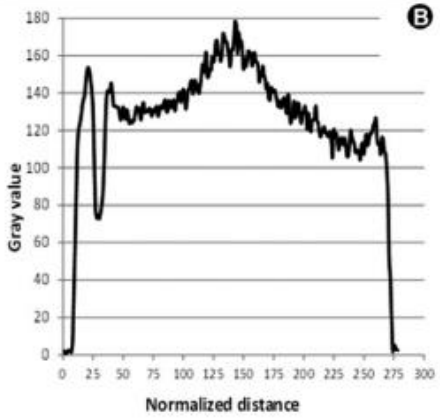
E. J. Silva[1], R. Perez[2], R. M. Valentim[1], F. G. Belladonna[3], G. A. De-Deus[1], I. C. Lima[4] & A. A. Neves[5]

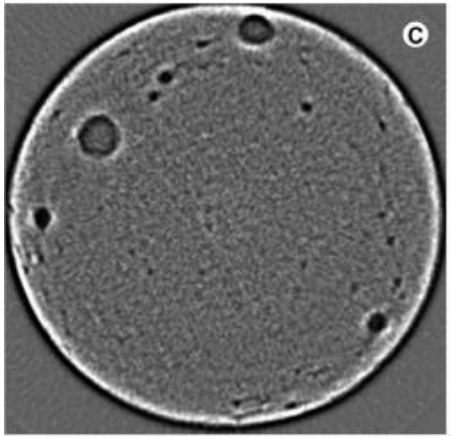


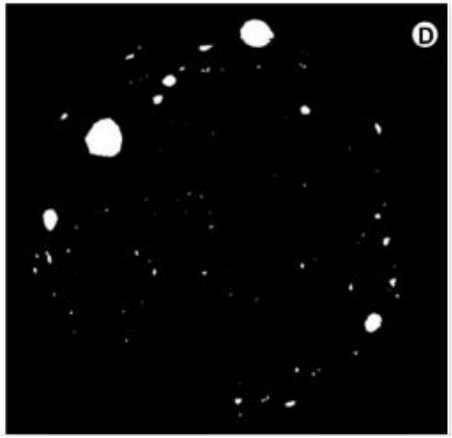
# Three-dimensional Quantitative Porosity Characterization of Syringe- versus Hand-mixed Set Epoxy Resin Root Canal Sealer

Gustavo De-Deus[1], Miriam Z. Scelza[1], Prasanna Neelakantan[2], Subash Sharma[2], Aline de Almeida Neves[3], Emmanuel João Nogueira Leal Silva[4]



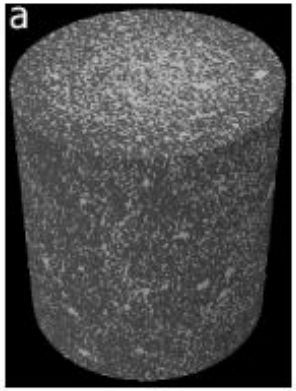



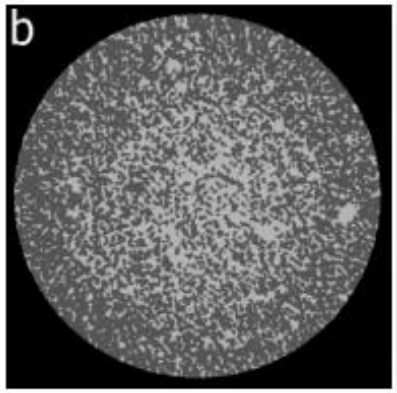




**Porosity analysis of MTA and Biodentine cements for use in endodontics by using micro–computed tomography**

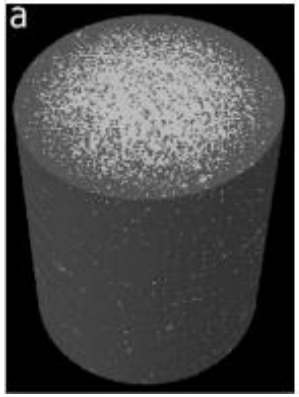
**Fabricio Guerrero [1], Esther Berástegui [2]**

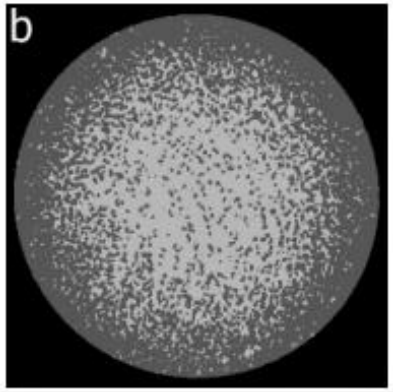
**Biodentine®**



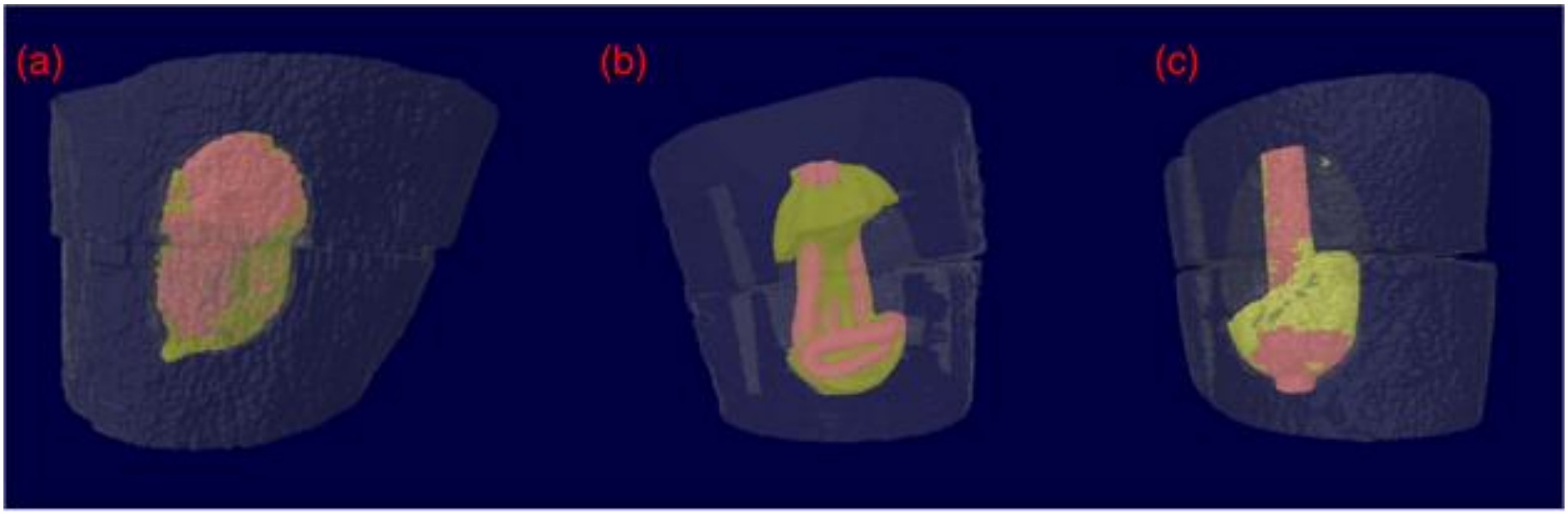

**ProRoot® MTA**



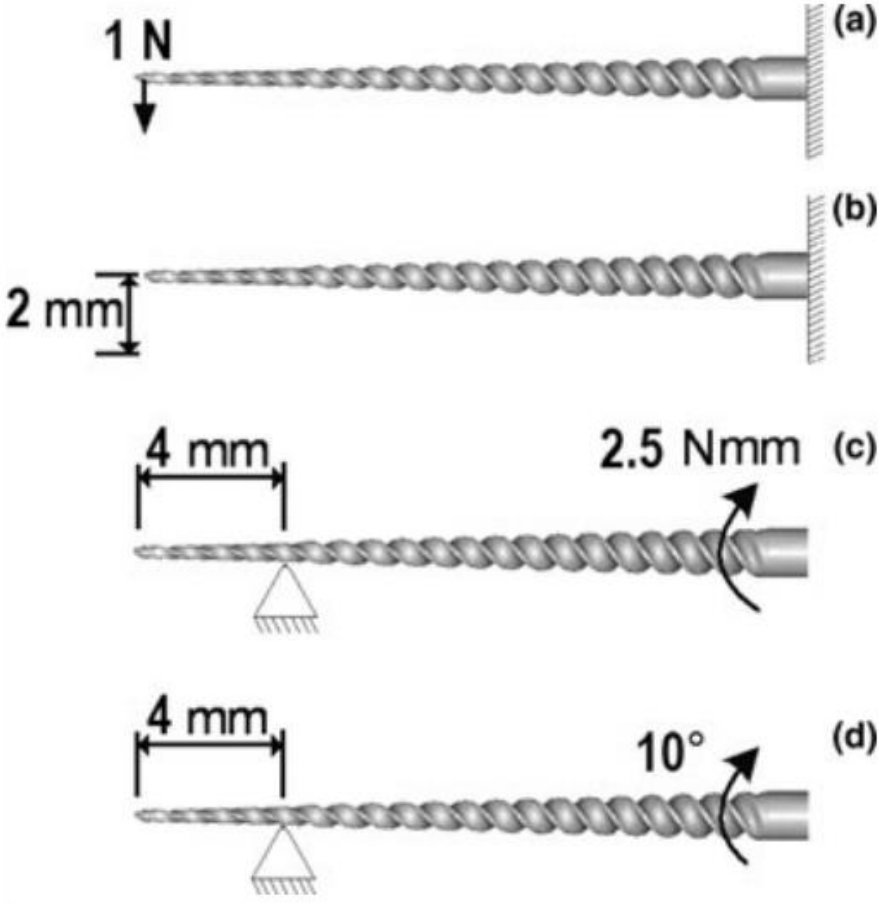
# Quality of different gutta-percha techniques when filling experimental internal resorptive cavities: A micro-computed tomography study

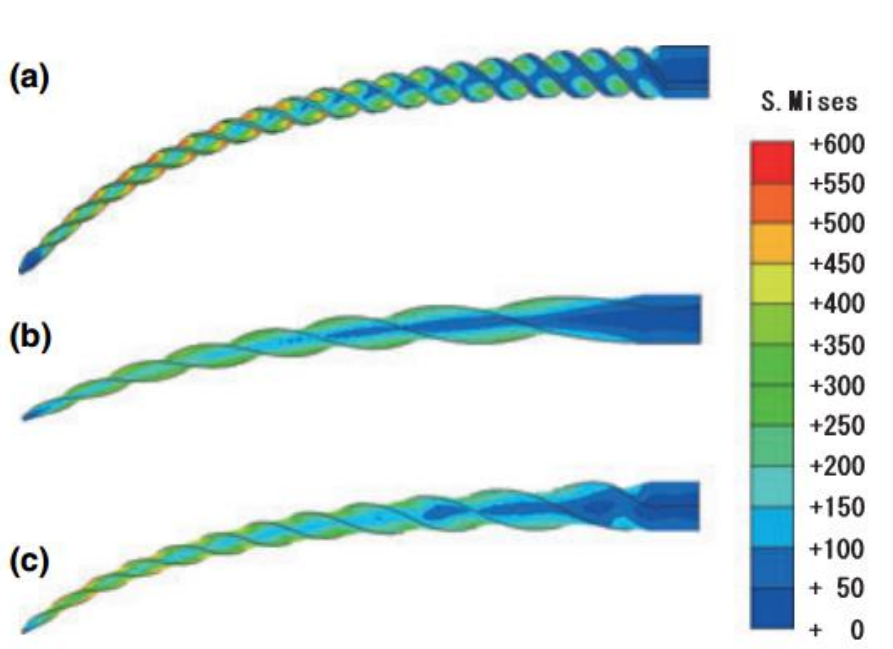
Ali Keles, DDS, PhD[1]; Fuat Ahmetoglu, DDS, PhD[1]; and Ismail Uzun, DDS, PhD[2]



# Stress distribution of three NiTi rotary files under bending and torsional conditions using a mathematic analysis

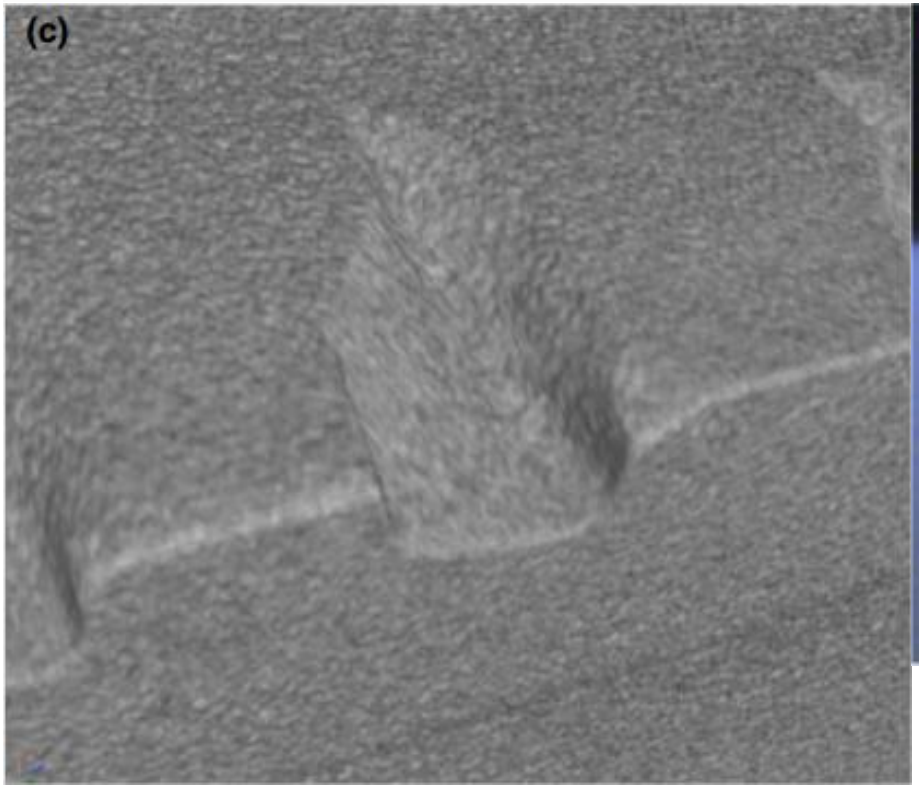
T. O. Kim[1], G. S. P. Cheung[2], J. M. Lee[3], B. M. Kim[3], B. Hur[1] & H. C. Kim[1]

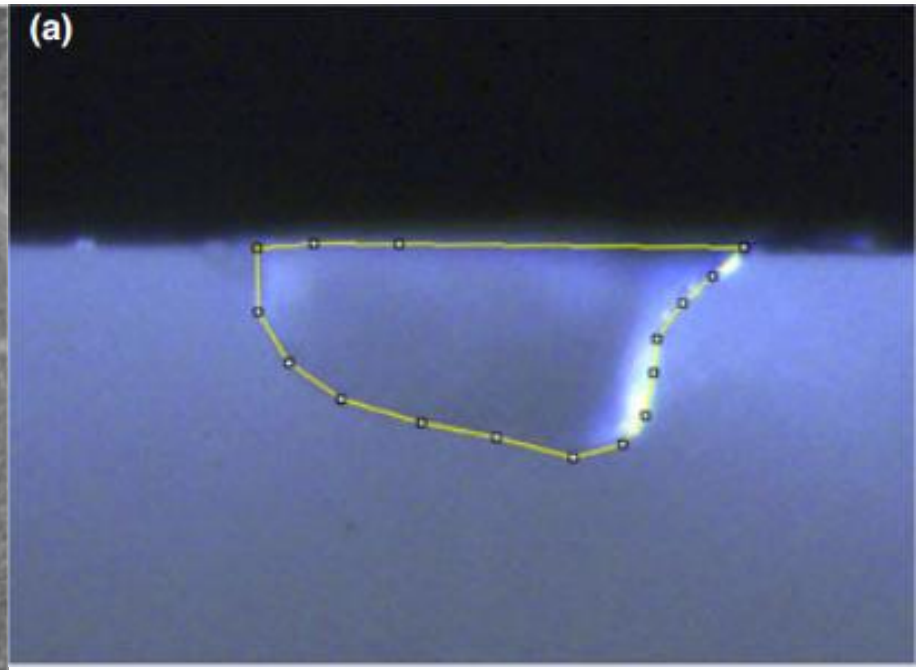


# Determining cutting efficiency of nickel-titanium coronal flaring instruments used in lateral action

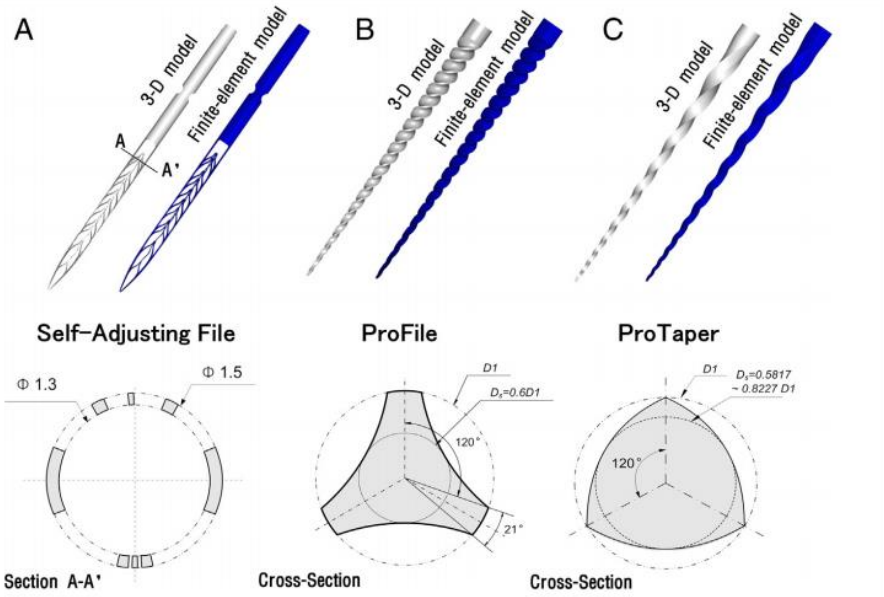
O. A. Peters[1], R. D. Morgental[1,2], K. A. Schulze[3], F. Paqué[4], P. M. P. Kopper[5] & F. V. Vier-Pelisser[2]



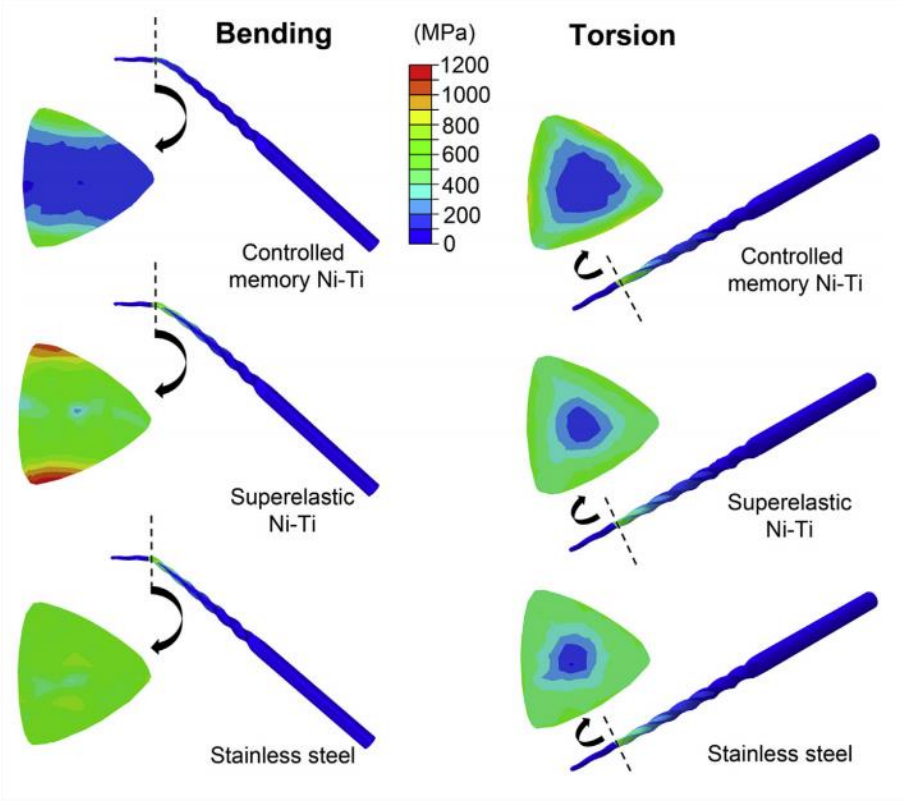
## Stress Generation during Self-Adjusting File Movement: Minimally Invasive Instrumentation

*Hyeon-Cheol Kim, DDS, MS, PhD,* Sang Yup Sung, DDS, MS,* Jung-Hong Ha, DDS, MS,† Michael Solomonov, DMD,‡ Jung-Min Lee, PhD,§ Chan-Joo Lee, PhD,§ and Byung-Min Kim, PhD‖*




## Comparison of the Mechanical Behavior between Controlled Memory and Superelastic Nickel-Titanium Files via Finite Element Analysis

*Leandro de Arruda Santos, BE, MS, PhD,* Maria Guiomar de Azevedo Babia, DDS, MS, PhD,† Estevam Barbosa de Las Casas, BE, MS, PhD,‡ and Vicente Tadeu Lopes Buono, BS, MS, PhD**

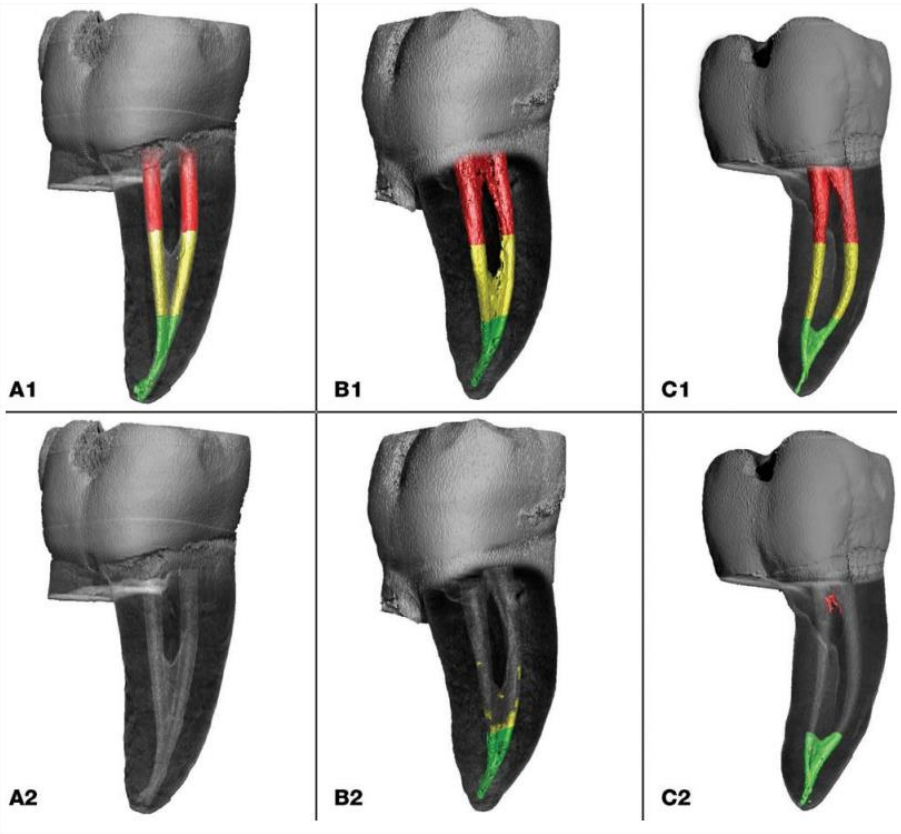


# Shaping ability of Reciproc and TF Adaptive systems in severely curved canals of rapid microCT-based prototyping molar replicas

**Ronald ORDINOLA-ZAPATA[1], Clovis Monteiro BRAMANTE[1], Marco Antonio Hungaro DUARTE[1], Bruno Cavalini CAVENAGO[1], David JARAMILLO[2], Marco Aurélio VERSIANI[3]**

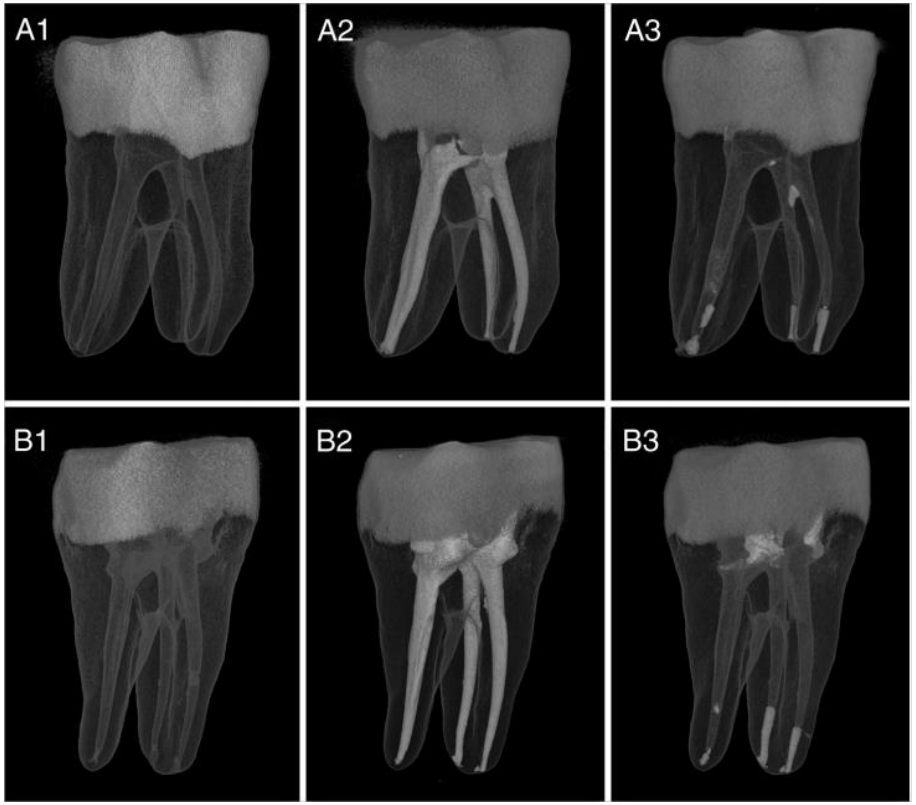
Removal of calcium hydroxide from Weine Type II systems using photon-induced photoacoustic streaming, passive ultrasonic, and needle irrigation: a microcomputed tomography study

Adam LLOYD[1], Geraldine NAVARRETE[1], Melissa Andreia MARCHESAN[1], David CLEMENT[2]



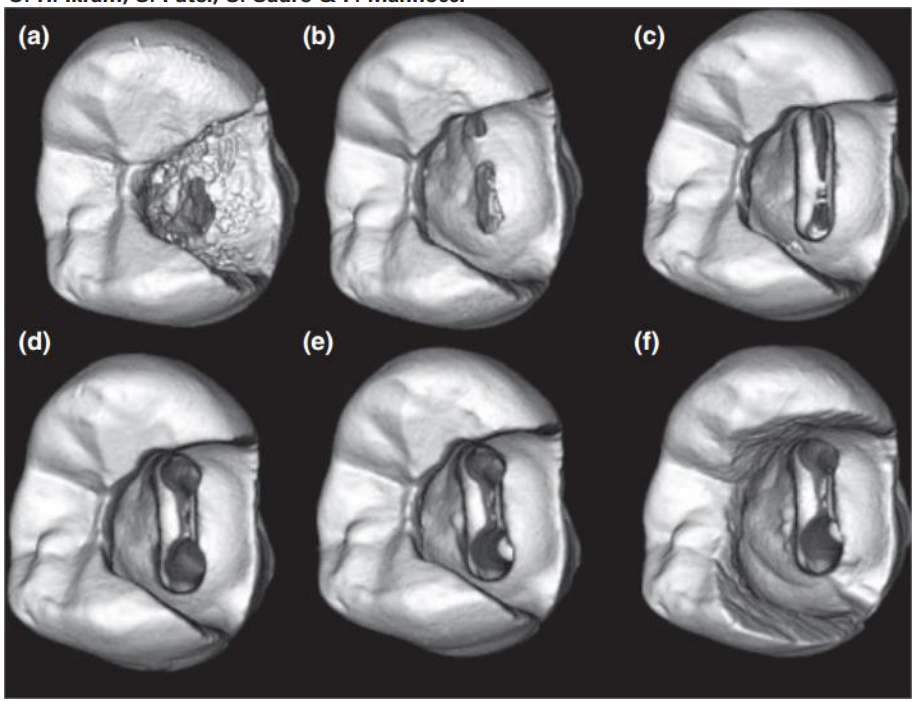

## *In Vitro* Study of Calcium Hydroxide Removal from Mandibular Molar Root Canals

*Jingzhi Ma, DDS, PhD,[*] Ya Shen, DDS, PhD,[†‡] Yan Yang, DDS,[*†] Yuan Gao, DDS, PhD,[§] Pan Wan, DDS,[*] Yan Gan, DDS,[*] Payal Patel, BSc,[‖] Allison Curtis, MSc,[‖] Mehrzad Khakpour, PhD,[‖] and Markus Haapasalo, DDS, PhD[†]*



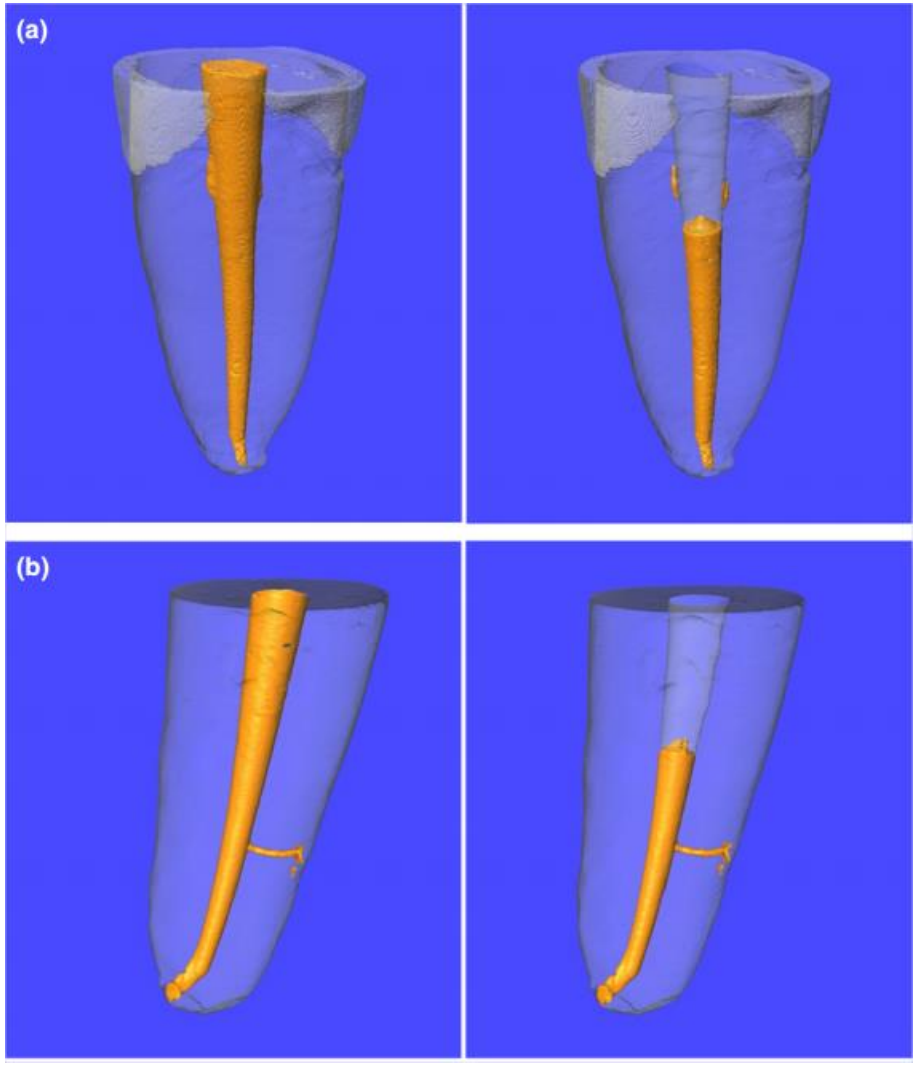
## Micro-computed tomography of tooth tissue volume changes following endodontic procedures and post space preparation

O. H. Ikram, S. Patel, S. Sauro & F. Mannocci



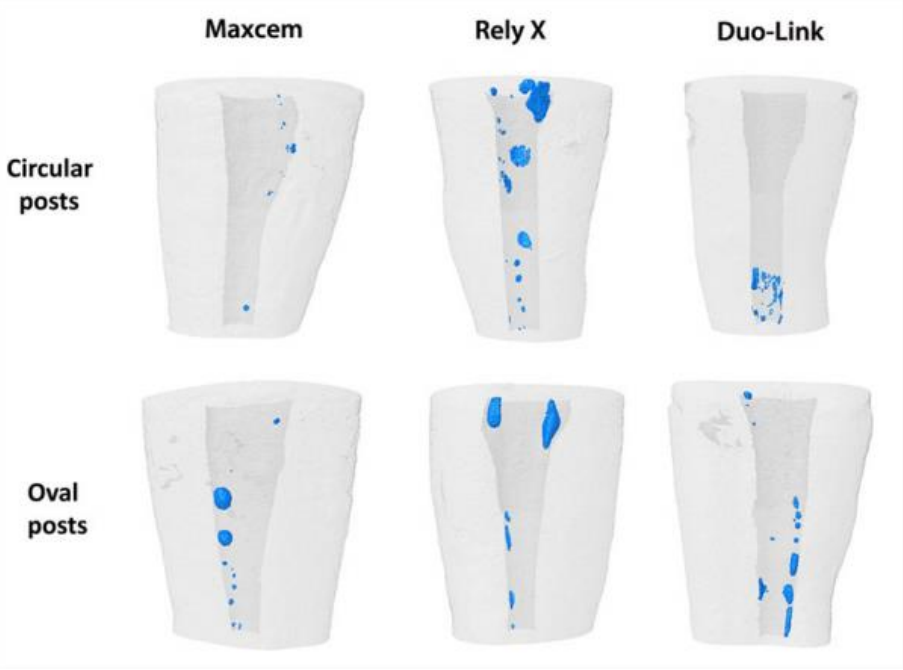

## Micro-computed tomography analysis of post space preparation in root canals filled with carrier-based thermoplasticized gutta-percha

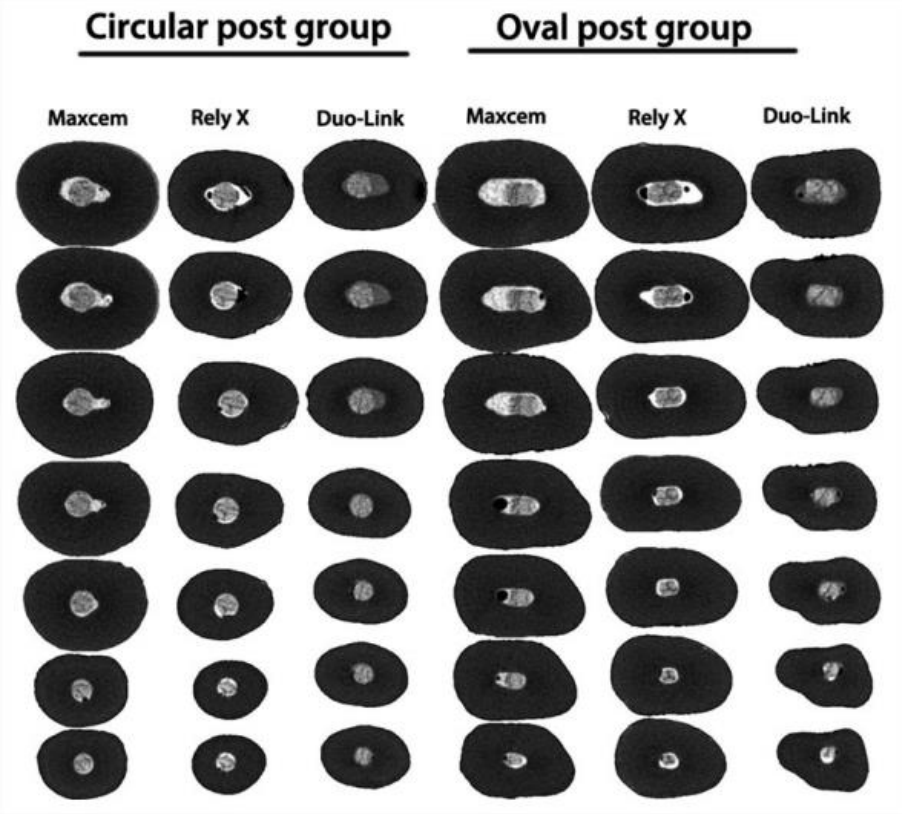
A. A. Schroeder[1], N. L. Ford[2] & J. M. Coil[1]



# Influence of oval and circular post placement using different resin cements on push-out bond strength and void volume analysed by micro-CT

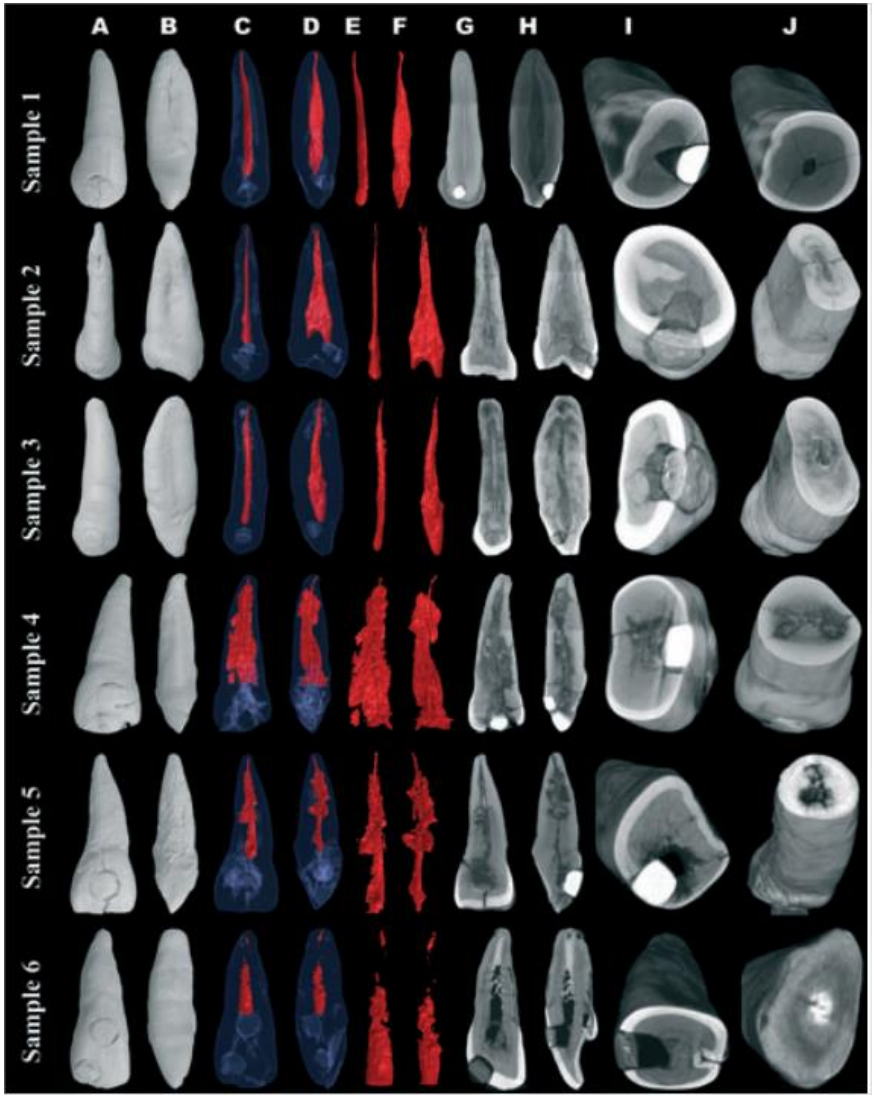
I. Uzun[1], A. Keleş[1], H. Arslan[2], B. Güler[1], C. Keskin[1] & K. Gündüz[3]



# Pulp pathosis in inlayed teeth of the ancient Mayas: a microcomputed tomography study

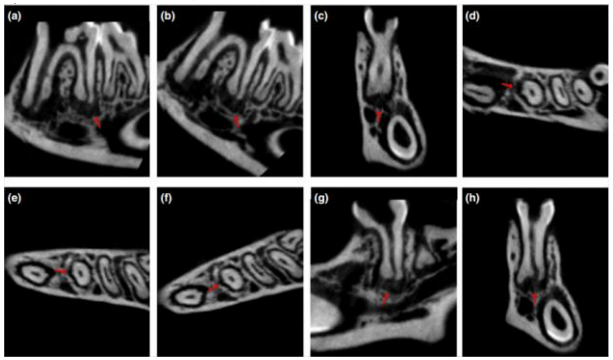
M. A. Versiani, M. D. Sousa-Neto & J. D. Pécora



REVIEW

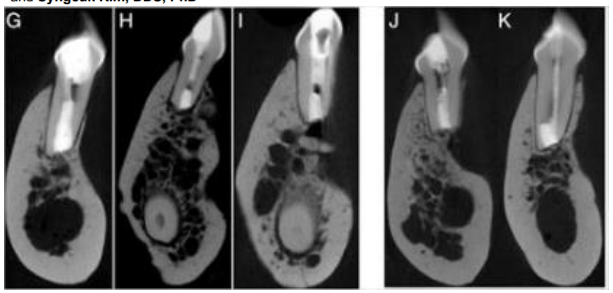
## Use of micro-computed tomography for the assessment of periapical lesions in small rodents: a systematic review

N. G. Kalatzis-Sousa[1], R. Spin-Neto[2], A. Wenzel[2], M. Tanomaru-Filho[1] & G. Faria[1]




## Healing after Root-end Microsurgery by Using Mineral Trioxide Aggregate and a New Calcium Silicate–based Bioceramic Material as Root-end Filling Materials in Dogs

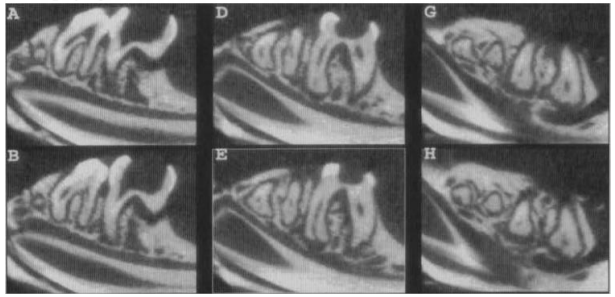
Ian Chen, DDS, MS*, Bekir Karabucak, DMD, MS*, Cong Wang, DDS†, Han-Guo Wang, DDS, PhD†, Eiki Koyama, DDS, PhD‡, Meetu R. Kohli, BDS, DMD*, Hyun-Duck Nah, DMD, PhD§, and Syngcuk Kim, DDS, PhD*




K. Balto[1,3], R. Müller[4], D.C. Carrington[4], J. Dobeck[2], and P. Stashenko[1]*

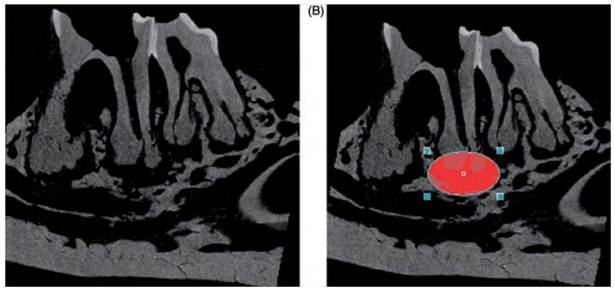
[1]Departments of Cytokine Biology and [2]Histology, Forsyth Institute, 140 Fenway, Boston, MA 02115; [3]Department of Endodontics, Harvard School of Dental Medicine; and [4]Department of Orthopedic Surgery, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, MA; *corresponding author, Pstashenko@forsyth.org.

## Quantification of Periapical Bone Destruction in Mice by Micro-computed Tomography



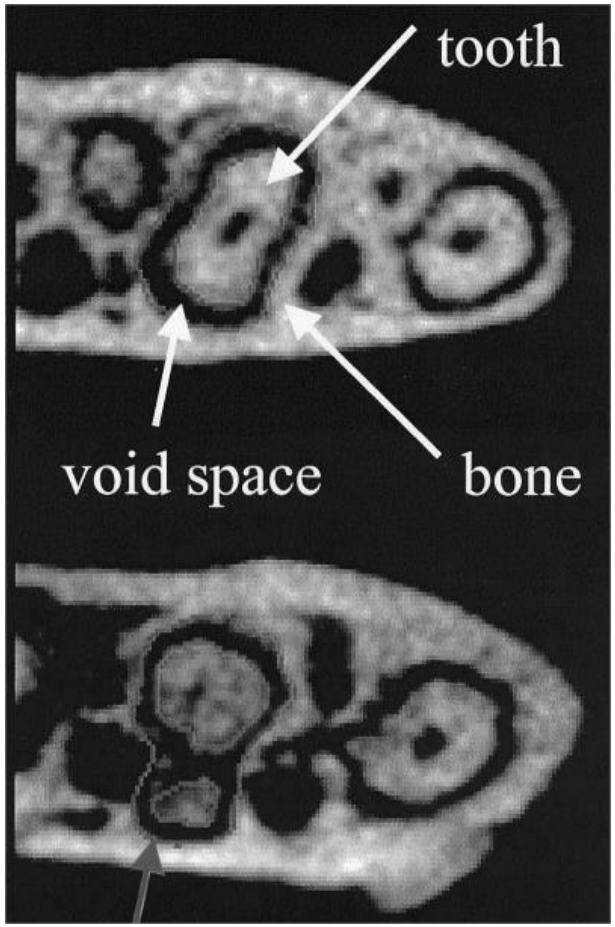

## Three-Dimensional Micro-Computed Tomography Analyses of Induced Periapical Lesions in Transgenic Mice

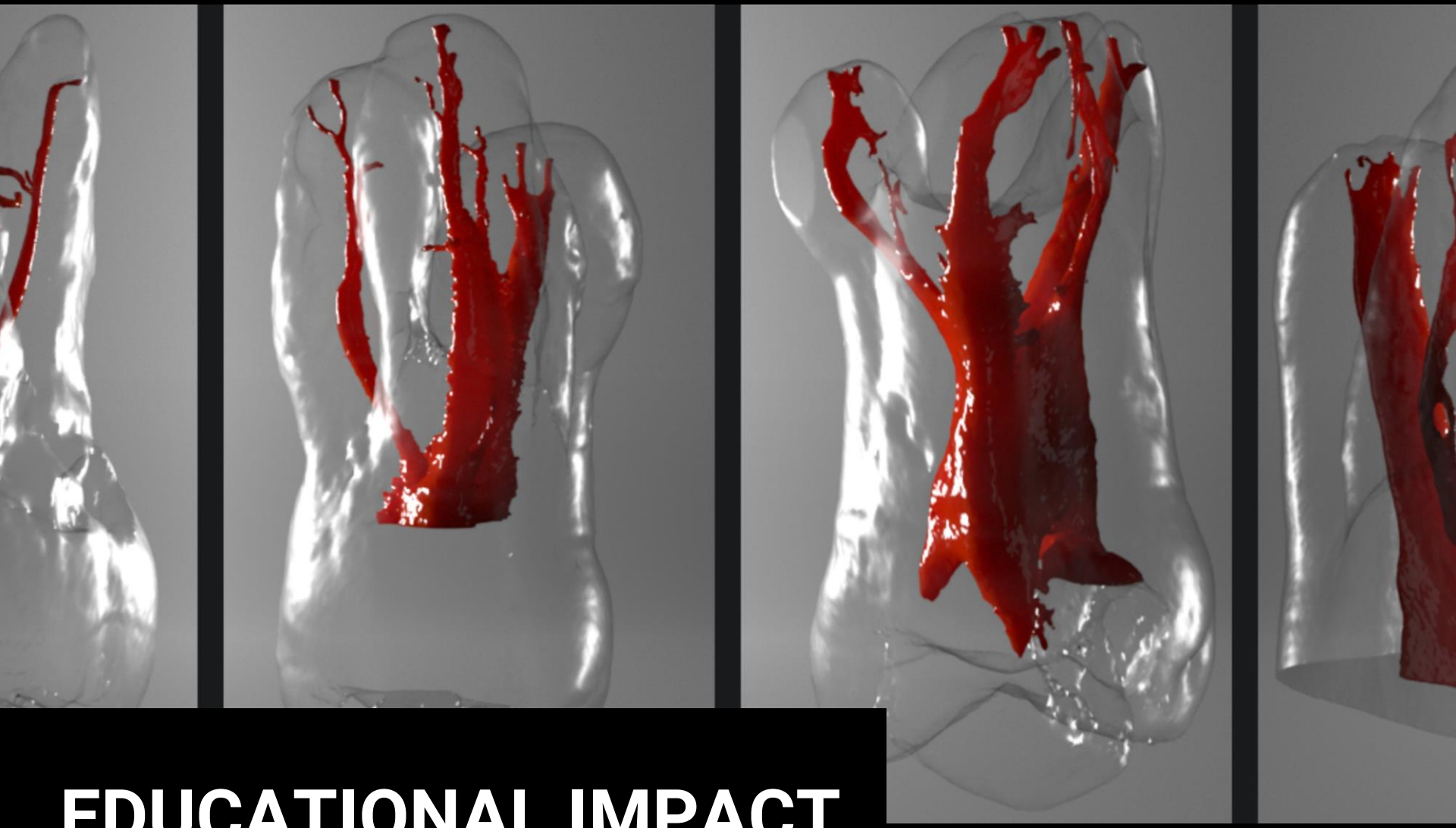
Katharina Morant Holanda de Oliveira MSc, PhD Student, Paulo Nelson-Filho MSc, PhD, Lea Assed Bezerra da Silva MSc, PhD, Erika Calvano Küchler MSc, PhD, Patrícia Gatón-Hernandez MSc, PhD & Raquel Assed Bezerra da Silva MSc, PhD




## Three-Dimensional Quantitation of Periradicular Bone Destruction by Micro-Computed Tomography

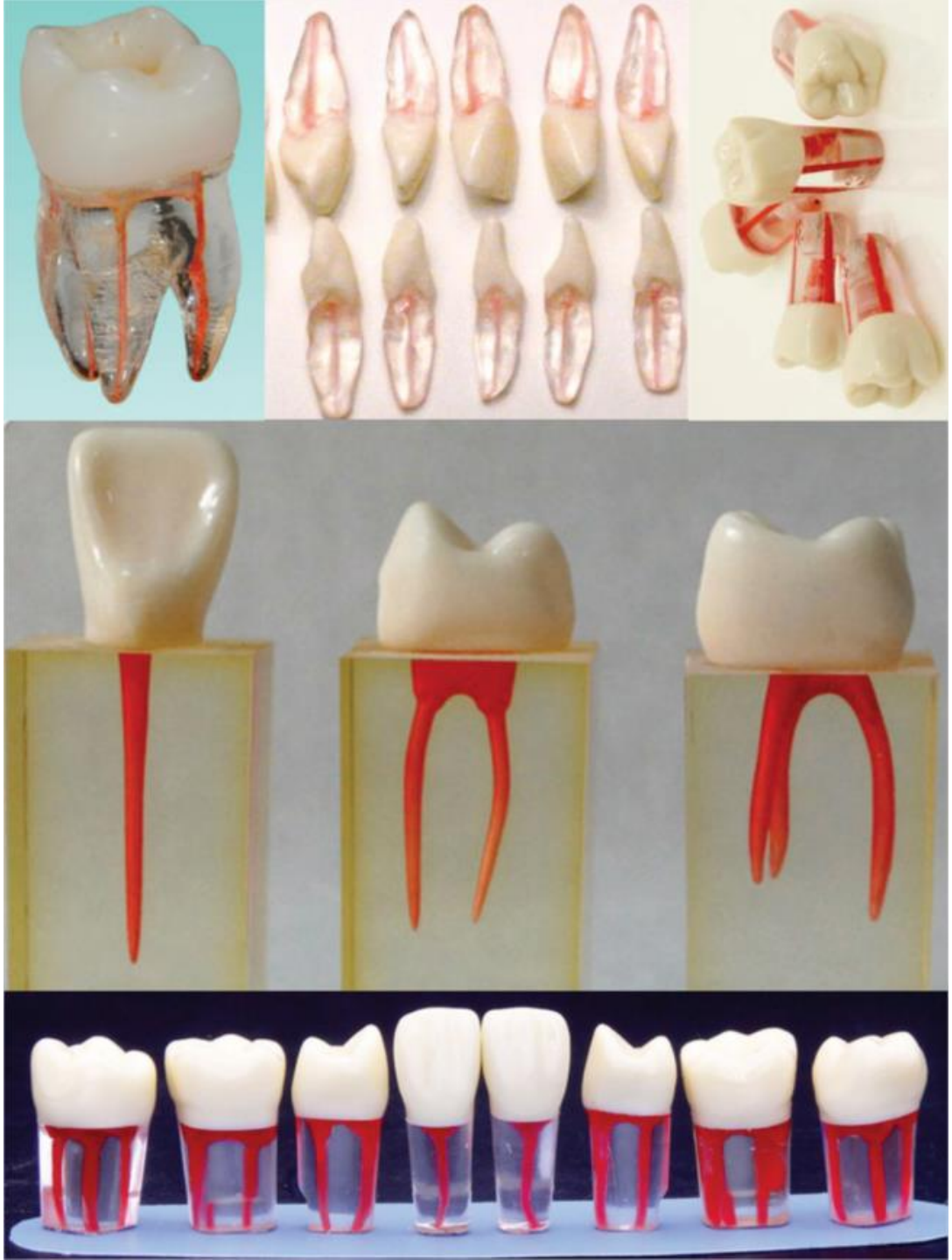
Dietrich von Stechow, MD, Khaled Balto, DDS, Philip Stashenko, DMD, PhD, and Ralph Müller, PhD



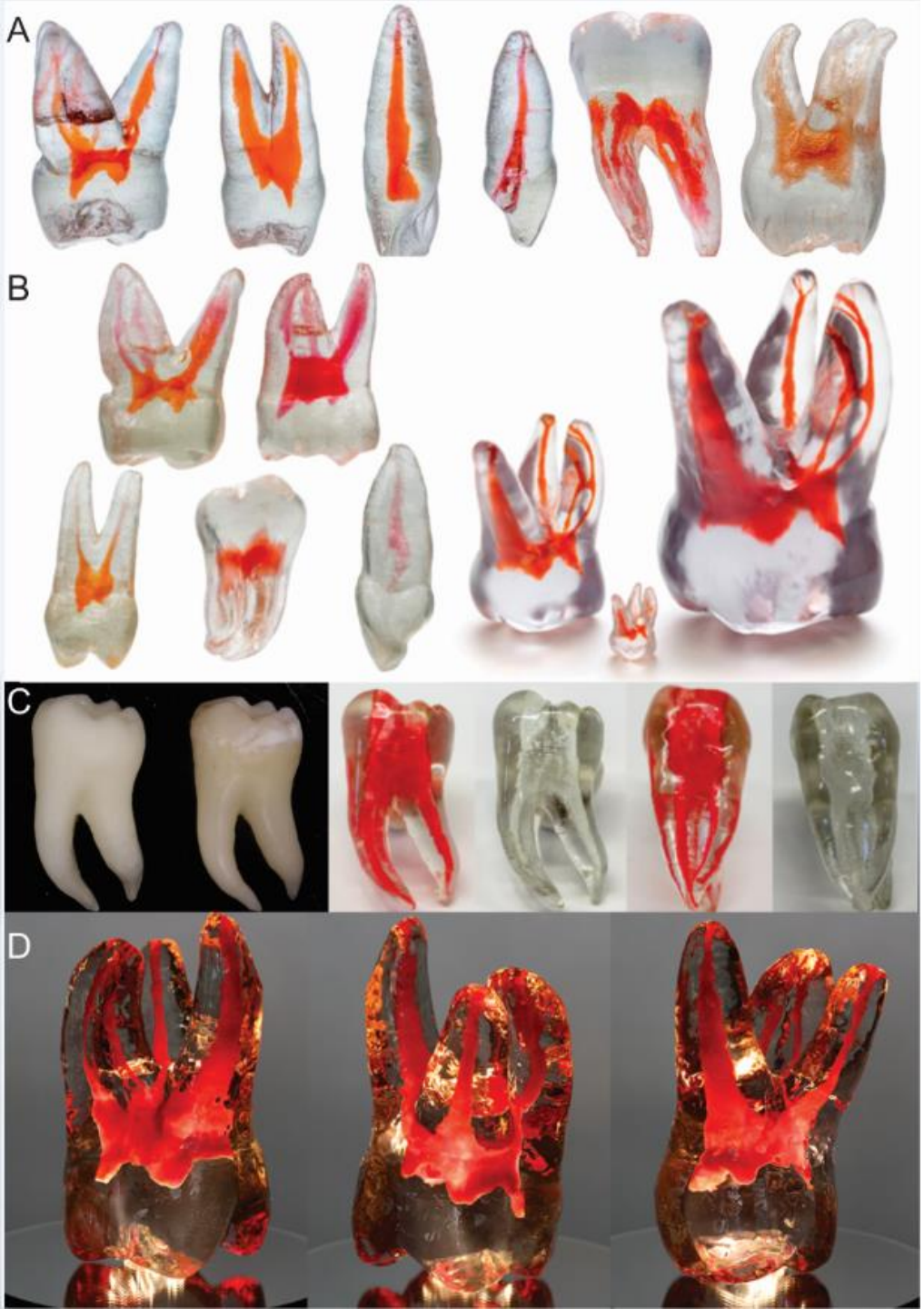


# EDUCATIONAL IMPACT

Preclinical Training Laboratory at School of Dental Medicine | EYP



# Micro-CT based replicas




True Tooth®
https://dentalengineeringlab.com/truetooth/

RepliDens®
https://www.smartodont.ch/replidens/

The Micro-CT Team

Prof. Marco A. Versiani, DDS, MS, PhD
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Prof. Manoel D. Sousa Neto, DDS, MS, PhD
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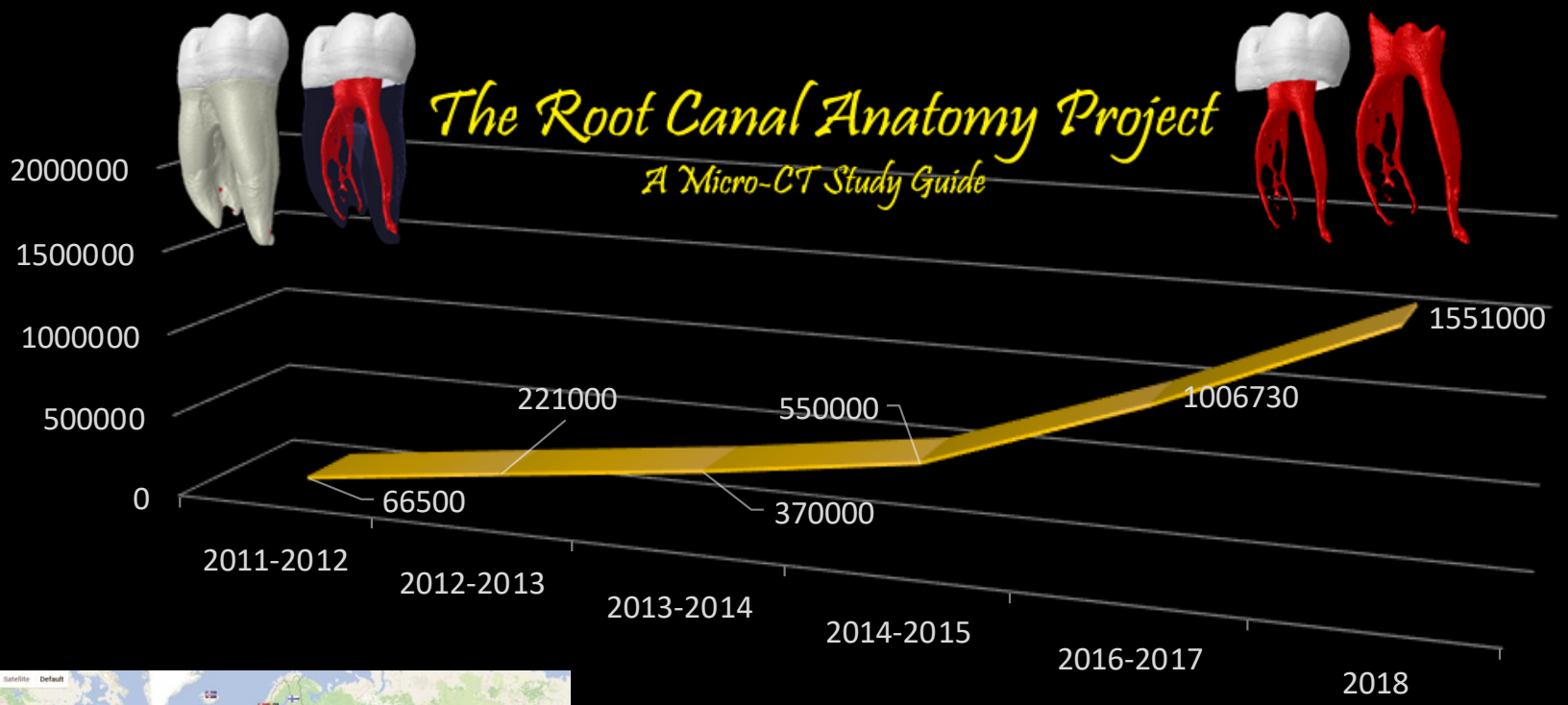
# The Root Canal Anatomy Project

## A Micro-CT Study Guide


192 different countries

rootcanalanatomy.blogspot.com

# A New MicroCT-Based Educational Resource

BRUKER Bruker microCT

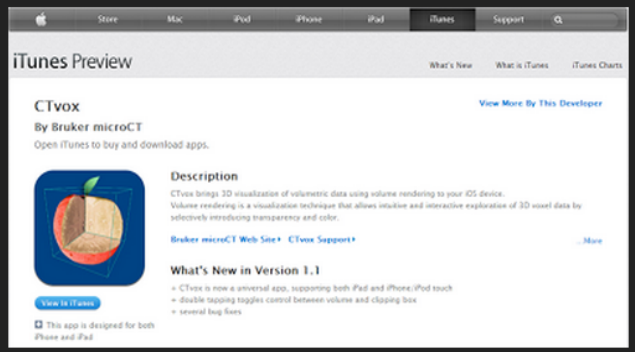
CTvox for iPad

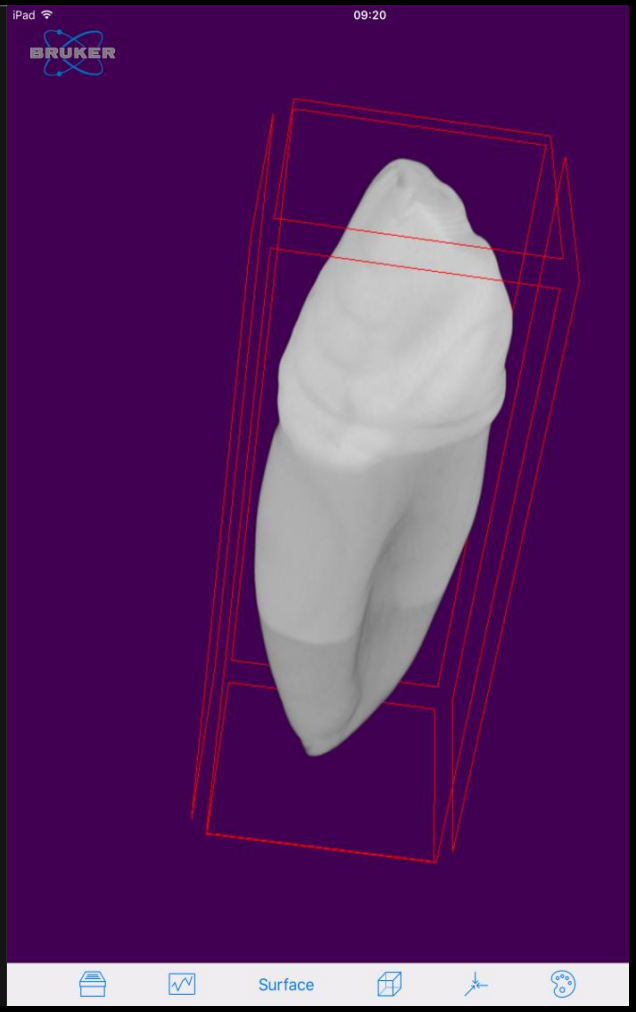
Version 1.1

## Realistic visualization by volume rendering

The volume rendering program **CTvox** (Brucker-MicroCT) for mobiles under iOS is a volume rendering app that runs on Apple iPad/iPhone/iPod. **CTvox** displays set of reconstructed slices as a realistic 3D object with intuitive navigation and manipulation of both object and camera, a flexible clipping tool to produce cut-away views, background selection including custom scenery and an interactive transfer function control to adjust colors and transparency. A "flight recorder" function allows fast creation of "fly around" and "fly through" animations based on the selection of several key frames with automatic interpolation in between. Imaging possibilities include lighting, shadows and stereo viewing.

This app is available free of charge through the App Store.



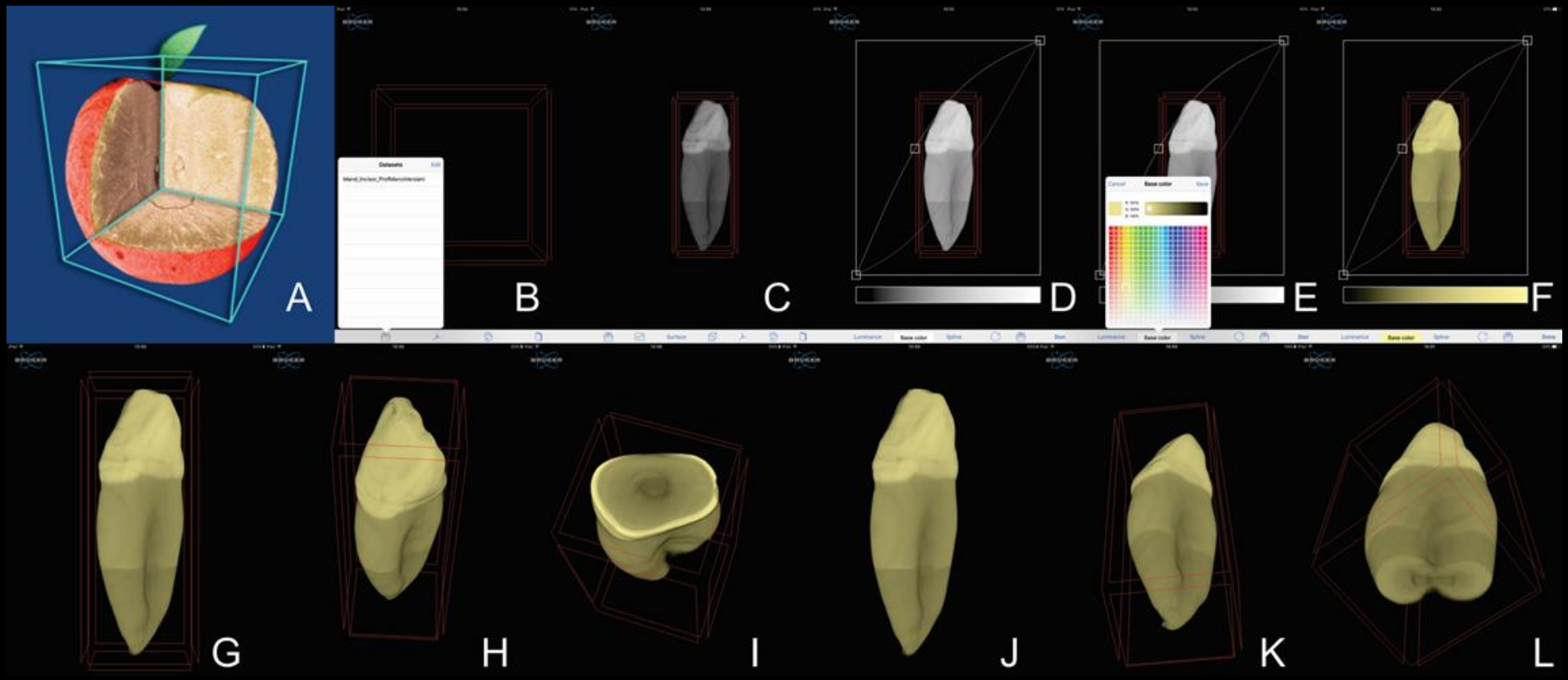

Download links:

**Maxillary Teeth**

central incisor, lateral incisor, canine, 1st premolar, 2nd premolar, 1st molar, 2nd molar, 3rd molar

**Mandibular Teeth**

incisor, canine, 1st premolar, 2nd premolar, 1st molar, 2nd molar, 3rd molar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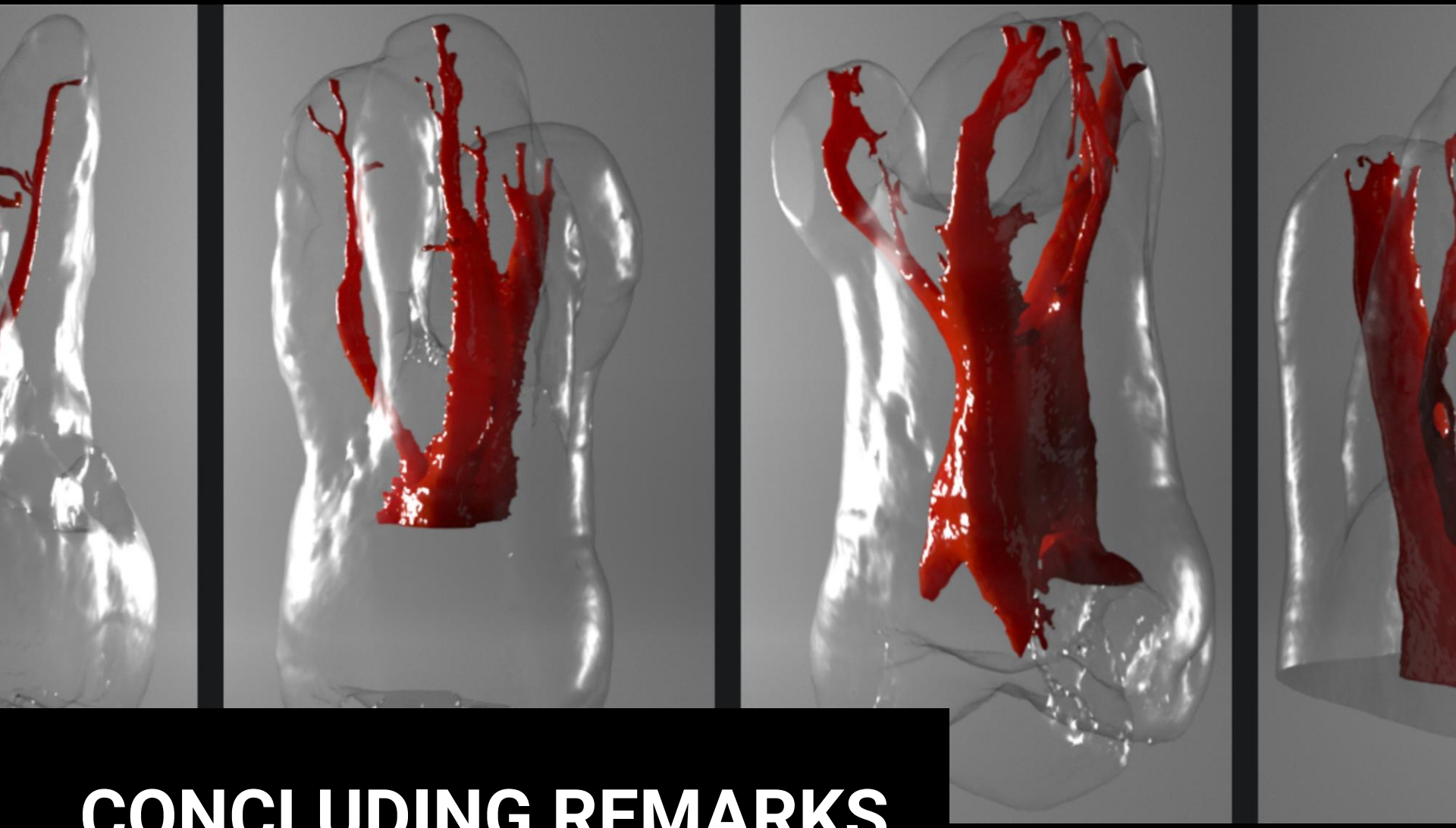
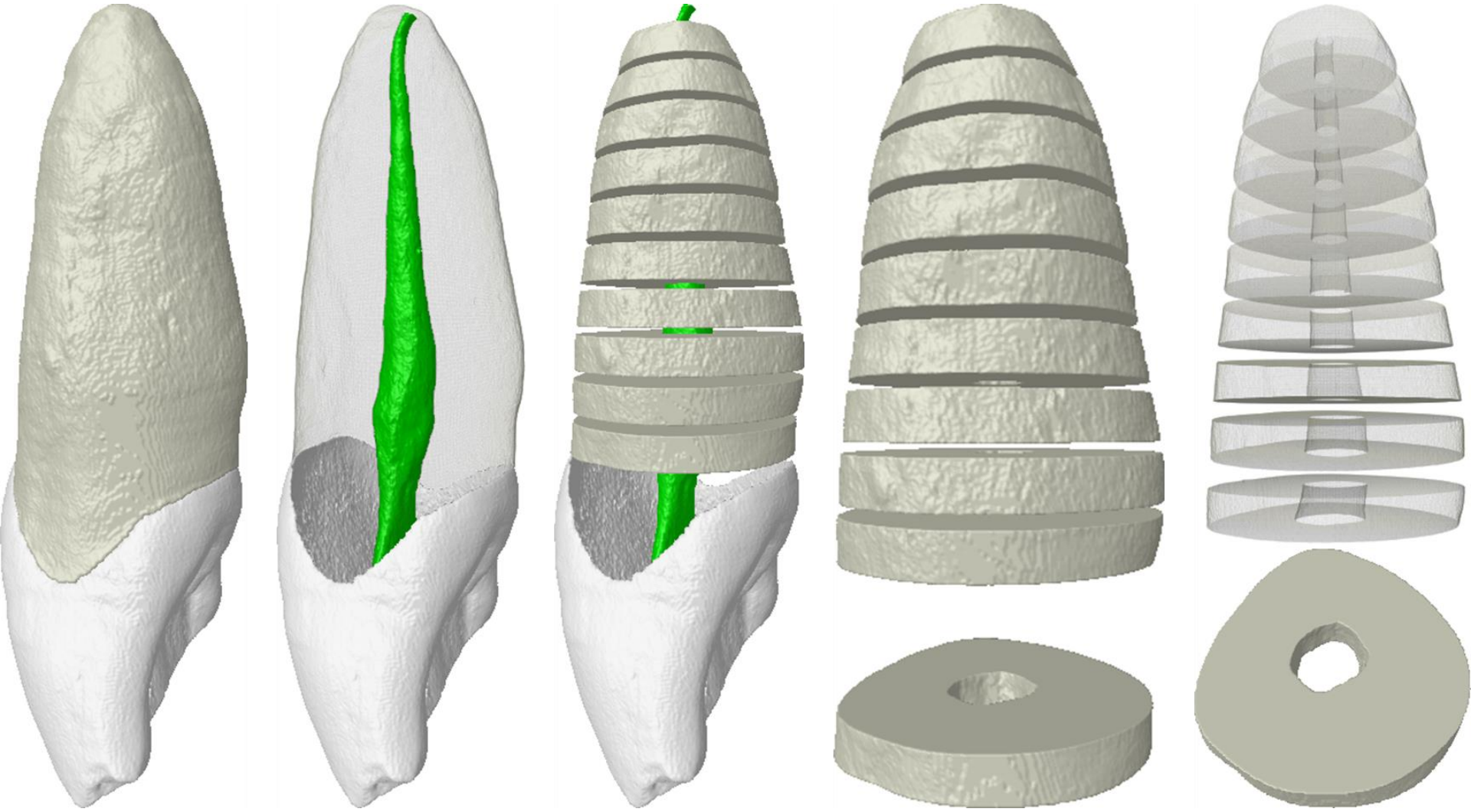
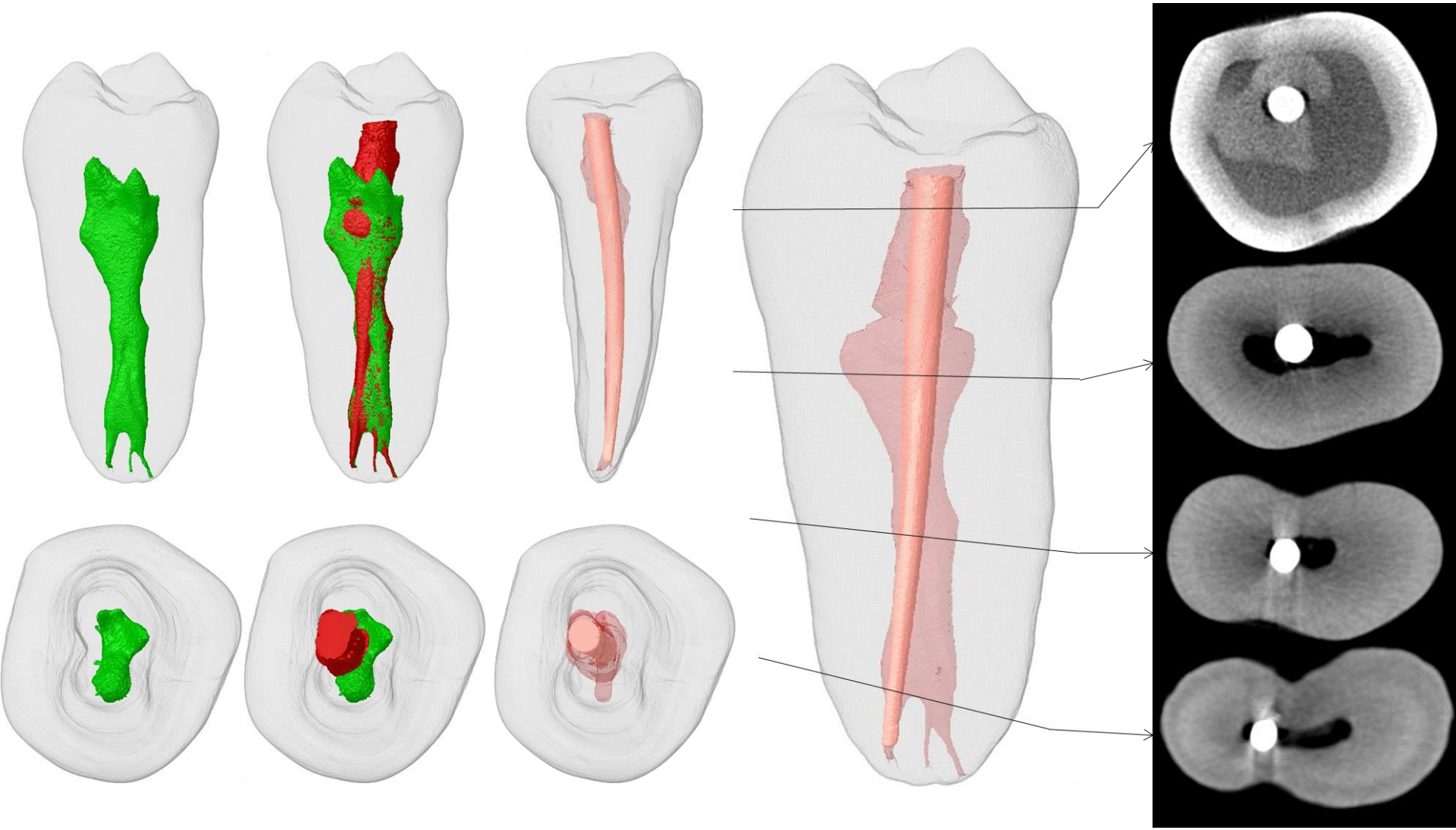
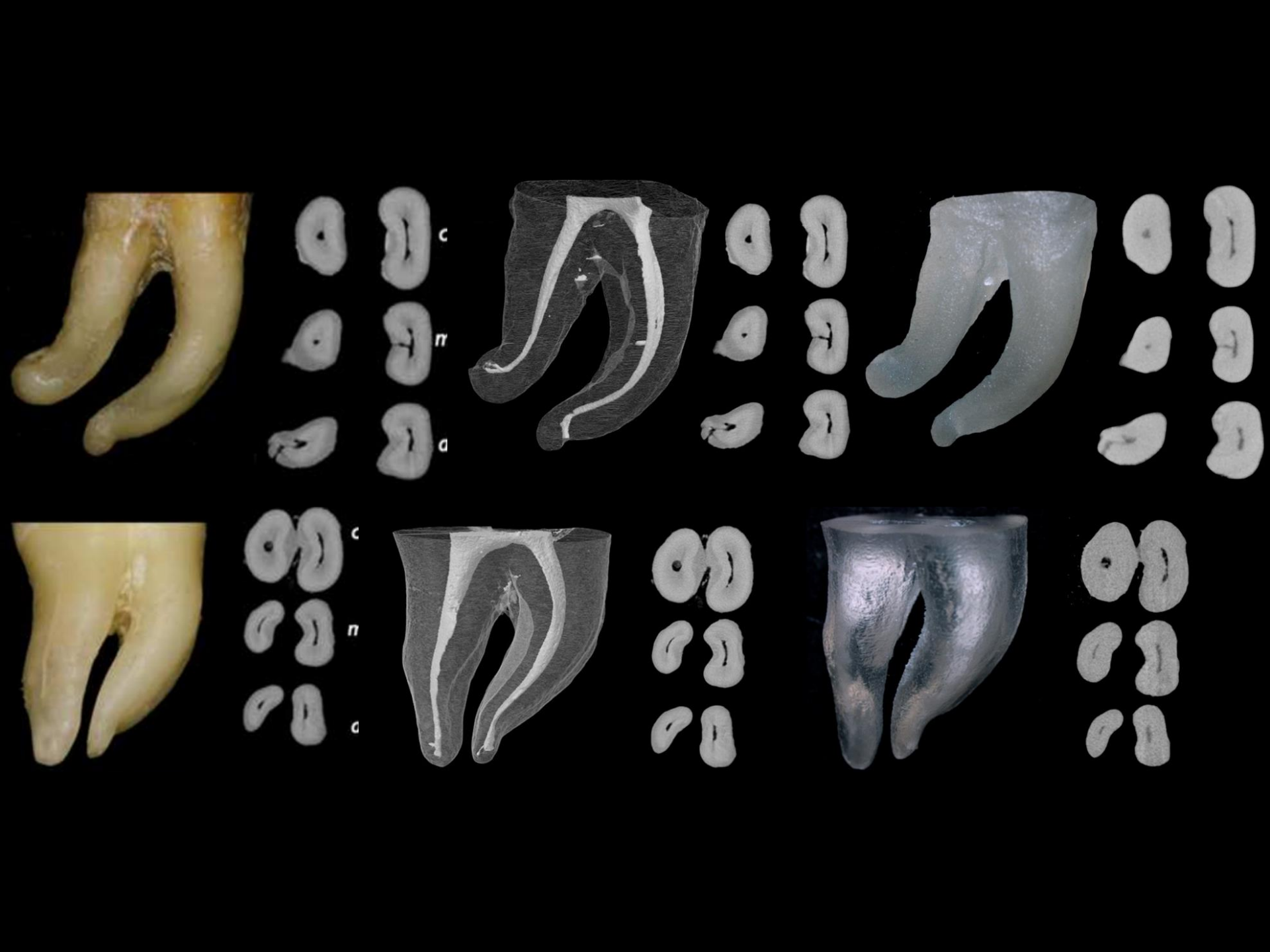


# CONCLUDING REMARKS



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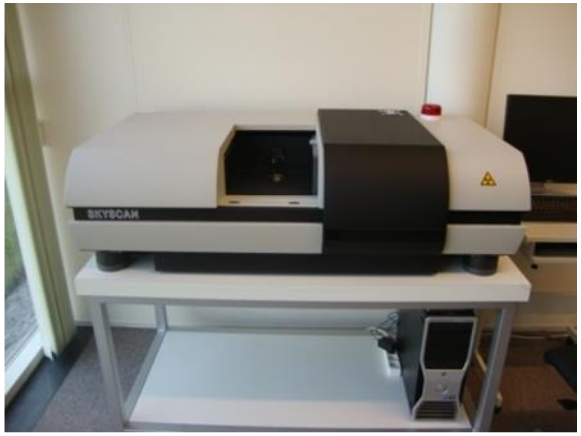
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μCT 80
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## Chapter 7

## Applications of Micro-CT Technology in Endodontics

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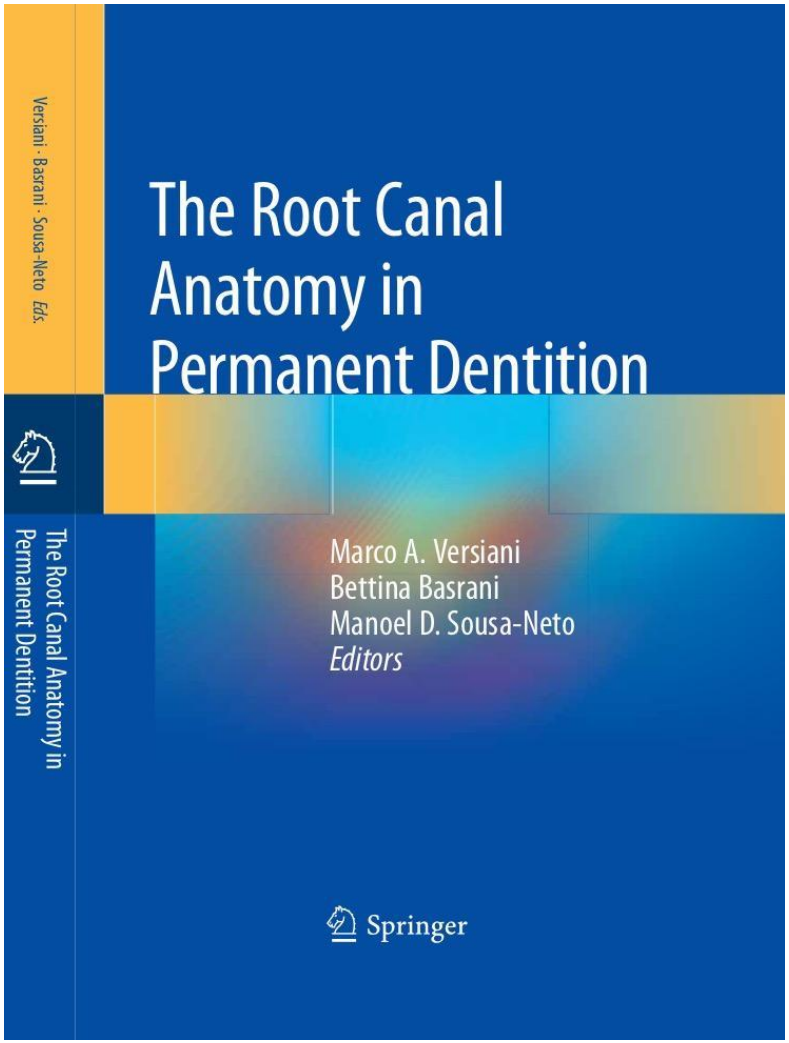
**Ali Keleş** DDS, MSc, PhD

Department of Endodontics, Faculty of Dentistry, Ondokuz Mayıs University, Samsun, Turkey.

Email: alikeles29@yahoo.com



# Thank you

**Marco A. Versiani**
DDS, MS, PhD

# ANY QUESTIONS