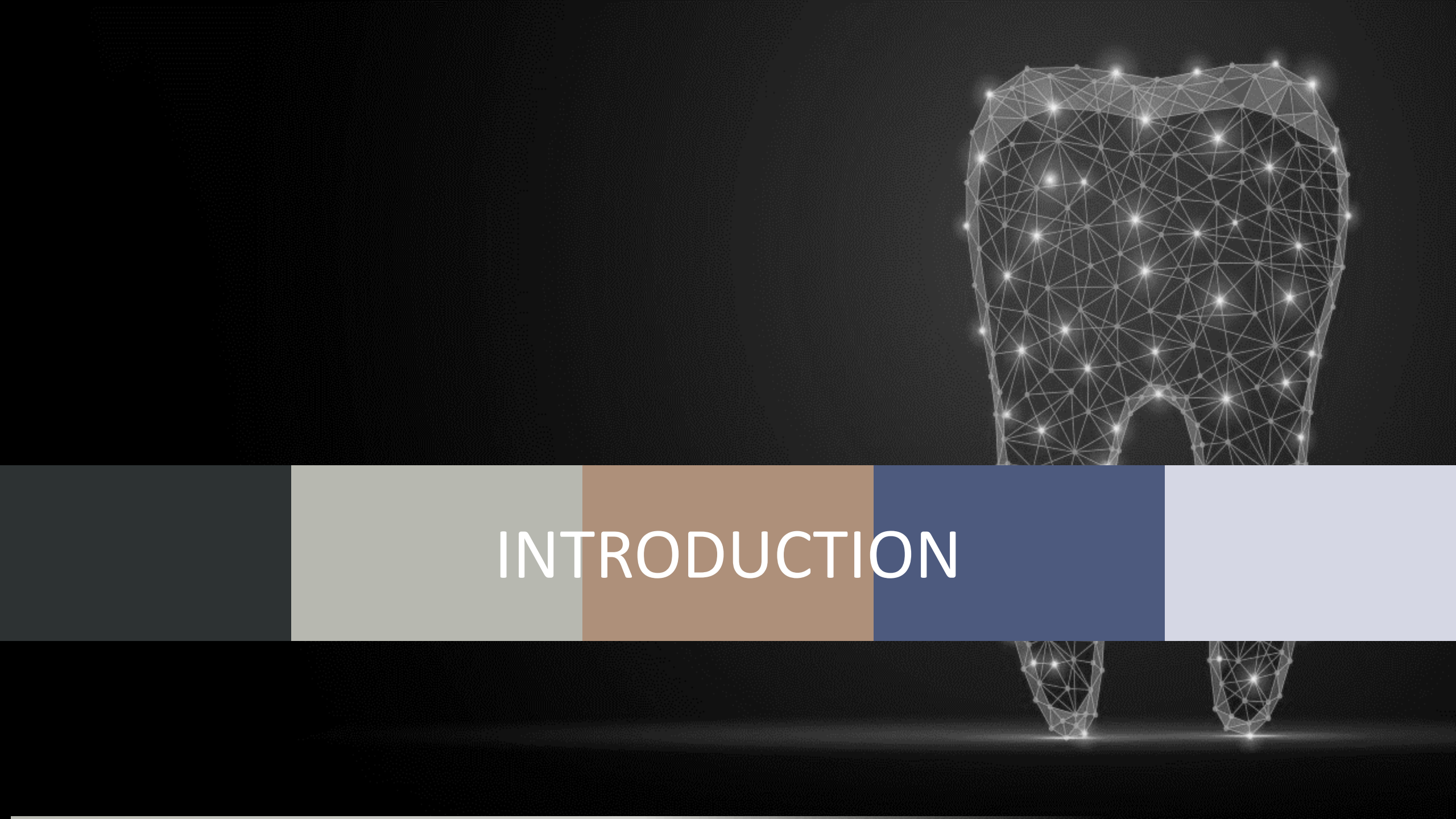
Chemomechanical Analysis of The Minimally- Excavated Carious Dentin

Assist. Professor Dr. Lamis Al-Taee



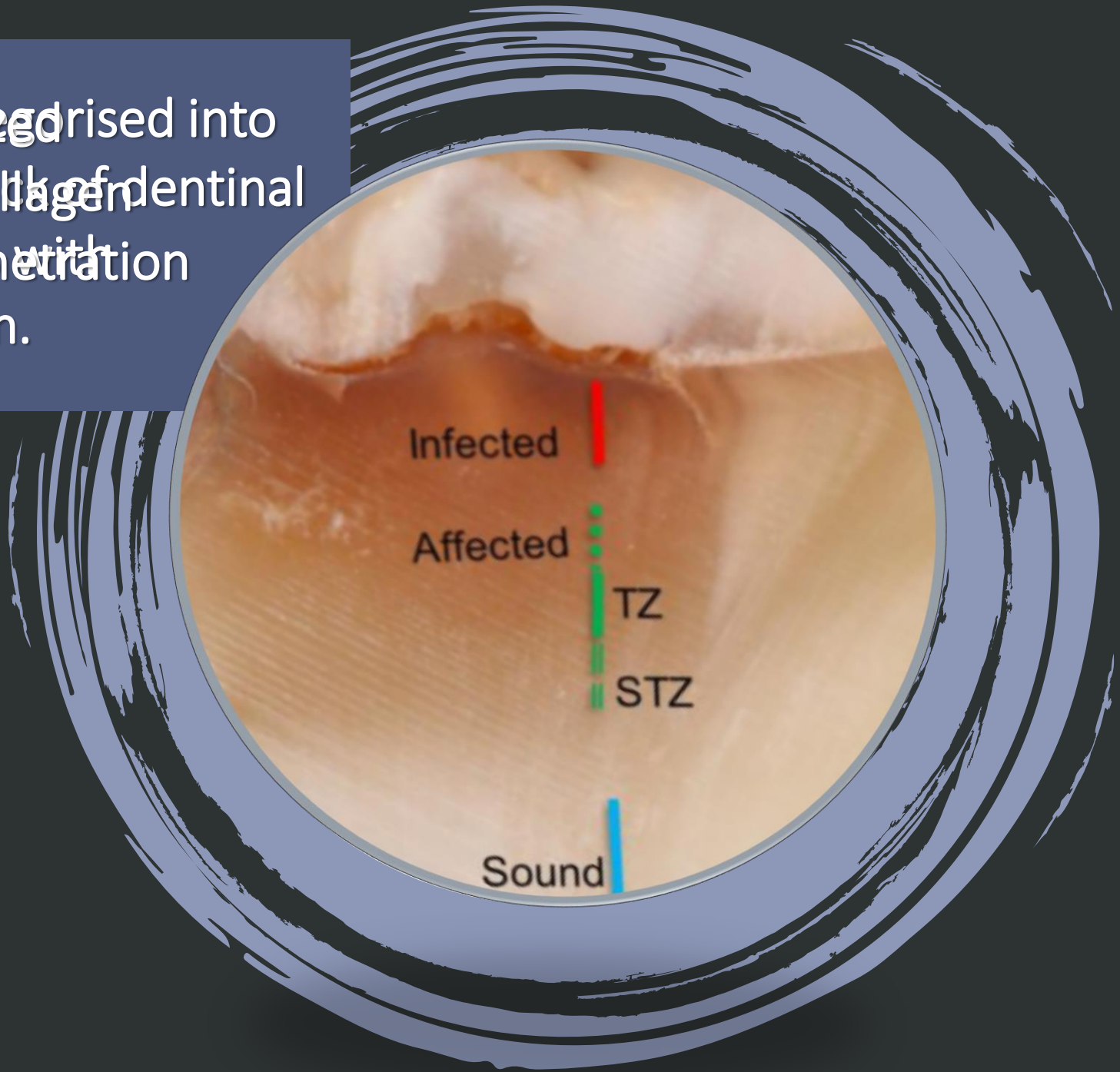
INTRODUCTION

Dental caries is a highly prevalent dental disease that affects 3.5 billion people worldwide according to Global Oral Health Status Report in 2022

Silva et al., 2023

The deeper CAD layer: Demineralized intertubular dentin with limited collagen matrix degradation & bacterial penetration

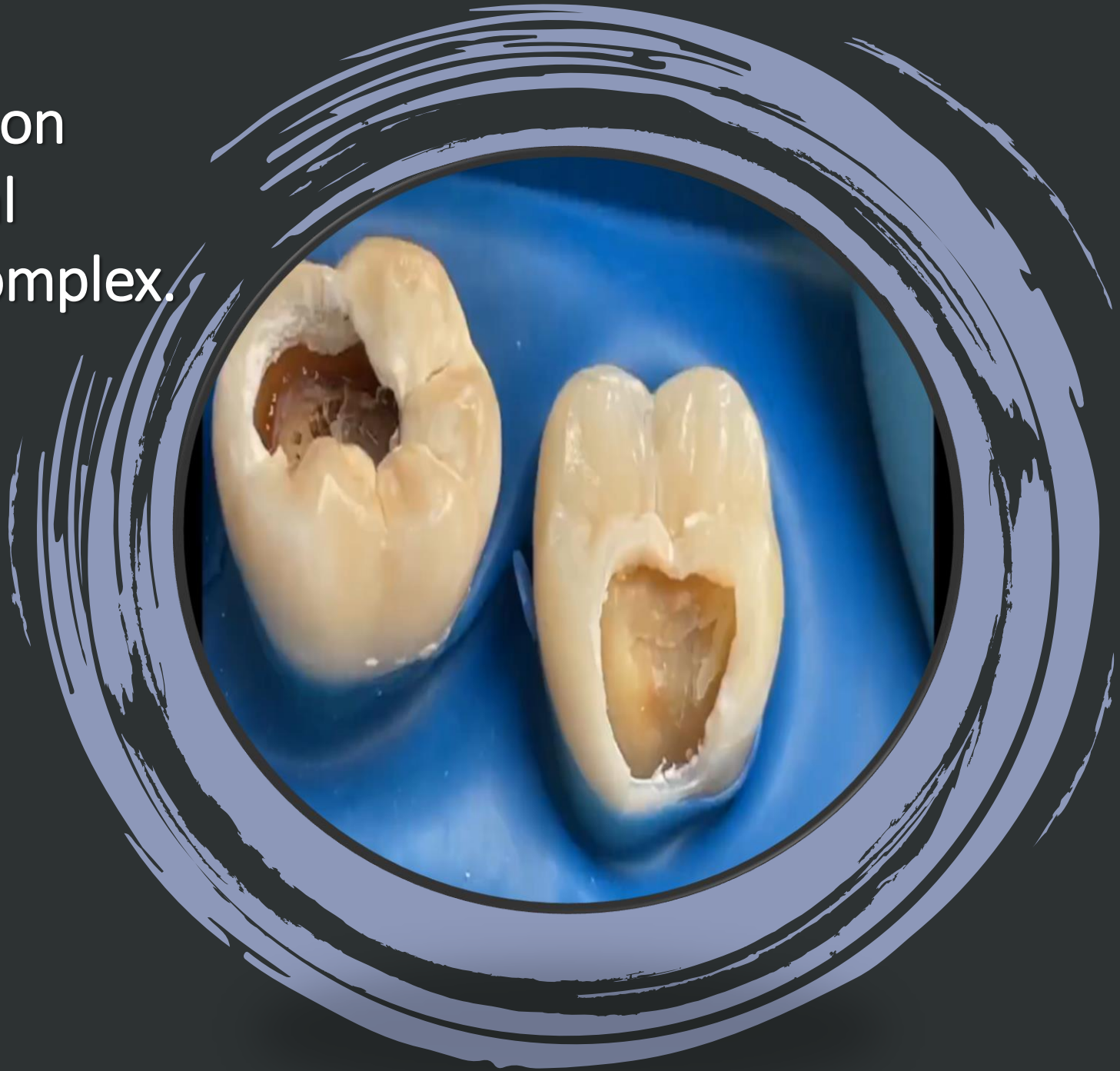
The superficial CAD layer: Demineralized intertubular dentin with loss of dentinal tubules denatured collagen fibres with prominent bacterial contamination.



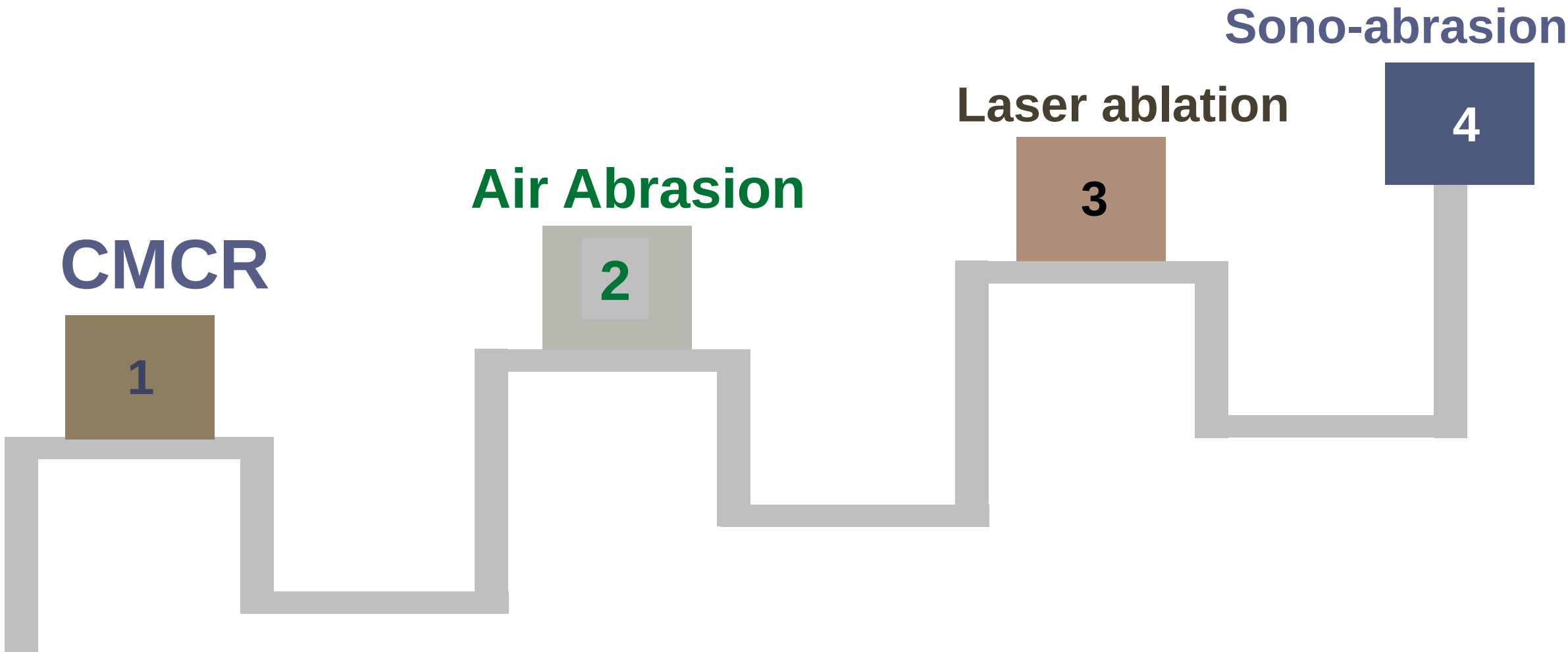
This can be remineralized & thereby preserved during the operative management of cavitated carious lesions

The traditional rotary excavation might cause adverse biological reaction to the dentin-pulp complex.

Moreover, the non-selective tissue removal of both infected, affected & sound dentin tissues.



Finding effective MI techniques to overcome the drawbacks of bur is an objective for researchers, to maintain the integrity of healthy & mineralizable tooth tissue, while maximizing the reparative potential of dentin-pulp complex



CHEMO-MECHANICAL CARIES REMOVAL AGENTS

Sodium hypochlorite caries removal agents

- GK-101
- GK-101E (Caridex)
- Carisolv

Chlorination involves hydrolysis of cross-links between the tropocollagen units or cleavage of polypeptide chains inside the triple helix. As a result, oxygen is released causing in the bleary-looking gel bubbling

Enzymatic-based caries removal agents

- Papacarie
- Biosolve

proteolytic enzyme like papain which is a cysteine protease enzyme obtained from the fruits and latex of green papaya with anti-inflammatory and antibacterial properties

Break down the partially damaged collagen molecules and assist in the disintegration of fibrin mantle produced by the carious process facilitating their removal without damaging the intact collagen fibrils. This specific mechanism due to the absence of a-1- antitrypsin, inhibitor in infected dentin

Brix 3000 is composed of papain enzyme

It is produced by the buffer emulsion technology to increase the enzyme activity that confers its stability & reactivity

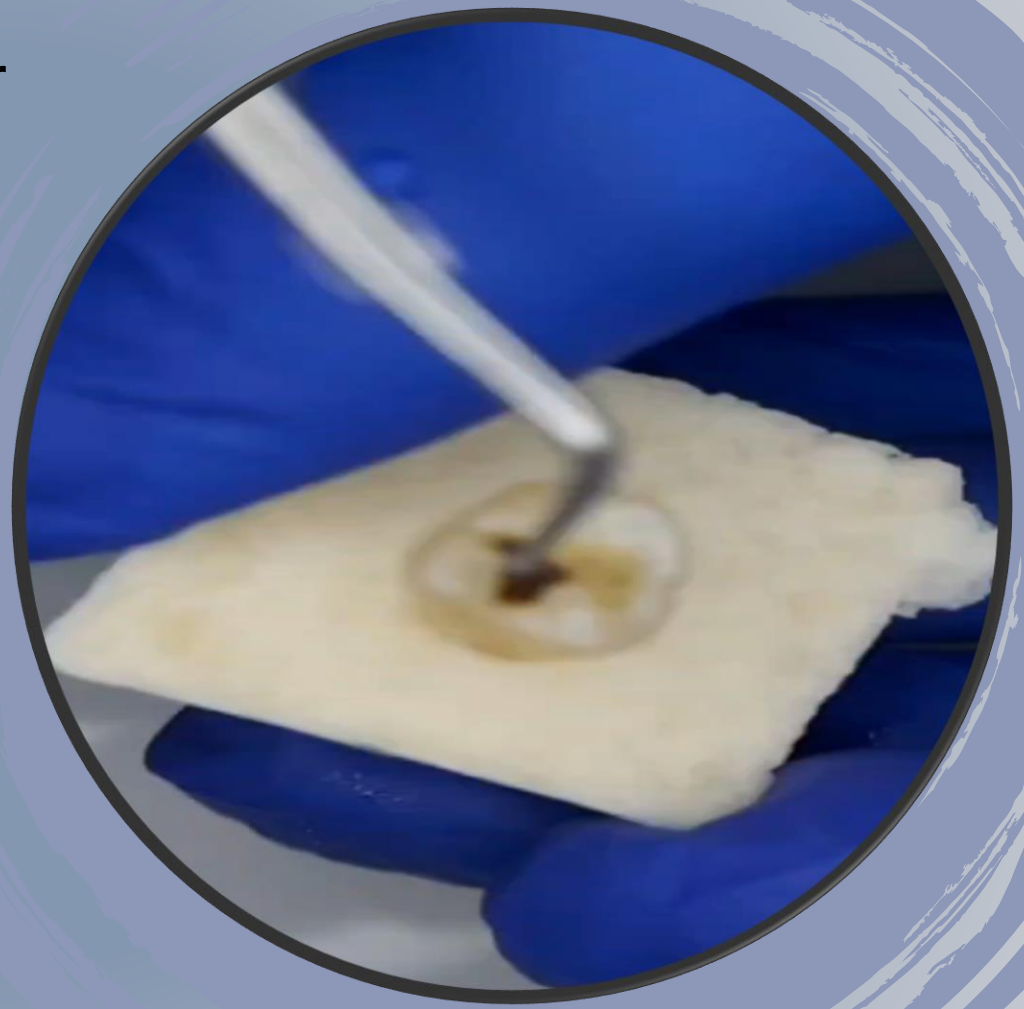
Meyfarth et al., 2020

Hegde RJ, Chaudhari S. Comparative Evaluation of Mechanical and Chemo-mechanical Methods of Caries Excavation: An In Vivo Study. Journal of International Oral Health. 2016;8(3):357-61.
S.Ali, A. et al. Self-limiting versus conventional caries removal: A randomized clinical trial. J. Dent. Res. 2018;97(11): 1207–1213.

Ultrasonic-abrasion technique

It relie… …y of water
mole… …o tooth
surfa… …ed
diam…
accor… …caler
device…
Banerje… …ves et al.
(2011) …nce of
residua… …s at the… …y walls
(under p… …ation)

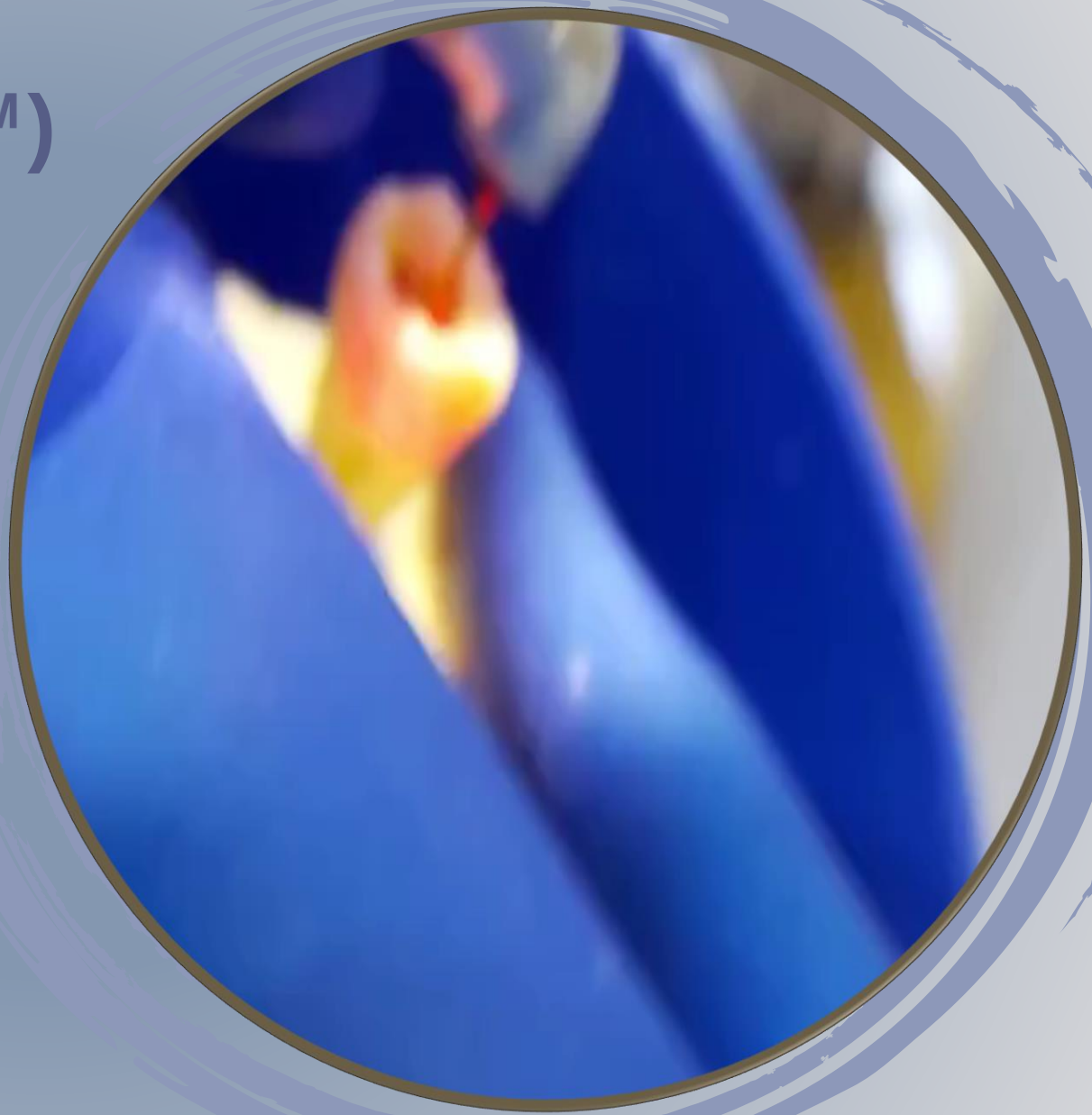
However, the utilization of advanced systems with different parameters might showed different caries removal efficiency



Hegde RJ, Chaudhari S. Comparative Evaluation of Mechanical and Chemo-mechanical Methods of Caries Excavation: An: In Vivo: Study. Journal of International Oral Health. 2016;8(3):357-61.
5.Ali, A. et al. Self-limiting versus conventional caries removal: A randomized clinical trial. J. Dent. Res. 2018;97(11), 1207–1213.

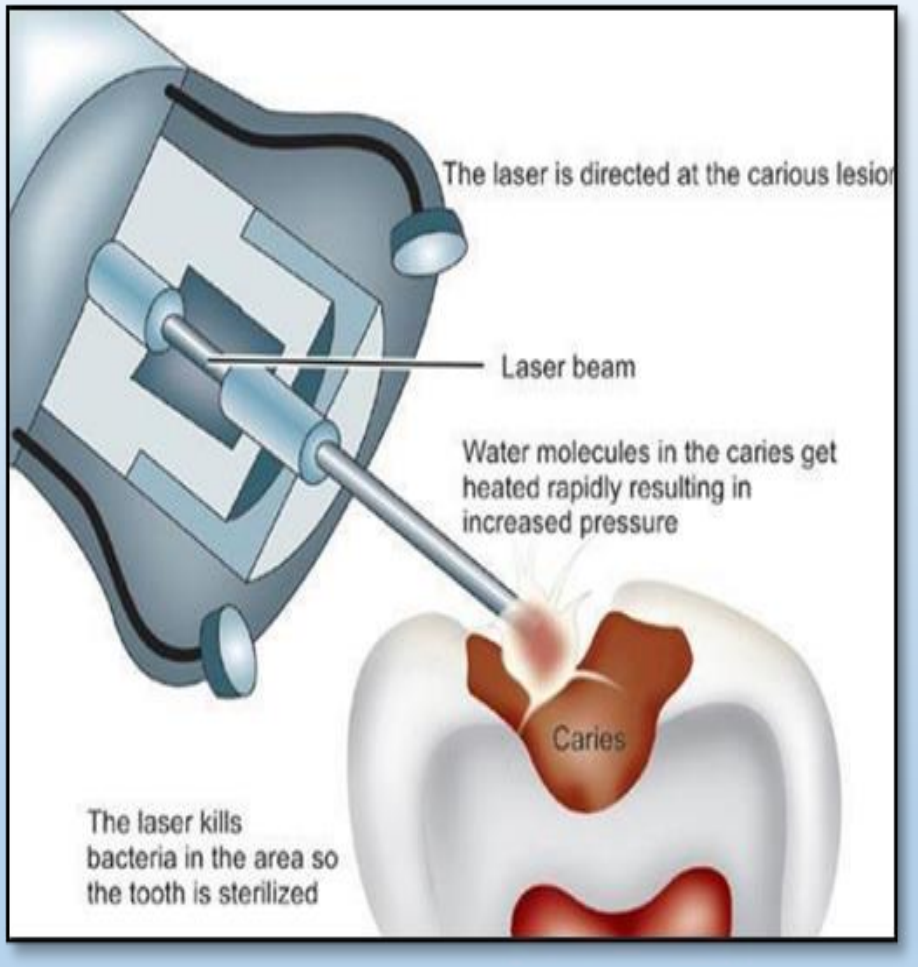
Er, Cr: YSGG laser (Biolase™, Waterlase™)

The lasers transfer high energy into dental hard tissues through a photoablation process mediated by a rapid expansion of subsurface water, leading to explosive ejection of tissue from the surface (Tao et al. 2017).

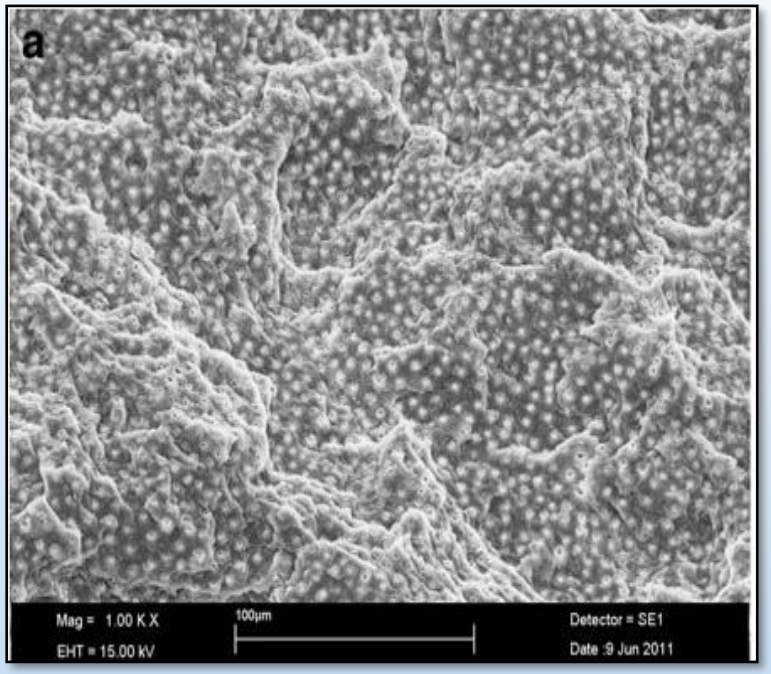


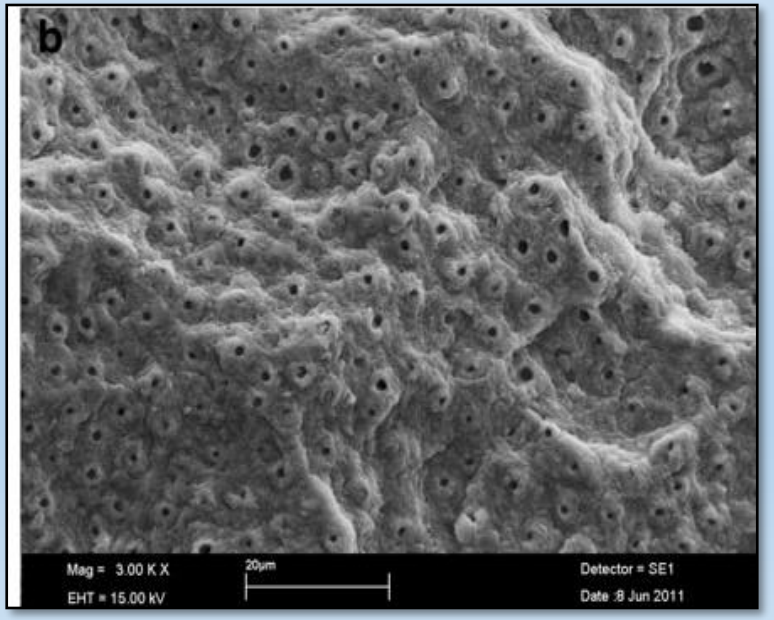
Tao, S. et al. Erbium laser technology vs traditional drilling for caries removal: A systematic review with meta-analysis. J. Evid.- Based Dent. 2017;Pr. 17(4), 324–334.
Kinoshita, J. I., Kimura, Y. & Matsumoto, K. Comparative study of carious dentin removal by Er, Cr: YSGG laser and Carisolv. J. Clin. Laser Med. Surg. 2003; 21, 307–315.

The Erbium lasers are delivered through a flexible Fiber optic cable and focused through a contra-angled handpiece bearing a sapphire tip.
It is absorbed by water & OH^{-1} in enamel or dentin, thus it is effective for cavity preparation & caries removal with less discomfort.
It is combined with air-water spray and effectively used for preparing Class I, III and V cavities in a conservative manner.

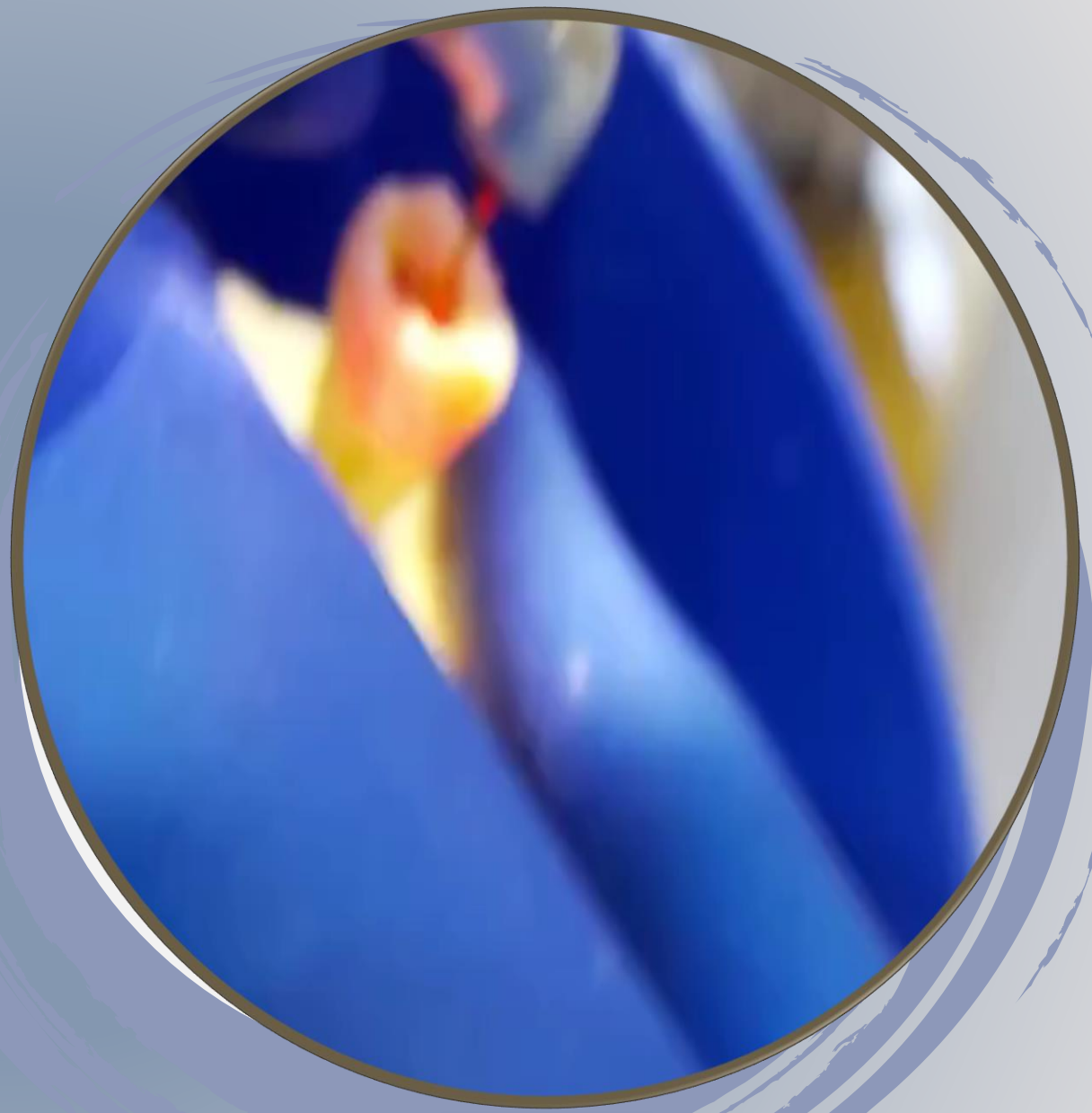


- ✓ The thermomechanical ablation causes changes in dentin including melting & recrystallization of inorganic components.
- ✓ The exposed surfaces illustrated irregular appearance free from smear layer with a large number of opened dentinal tubules.
- ✓ It produces high surface energy with a rough texture that is similar to the etching pattern produced by acids or micro-abrasion, which expected to improve the adhesion strength of resin restorations to sound & CAD.
- ✓ There is also a reduction in the bacterial load in the irradiated surfaces which reduces the possibility of recurrent caries.





However, the laser irradiation may cause a thermal tissue injury or even pulp necrosis when applied without proper cooling.
Bakry et al., (2007) reported a sign of carbonization and heat damage when the specimens are irradiated without proper water irrigation. So the application of the appropriate laser parameter is considered the key factor in preserving tooth vitality.



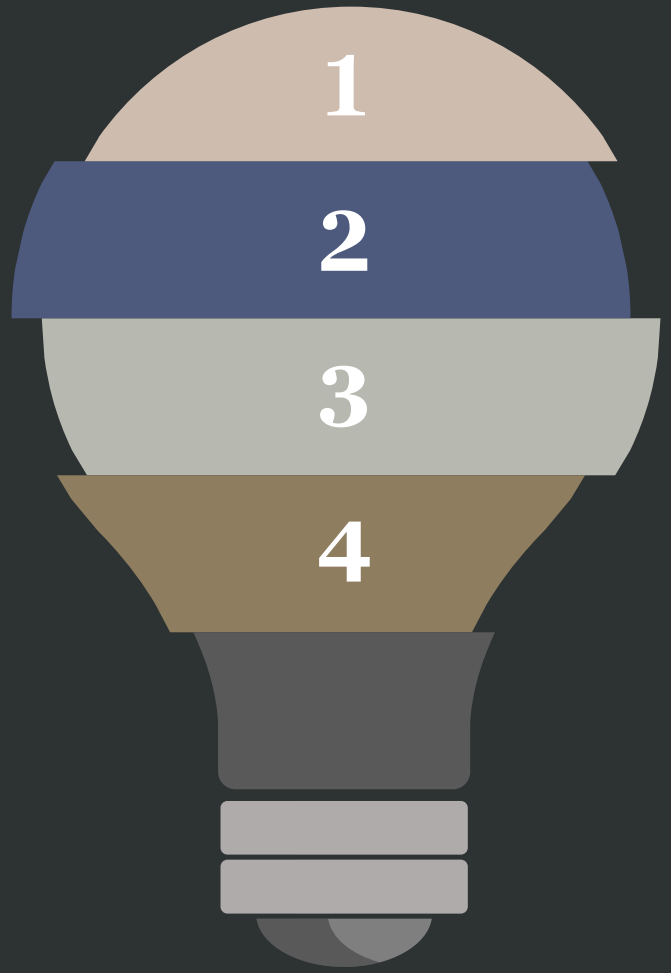
- **Er, Cr: YSGG laser (Biolase™, Waterlase™)**

AIM OF THE STUDY

Aim of the study

1

To evaluate the efficiency & effectiveness of three MI caries removal techniques; Brix 3000, air abrasion & laser ablation, in comparison to the rotary method for managing moderately/deep dentin carious lesions.



2

Calculating the excavation time

3

Assessing the chemo mechanical characteristics of the remaining dentin after caries removal

4

Assessing the morphological characteristics of dentin by SEM-EDX

Null hypotheses

01

There is no significant difference in the excavation time between the experimental groups (Brix3000, ultrasonic abrasion, Er, Cr: YSGG laser) and the conventional rotary excavation (control)

02

There are no significant differences in the mineral and matrix contents of the remaining dentin between groups at each area and between areas

03

There are no significant differences in VHN of the remaining dentin between groups at each area and between areas.

METHODOLOGY

Sixty extracted human molars with natural carious lesions were collected from patients 25-40 yrs. The lesions had a score >4 following ICDAS-II which appeared as a dark shadow of the underlying dentin with or without loss of the surface integrity

- The lesions extended through the middle third of dentin without pulp exposure, when verified by X-ray CCD-detector.

Sample Grouping

60 carious molar teeth
(n=15 per group)

Group A: Rotary excavation
(Control group)

Group B: CMCR agent (Brix 3000)

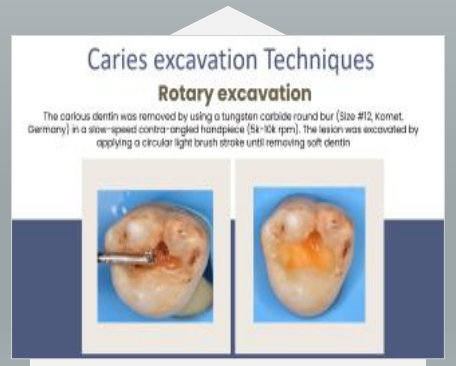
Group C: Ultrasonic abrasion

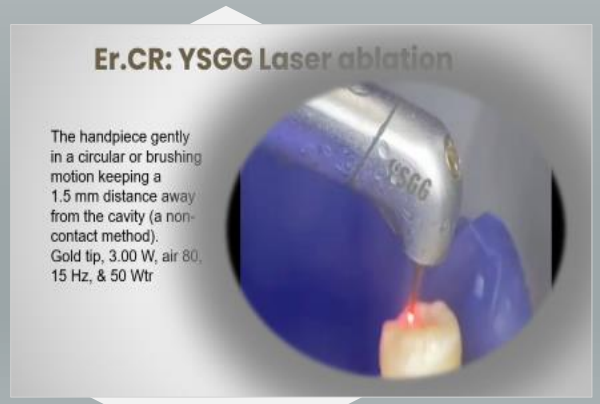
Group D: Er,CR:YSGG Laser ablation

Sample preparation:

An access class I cavity preparation was prepared through the enamel surface using tungsten carbide bur at a high-speed air turbine handpiece (300k rpm) by using a dental surveyor.

Caries excavation Techniques



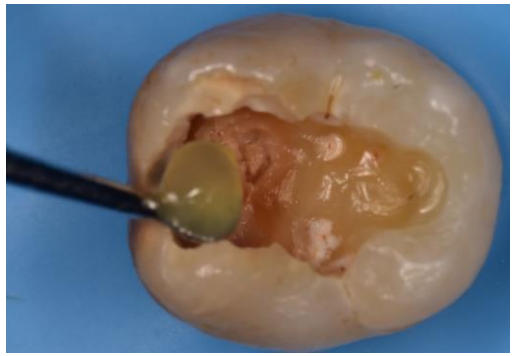


Caries excavation Techniques

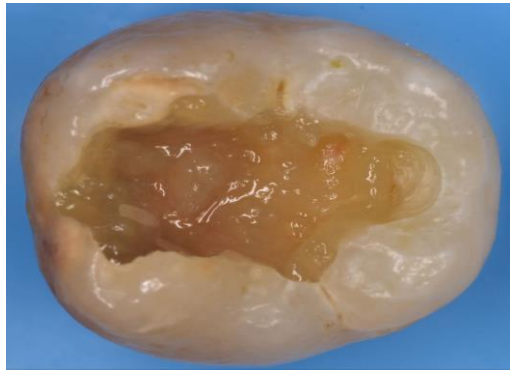
Rotary excavation

The carious dentin was removed by using a tungsten carbide round bur (Size #12, Komet, Germany) in a slow-speed contra-angled handpiece (5k-10k rpm). The lesion was excavated by applying a circular light brush stroke until removing soft dentin

Brix 3000

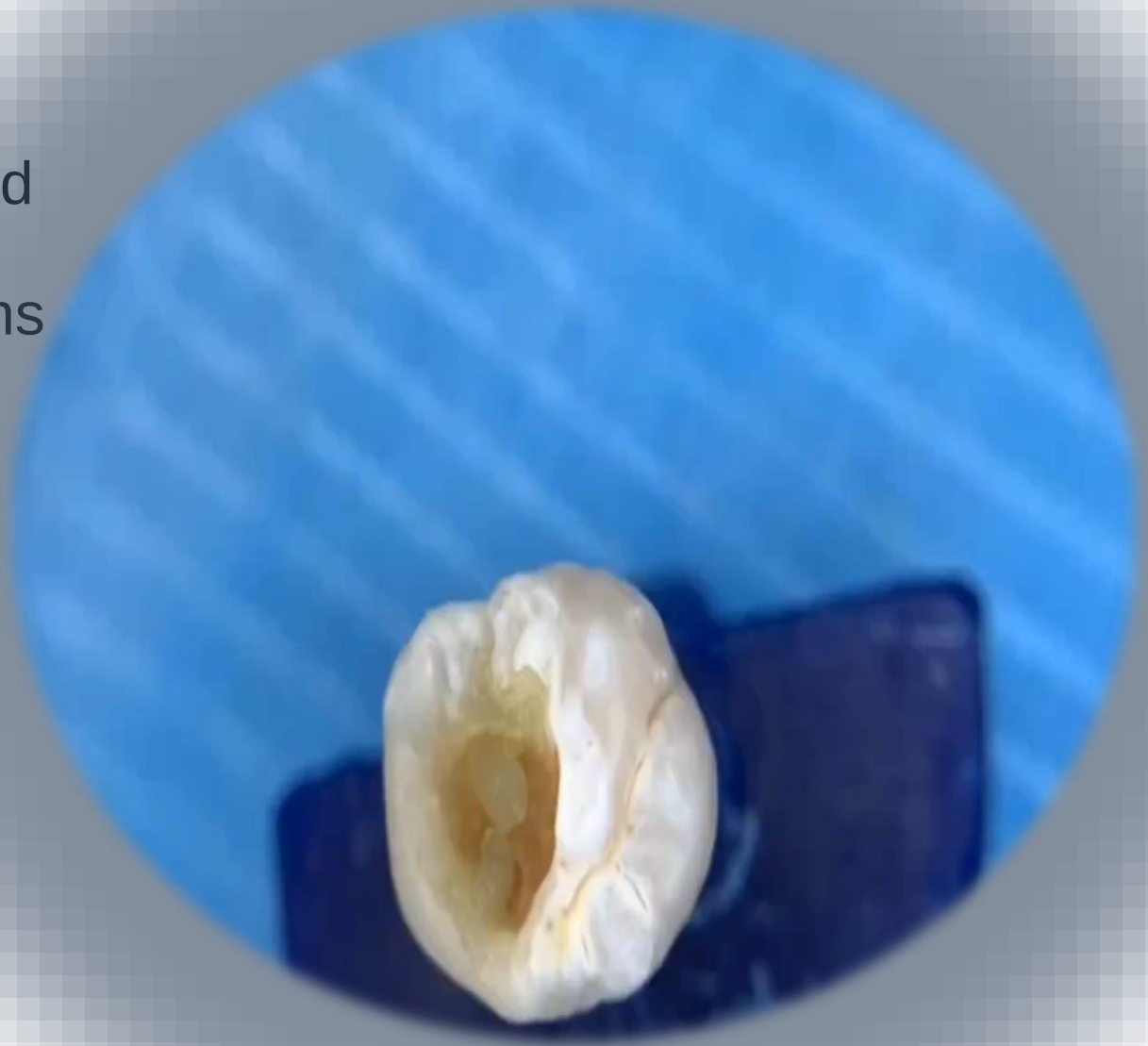


The Brix 3000 was applied following the manufacturer’s instructions

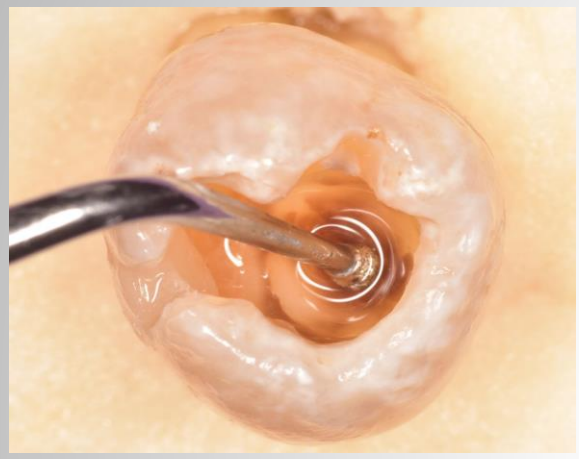


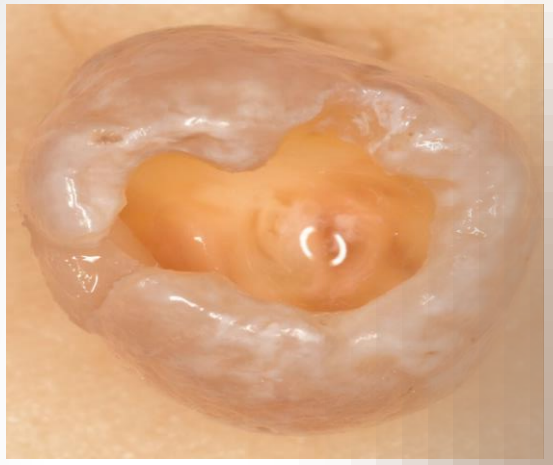
Left for 2 min

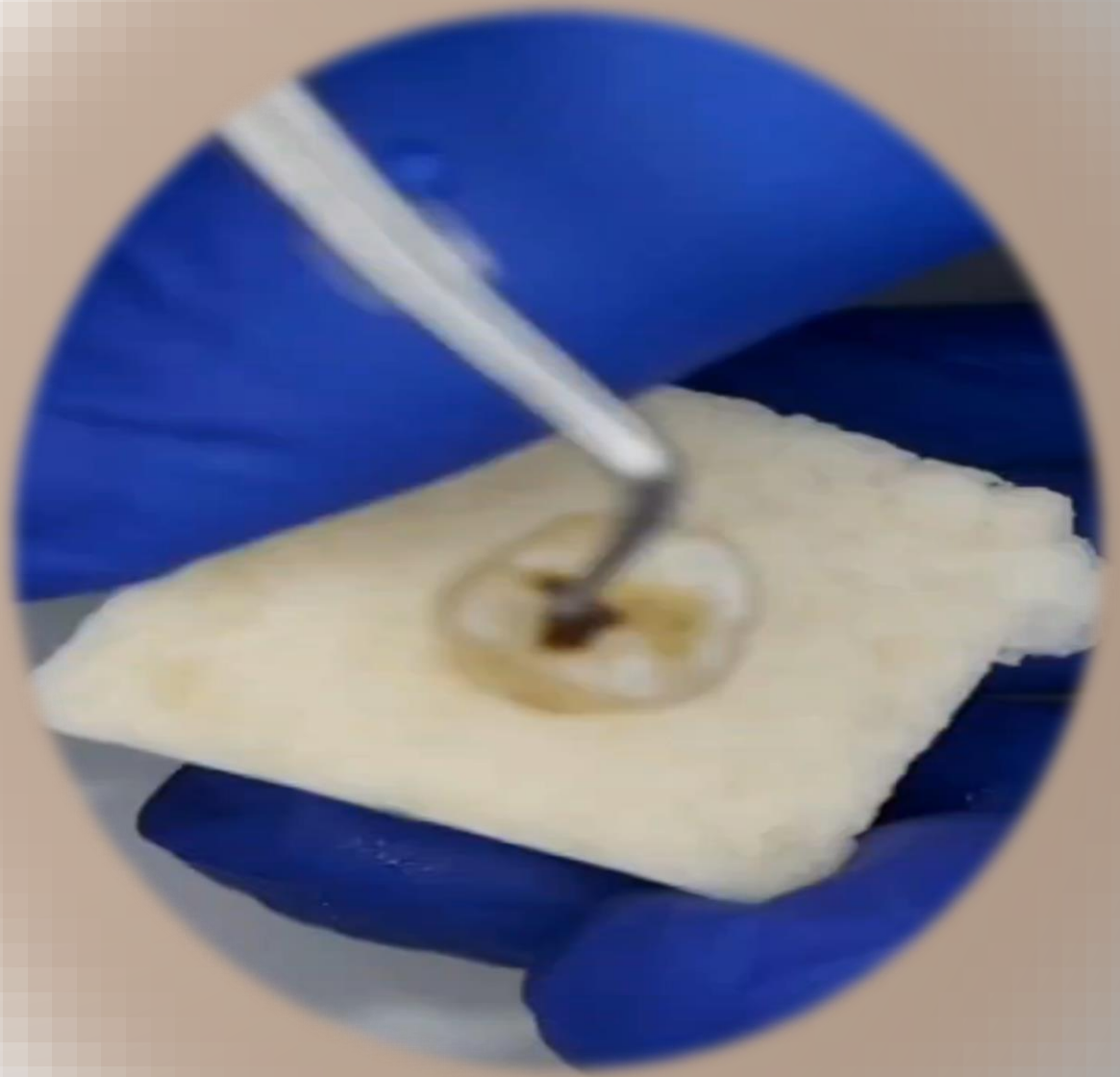
The caries was scraped away by a non-sharp spoon excavator in a pendulum motion with light pressure



Ultrasonic abrasion



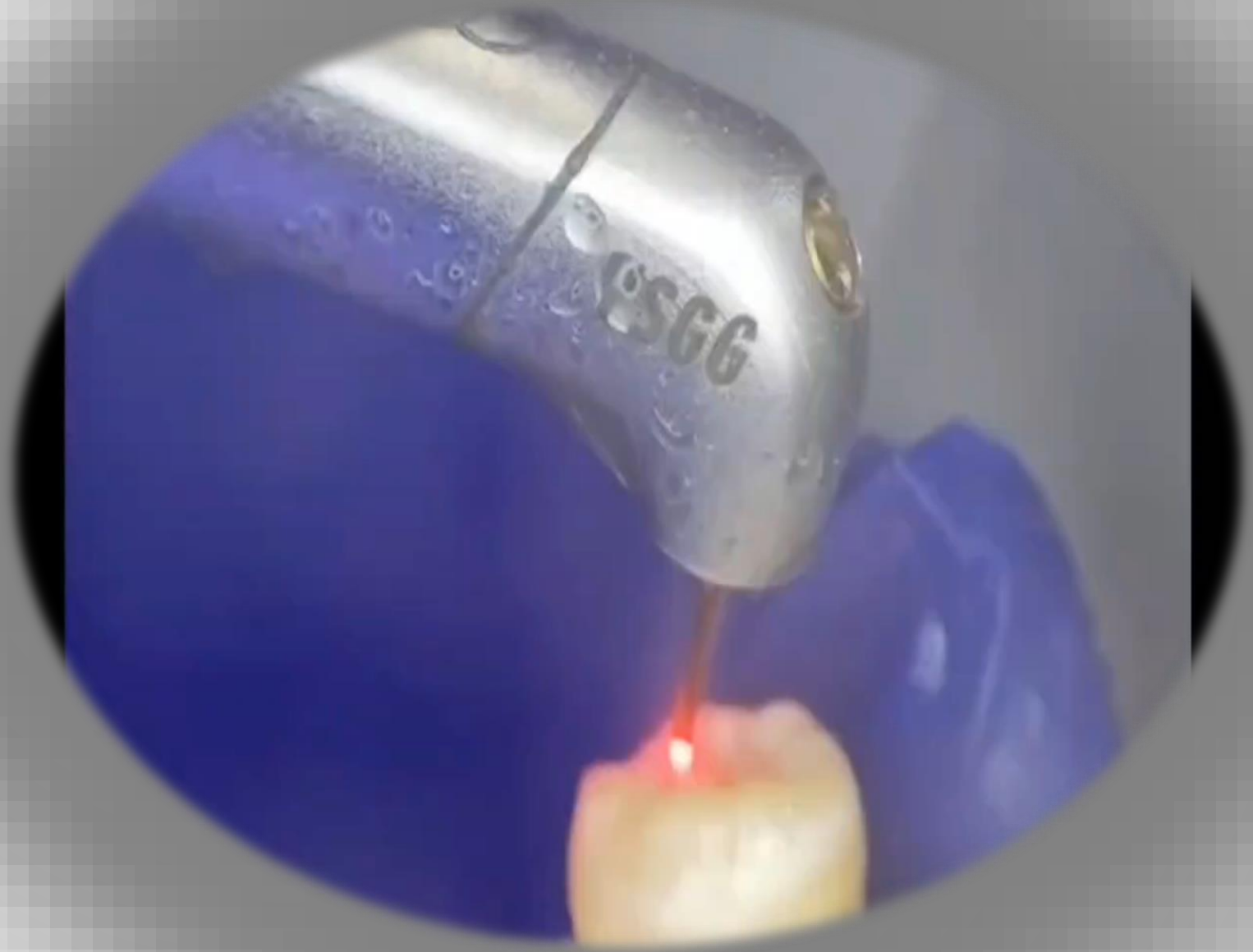




- A stainless-steel diamond-coated tip SB1 attached to woodpecker ultrasonic dental scaler (Woodpecker, China)
- Vibration frequency of 28±3 kHz
- Under copious water irrigation

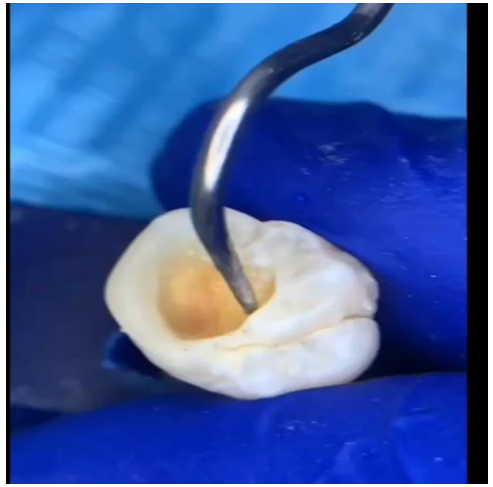
Er.CR: YSGG Laser ablation

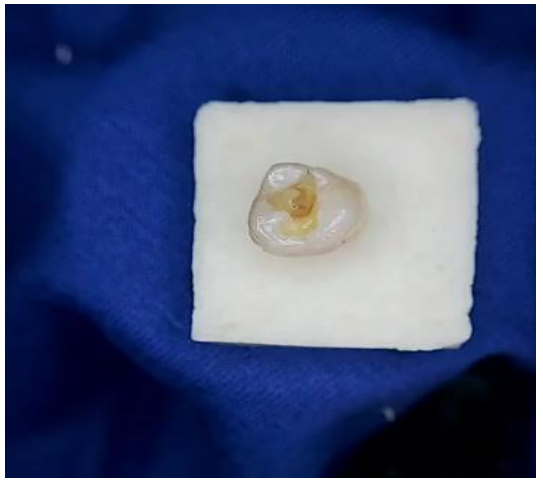
The handpiece gently in a circular or brushing motion keeping a 1.5 mm distance away from the cavity (a non-contact method).
Gold tip, 3.00 W, air 80, 15 Hz, & 50 Wtr



The excavation endpoint was determined following the recommended criteria in the literature

Techniques	CID	CAD	Sound	References
Visual inspection	Dark brown	Paler-light brown	Yellowish/ white	Banerjee et al 1999
Relative tissue hardness	Wet/ soft	sticky/ scratchy	Hard	Kidd et al., 1993; Banerjee et al 1999
DIAGOdent pen	Value > 20	Value 10-20	Value < 0-10	Tagtekin et al., 2008





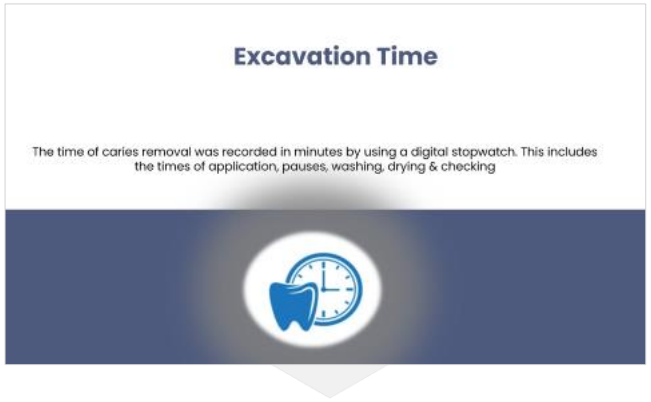
Assessments

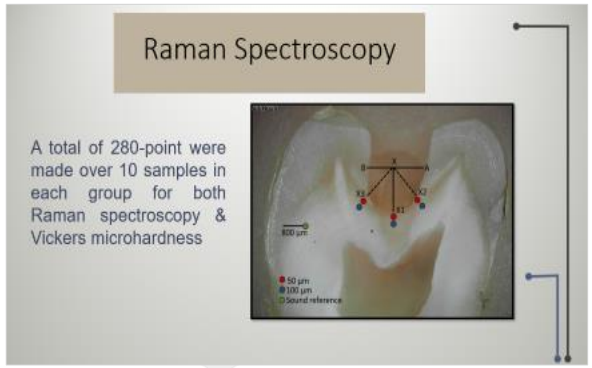
01 Excavation Time

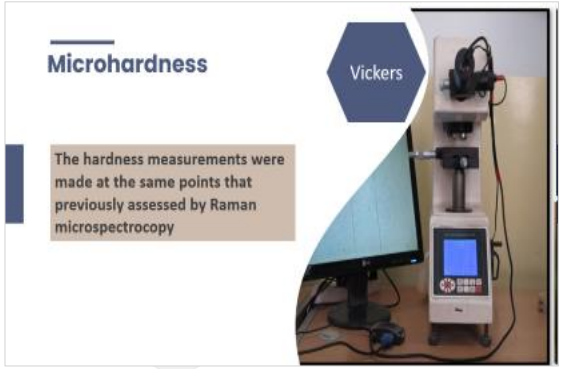
02 Raman Spectroscopy

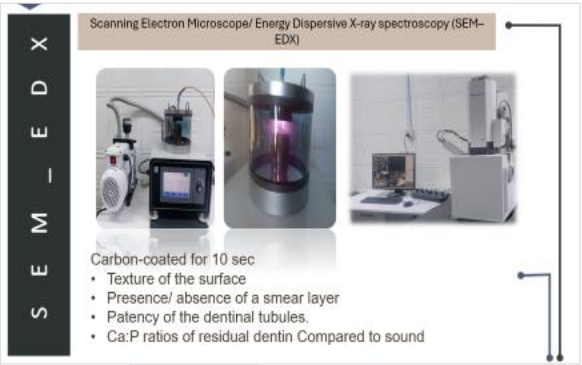
03 Vickers Microhardness

04 SEM-EDX







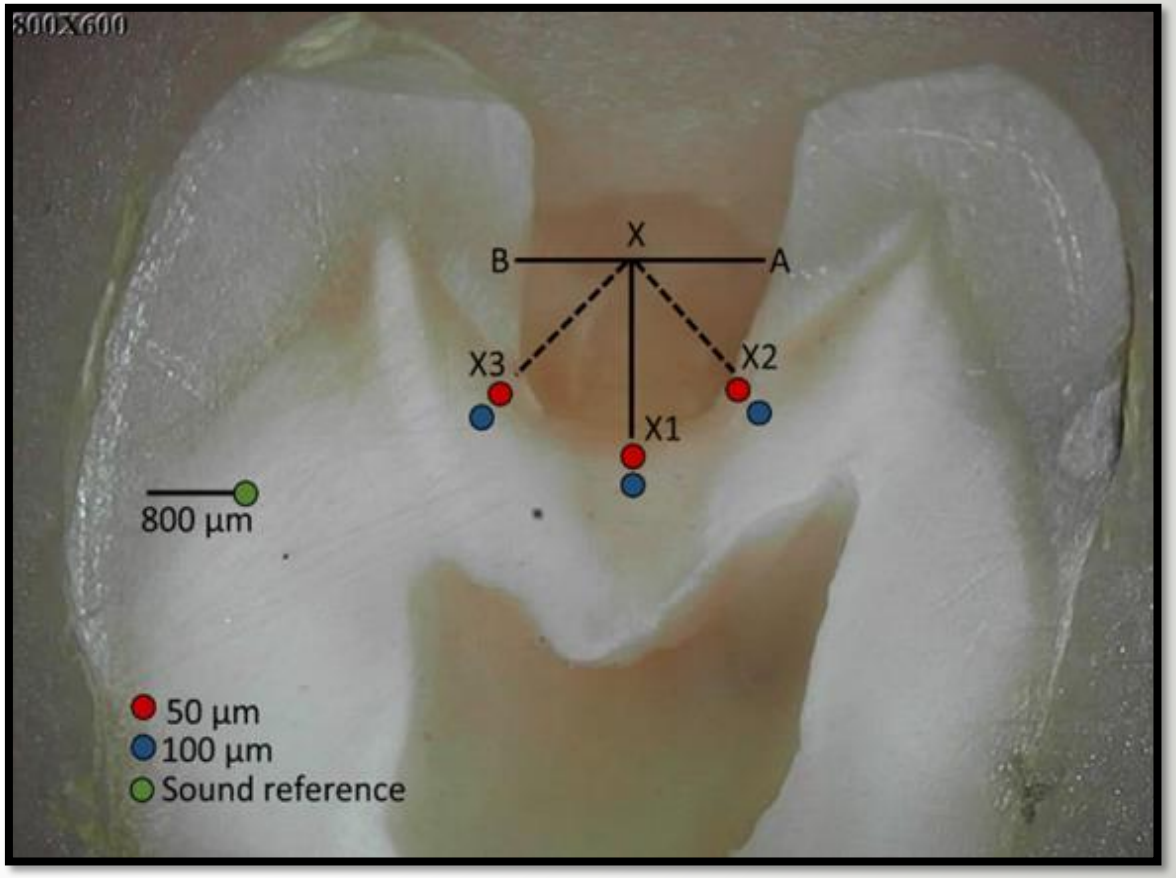


Excavation Time

The time of caries removal was recorded in minutes by using a digital stopwatch. This includes the times of application, pauses, washing, drying & checking

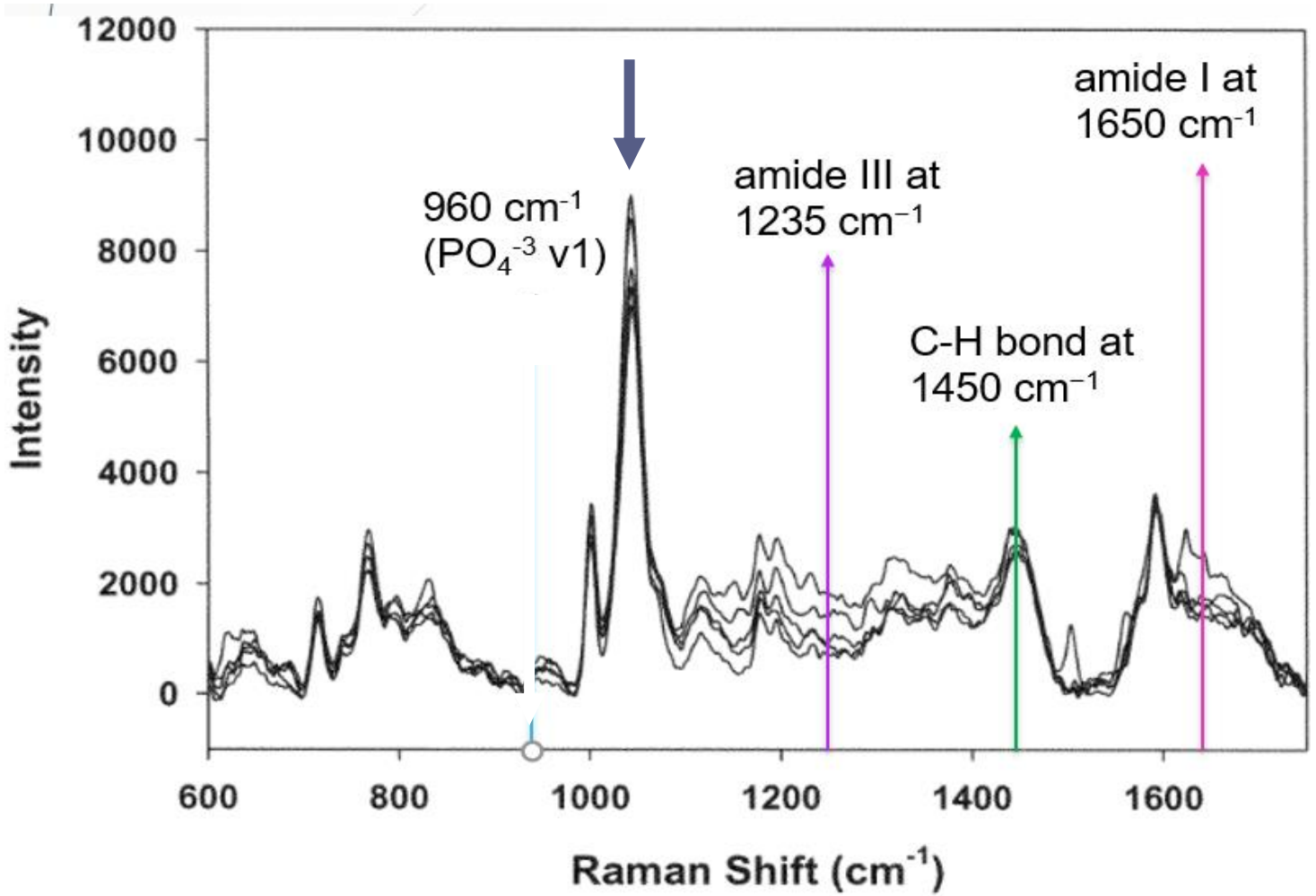
Raman Spectroscopy

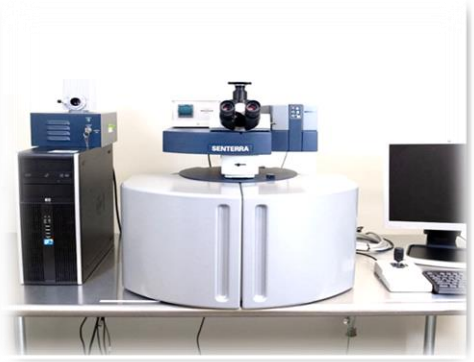
A total of 280-point were made over 10 samples in each group for both Raman spectroscopy & Vickers microhardness



Raman Spectroscopy

A high-resolution Raman spectrocroscopy, operating in line scan mode were used to scan remaining dentin after caries removal





The collagen integration of remaining dentin were assessed by calculating the absorbance ratio of 1235 cm^{-1} to 1450 cm^{-1}

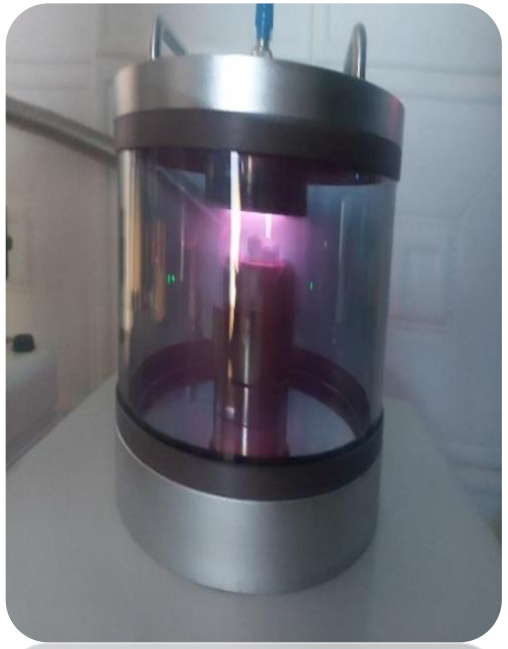
Microhardness

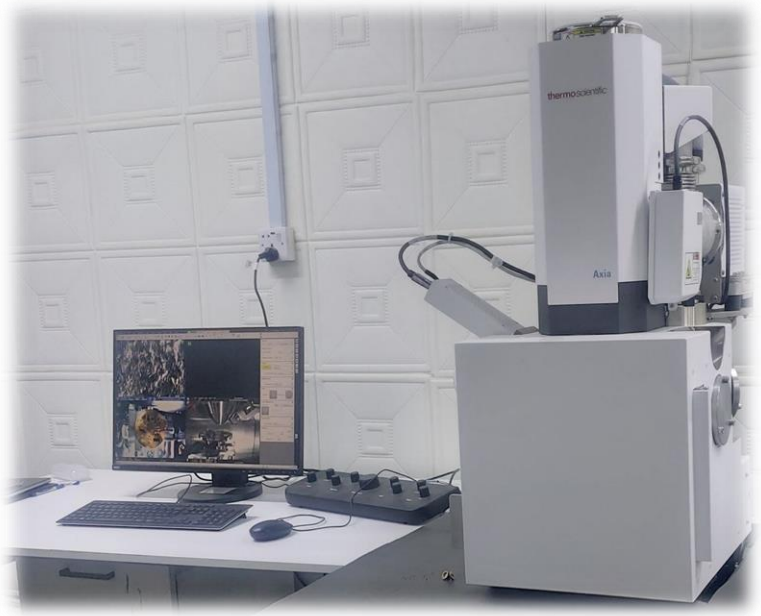
Vickers

The hardness measurements were made at the same points that previously assessed by Raman microspectrocopy

S E M – E D X

Scanning Electron Microscope/ Energy Dispersive X-ray spectroscopy (SEM–EDX)



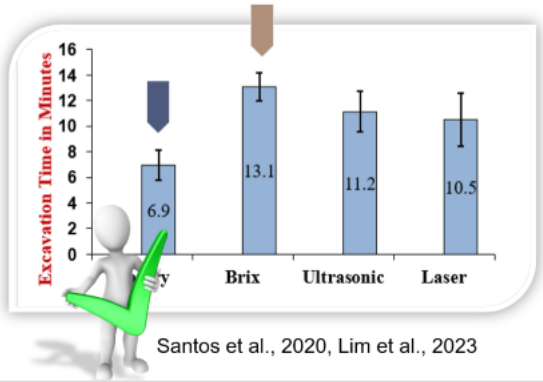


Carbon-coated for 10 sec

- Texture of the surface
- Presence/ absence of a smear layer
- Patency of the dentinal tubules.
- Ca:P ratios of residual dentin Compared to sound

Excavation Time

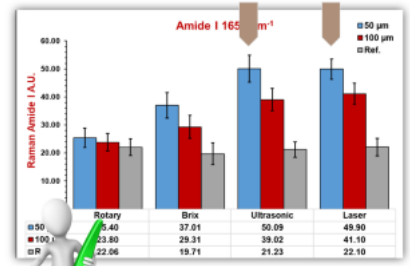
Excavation Time



Santos et al., 2020, Lim et al., 2023

Raman Amide I Peak Intensity

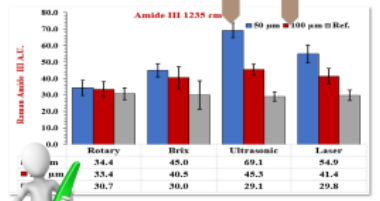
The organic Phase: Amide I Intensity



Al-Shareefi et al., 2022; Alturki et al., 2022

Raman Amide III Peak Intensity

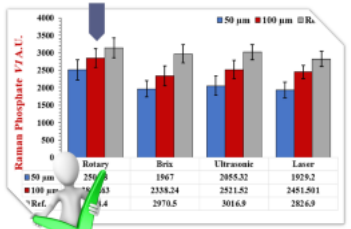
The organic Phase: Amide III Intensity



Al-Shareefi et al., 2022; Alturki et al., 2022

Raman Phosphate Peak Intensity

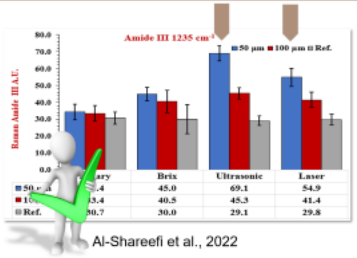
Inorganic Phase: Phosphate Intensity



Mollica et al ., 2012; Hamama et al., 2013

Raman CH-Bond Peak Intensity

The organic Phase: C-H bond Intensity

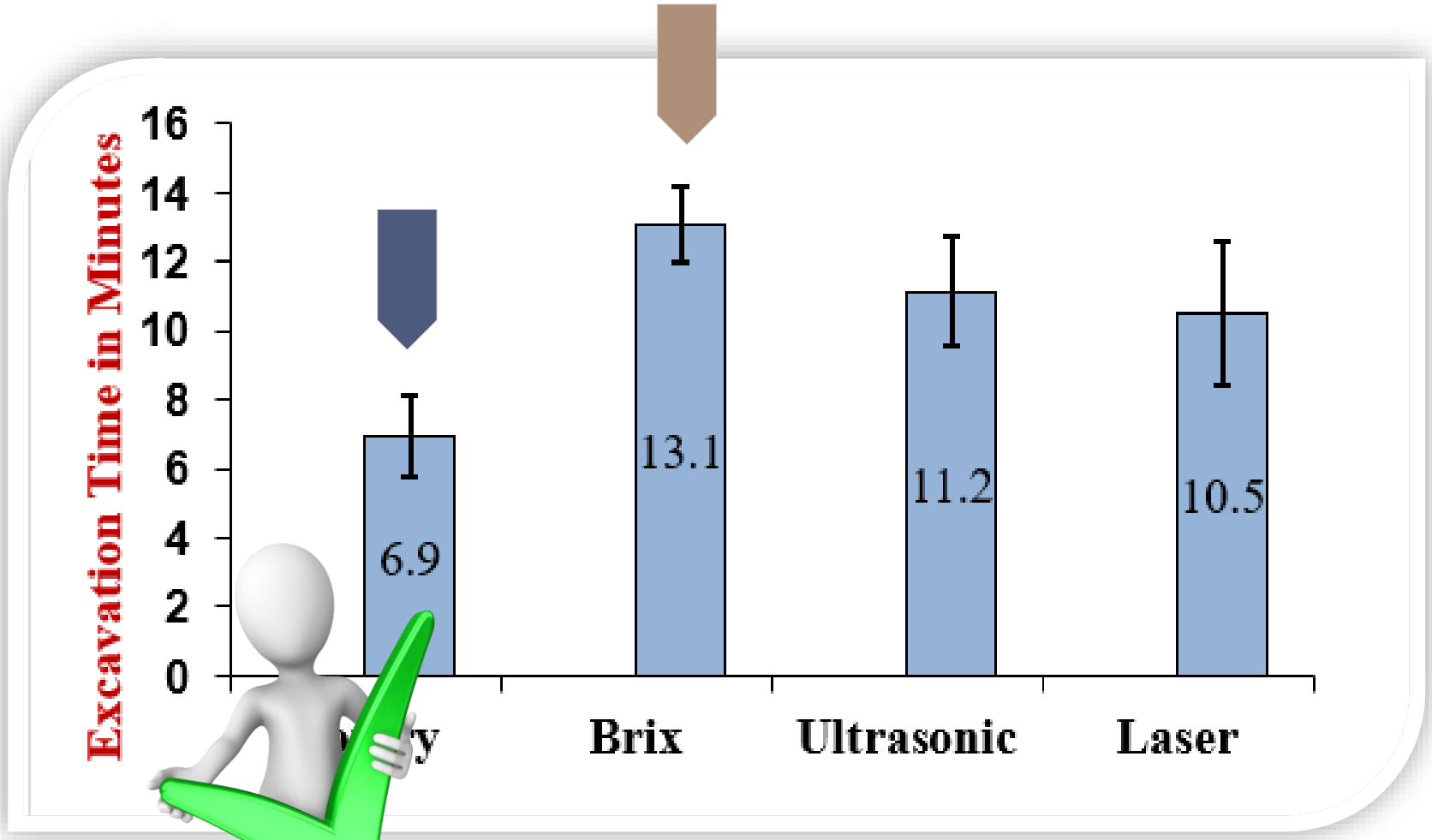


Al-Shareefi et al., 2022

RESULT AND DISCUSSION

Excavation Time

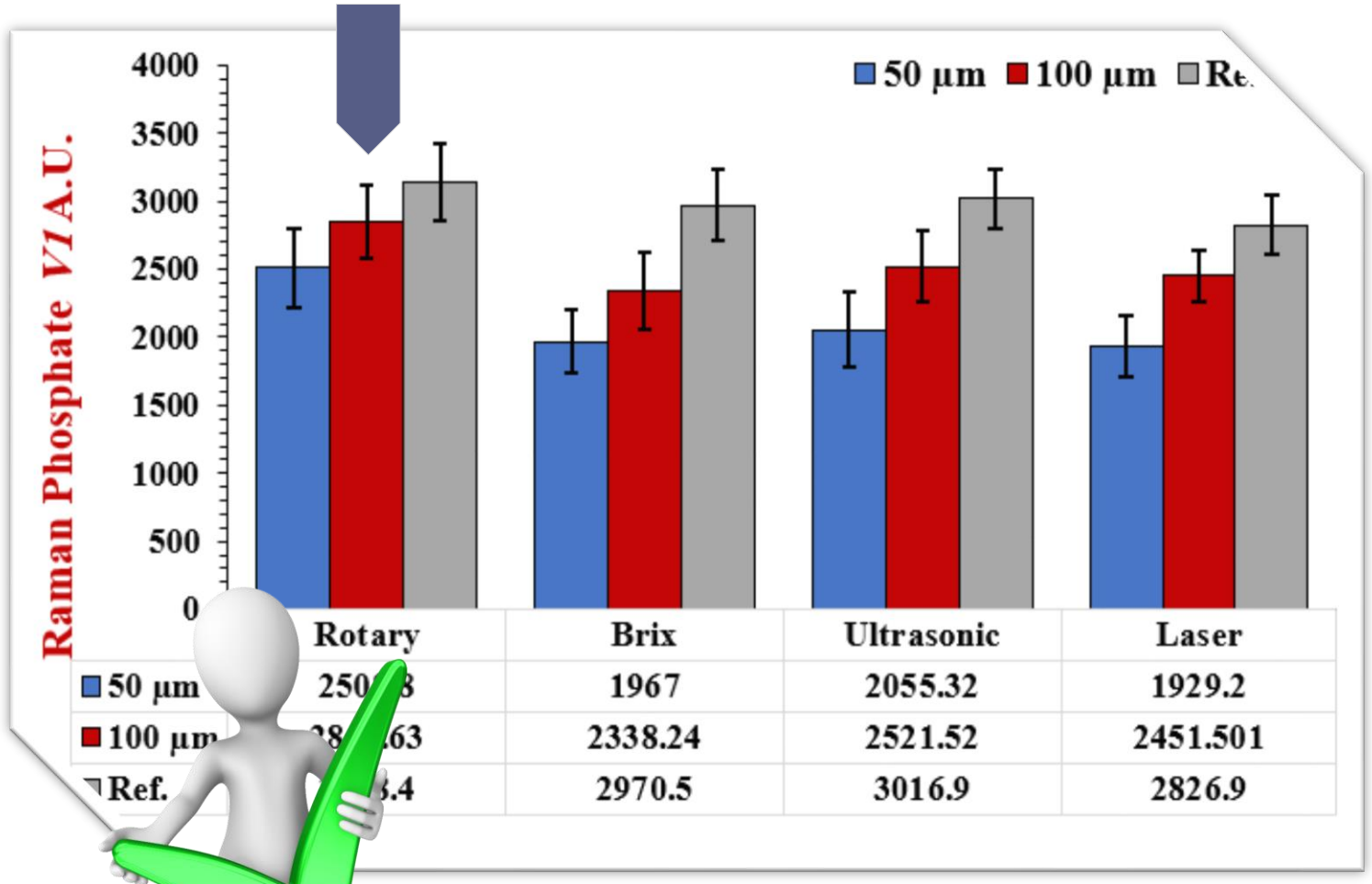
Excavation Time



Santos et al., 2020, Lim et al., 2023

Raman Phosphate Peak Intensity

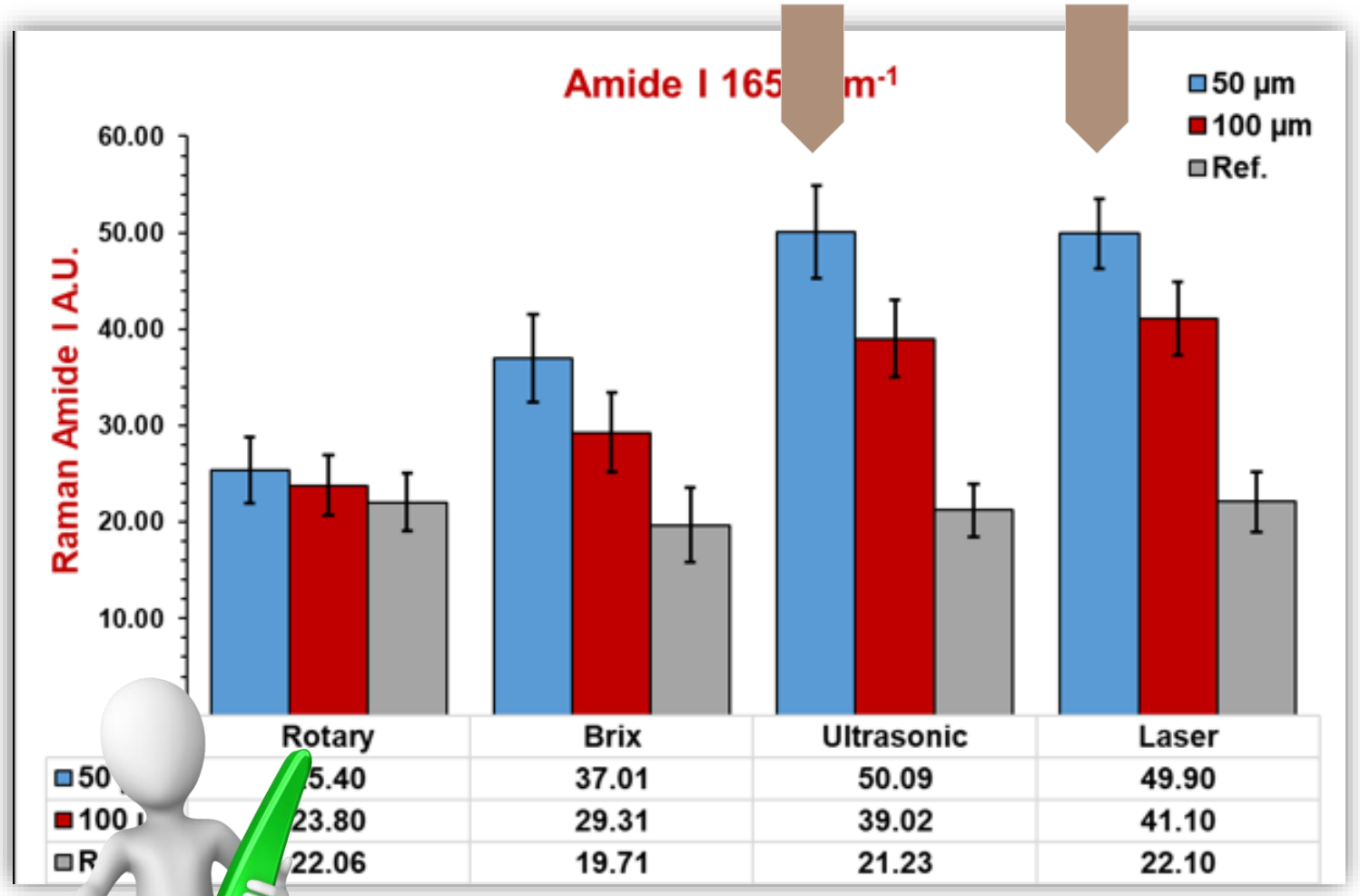
Inorganic Phase: Phosphate Intensity



Mollica et al ., 2012; Hamama et al., 2013

Raman Amide I Peak Intensity

The organic Phase: Amide I Intensity

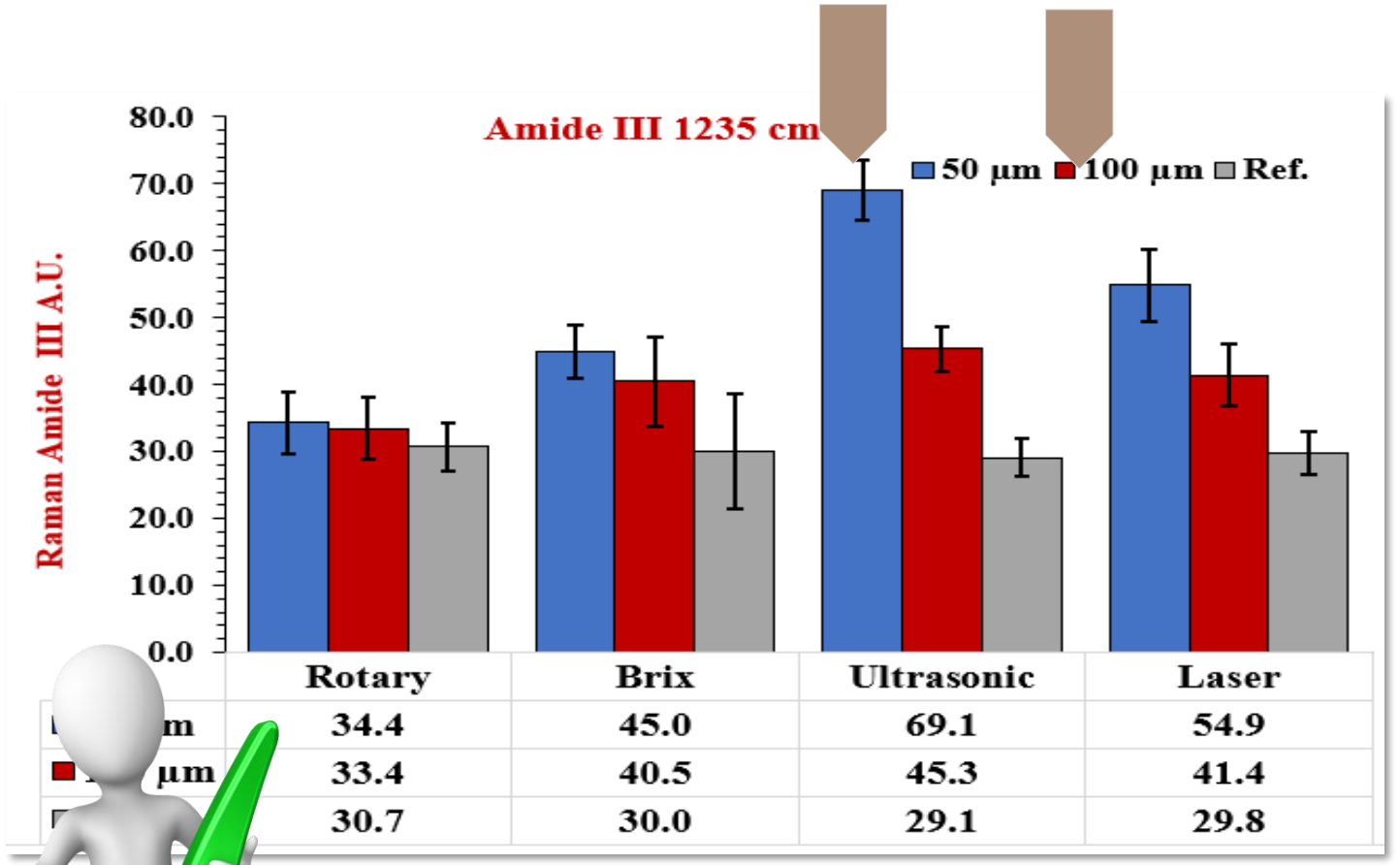


	Rotary	Brix	Ultrasonic	Laser
50	5.40	37.01	50.09	49.90
100	23.80	29.31	39.02	41.10
R	22.06	19.71	21.23	22.10

Al-Shareefi et al., 2022; Alturki et al., 2022

Raman Amide III Peak Intensity

The organic Phase: Amide III Intensity

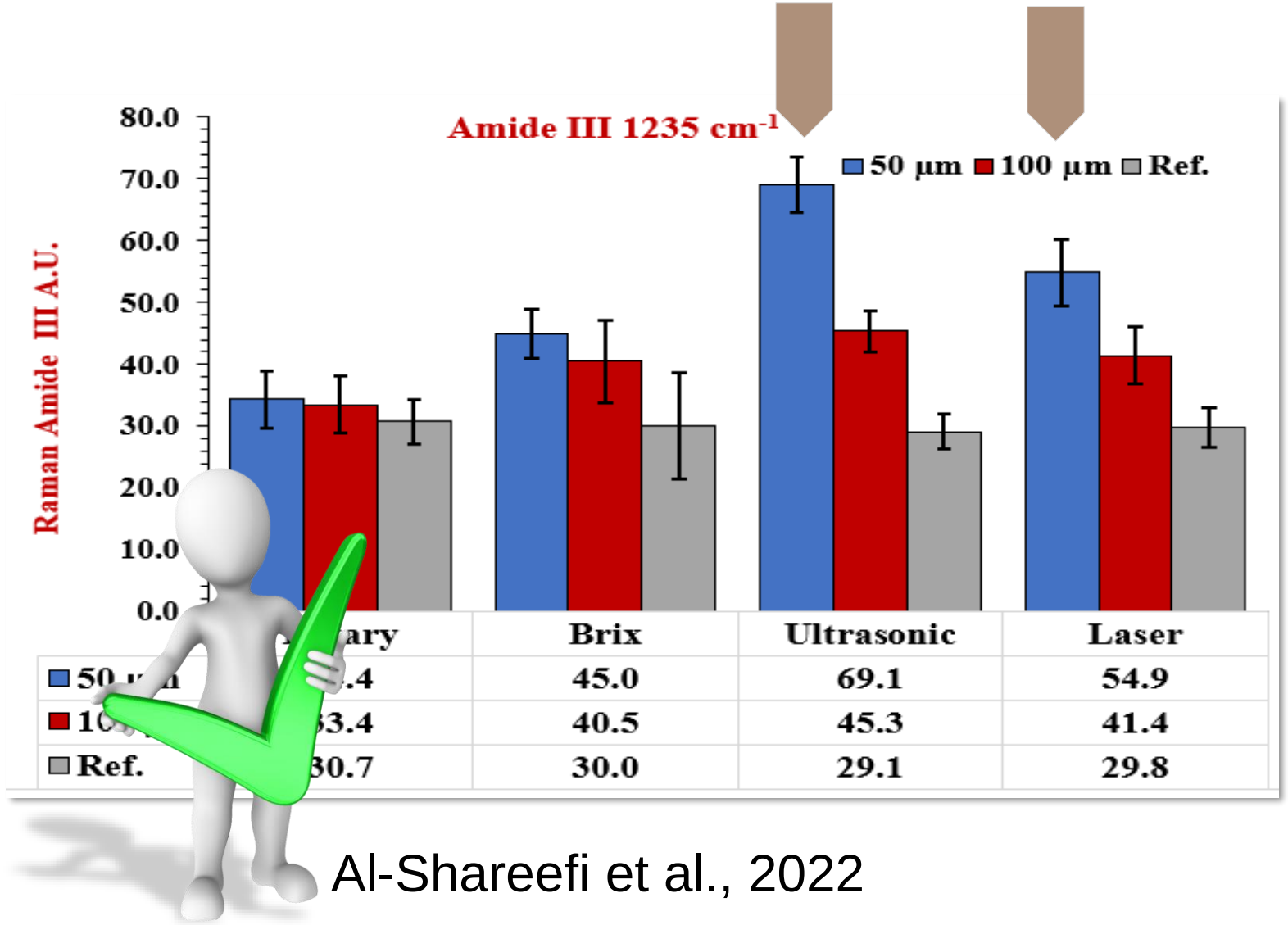


	Rotary	Brix	Ultrasonic	Laser
m	34.4	45.0	69.1	54.9
µm	33.4	40.5	45.3	41.4
	30.7	30.0	29.1	29.8

Al-Shareefi et al., 2022; Alturki et al., 2022

Raman CH-Bond Peak Intensity

The organic Phase: C-H bond Intensity



	ary	Brix	Ultrasonic	Laser
50 µm	.4	45.0	69.1	54.9
100 µm	3.4	40.5	45.3	41.4
Ref.	30.7	30.0	29.1	29.8

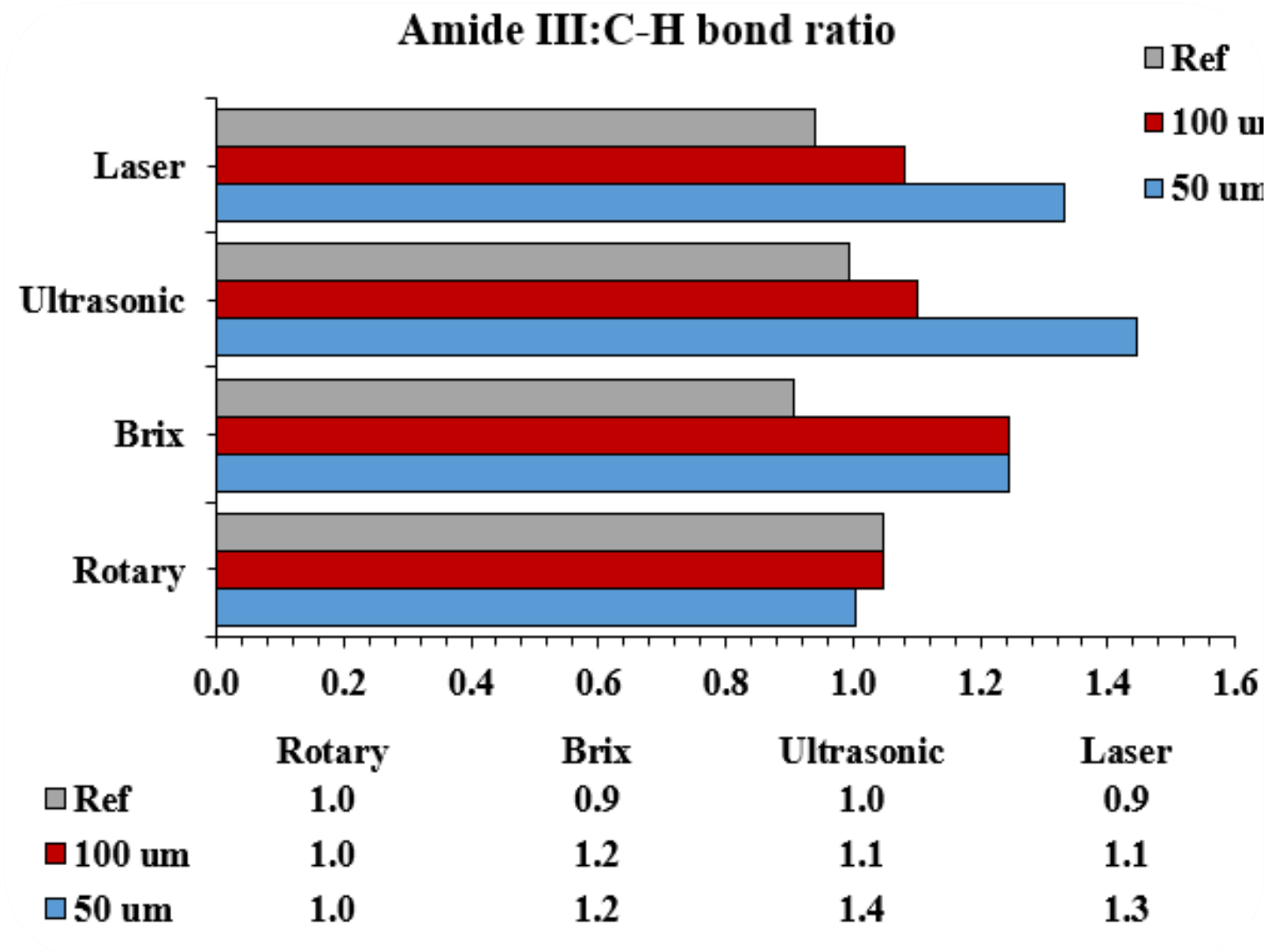
Al-Shareefi et al., 2022

This might indicate that the residual dentin in the minimally excavated cavities contains demineralized tissues with high organic contents resulted from the degradation of extracellular organic matrix

This might support the selective ability of both techniques as this altered organic matrix can regulate the growth & maturation of apatite crystals & thus the mineralization process

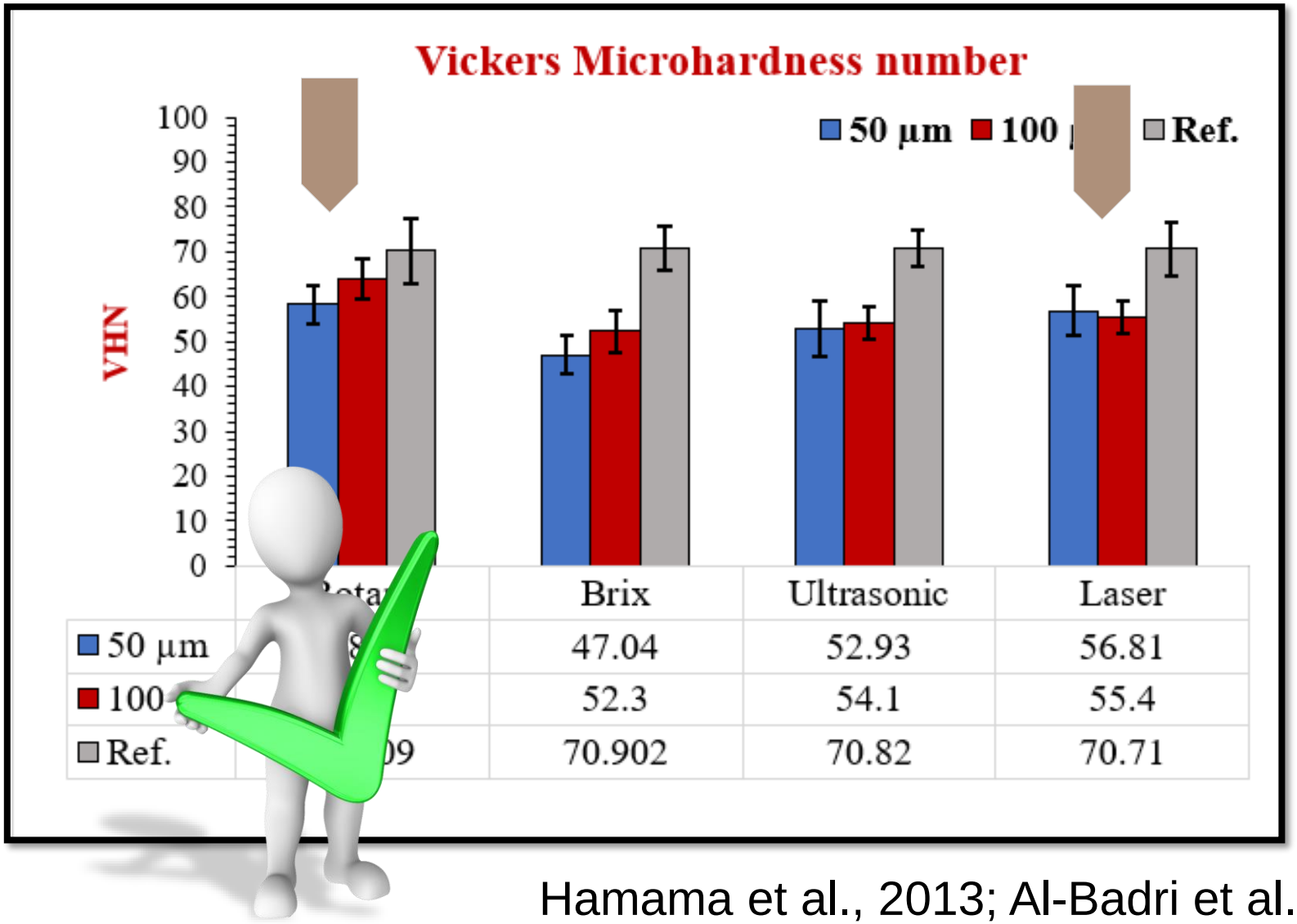
Collagen integrity ratio

Amide III: C-H bond



	Rotary	Brix	Ultrasonic	Laser
Ref	1.0	0.9	1.0	0.9
100 um	1.0	1.2	1.1	1.1
50 um	1.0	1.2	1.4	1.3

Vickers Microhardness Number

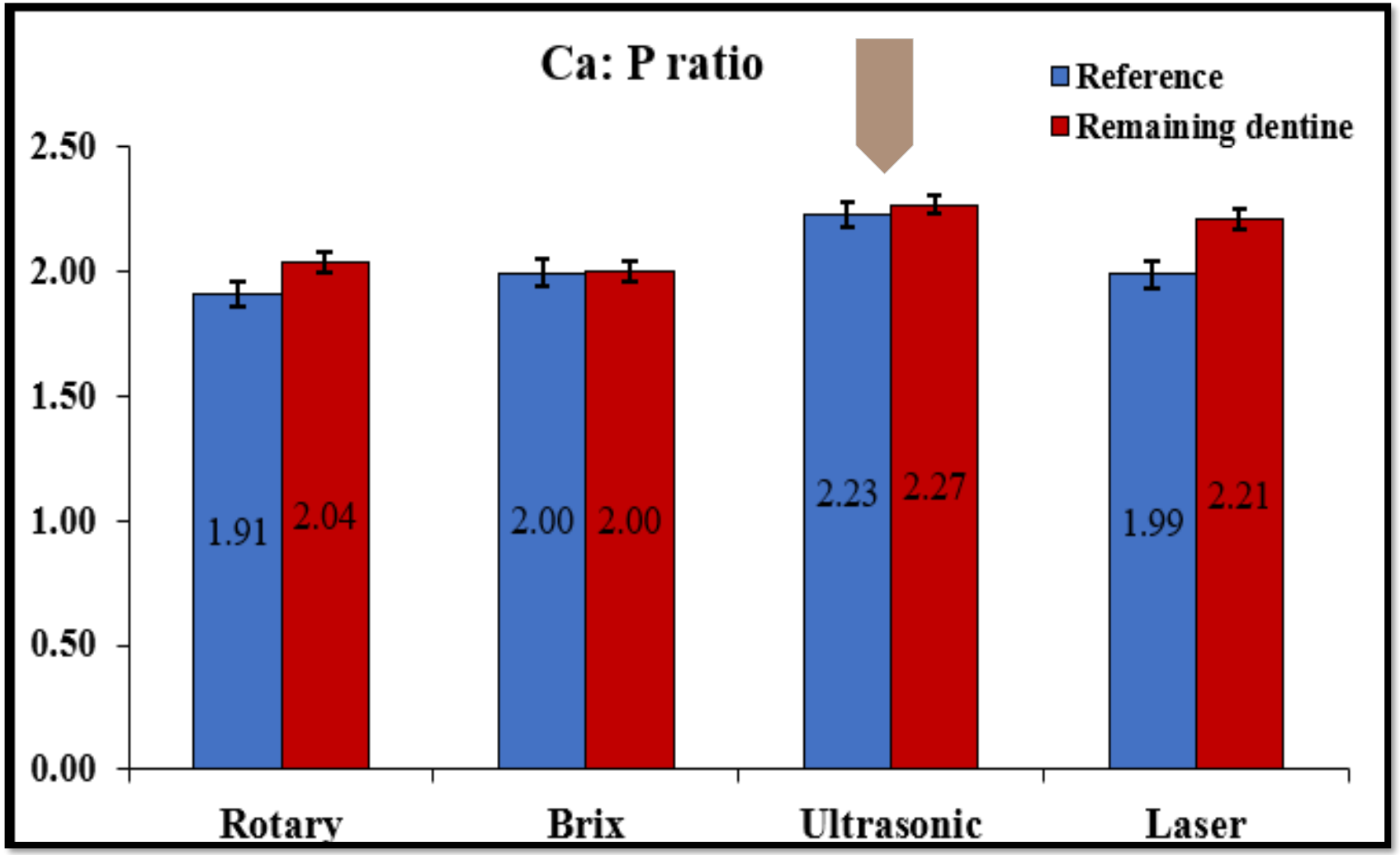


	Brix	Ultrasonic	Laser
50 µm	47.04	52.93	56.81
100	52.3	54.1	55.4
Ref.	70.902	70.82	70.71

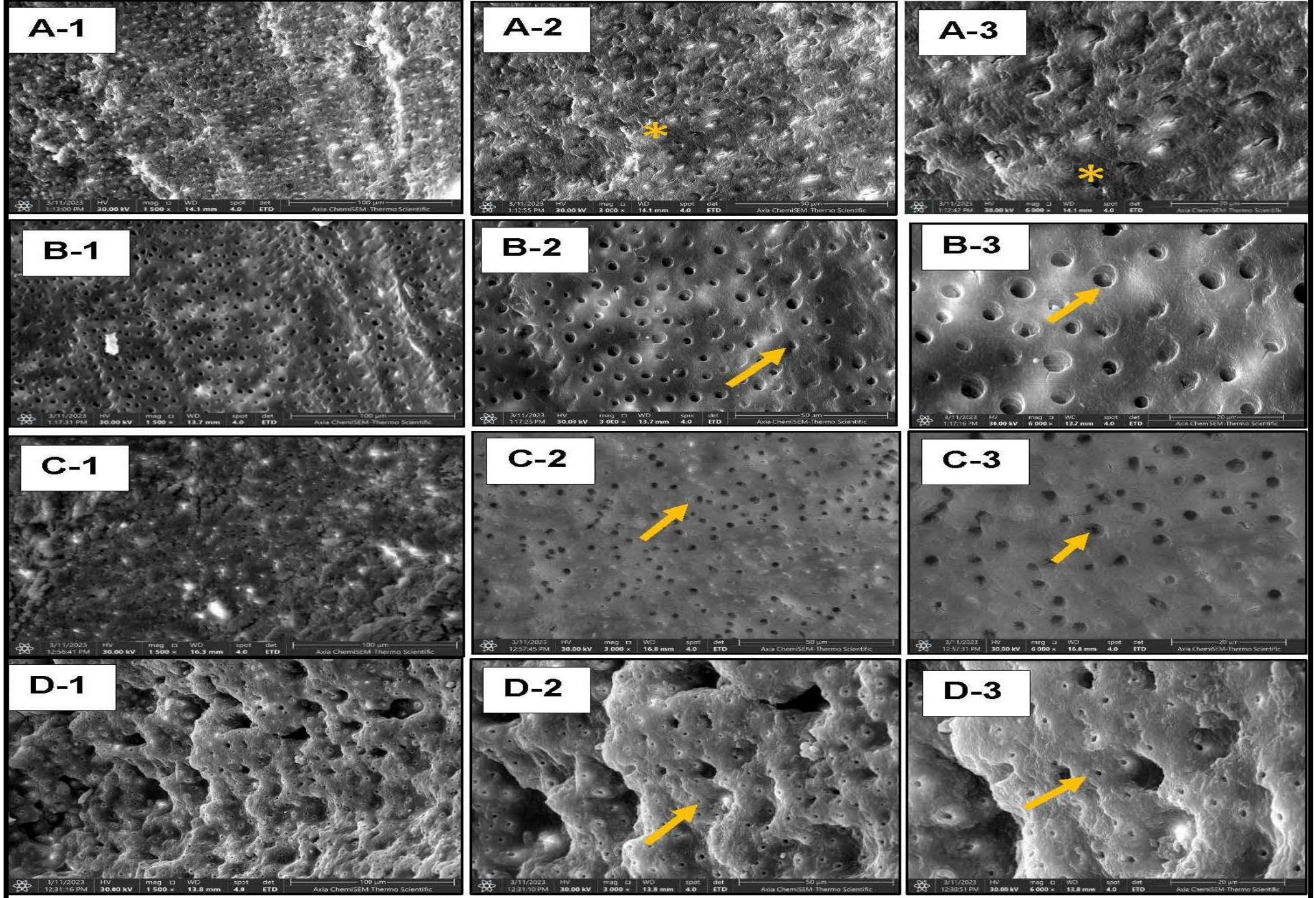
Hamama et al., 2013; Al-Badri et al., 2024

Ca : P Ratio

Ca:P ratio



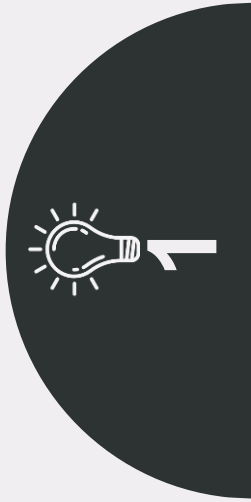
Morphological assessment



Conclusions

Conclusions

The rotary technique recorded the shortest excavation time, Brix 3000 gel showed the longest time with a comparable excavation time between the ultrasonic & laser techniques



Conclusions

The phosphate peak intensities were the lowest in the superficial remaining dentin after all excavation methods, which increased towards the deeper layer but still lower than sound dentin. The rotary group recorded the highest phosphate intensity at both layers

Conclusions

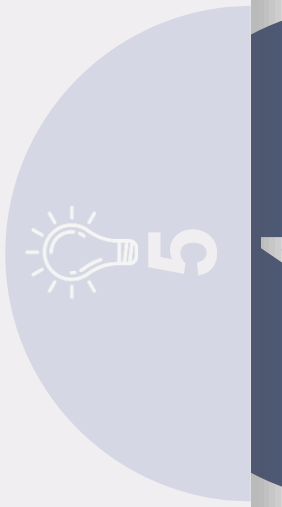
The organic components were higher in the superficial dentin after the MI methods which decreased towards the deeper layers. The highest values were observed in the ultrasonic and laser groups, while the bur-excavated dentin recorded the lowest organic contents

Conclusions

The rotary group recorded the highest VHN at both layers, followed by the laser ablation technique at the superficial dentin, however, the values were comparable between the MI methods at the deeper layer

Conclusions

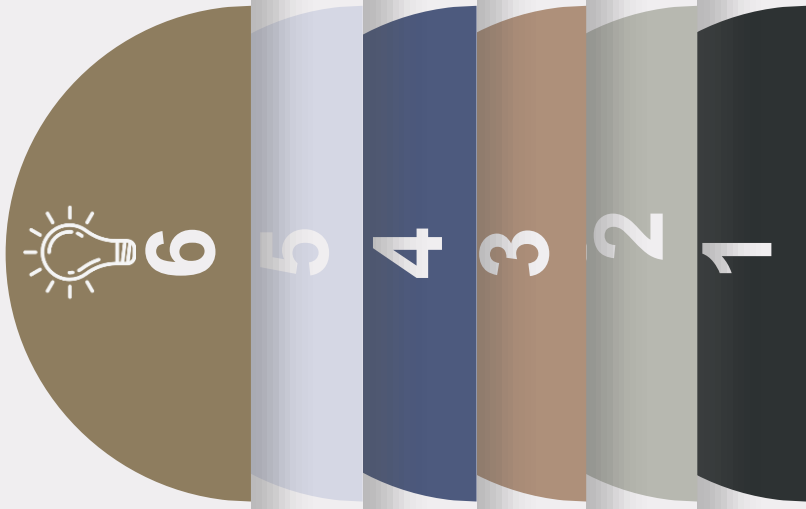
Ca:P ratio of the residual dentin was highest in the ultrasonic group, the lowest in the rotary technique with statistically no significant difference from Brix & laser groups



6 5 4 3 2 1

Conclusions

SEM revealed smooth dentin surfaces, free from smearing with patent dentinal orifices after implementing the MI techniques in comparison to the conventional rotary technique that illustrated a rough surface, covered with smearing occluding the dentinal tubule.



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An in vitro assessment of the residual dentin after using three minimally invasive caries removal techniques

Rand Mohammed Al-Sagheer[1], Ali J. Addie[2] & Lamis A. Al-Taee[1]✉

To evaluate the efficiency and effectiveness of three minimally invasive (MI) techniques in removing deep dentin carious lesions. Forty extracted carious molars were treated by conventional rotary excavation (control), chemomechanical caries removal agent (Brix 3000), ultrasonic abrasion (WOODPECKER, GUILIN, China); and Er, Cr: YSGG laser ablation (BIOLASE San Clemente, CA, USA). The assessments include; the excavation time, DIAGNOdent pen, Raman spectroscopy, Vickers microhardness, and scanning electron microscope combined with energy dispersive X-ray spectroscopy (SEM–EDX). The rotary method recorded the shortest excavation time ($p < 0.001$), Brix 3000 gel was the slowest. DIAGNOdent pen values ranged between 14 and 18 in the remaining dentin and laser-ablated surfaces recorded the lowest reading ($p < 0.001$). The Ca:P ratios of the remaining dentin were close to sound dentin after all excavation methods; however, it was higher in the ultrasonic technique ($p < 0.05$). The bur-excavated dentin showed higher phosphate and lower matrix contents with higher tissue hardness that was comparable to sound dentin indicating the non-selectiveness of this technique in removing the potentially repairable dentin tissue. In contrast, the MI techniques exhibited lower phosphate and higher organic contents associated with lower microhardness in the deeper dentin layers. This was associated with smooth residual dentin without smearing and patent dentinal tubules. This study supports the efficiency of using MI methods in caries removal as conservative alternatives to rotary excavation, providing a promising strategy for the clinical dental practice.

The management of deep dentin carious lesions have been directed towards more conservative and biological directions[1], as the traditional rotary excavation causes adverse biological reactions to the dentin-pulp complex. This is attributed to the heat and vibration associated with the procedure, as well as the non-selective behavior in removing both healthy and diseased tissues[2,3].

Finding effective minimally invasive (MI) techniques to overcome the drawbacks of bur excavation is an objective for dental researchers, in order to remove the superficial, bacterially-contaminated and denatured dentin while preserving the partially demineralized tissue that can be sealed with suitable therapeutic restorations[4]. This will maintain the integrity of healthy and mineralizable tooth tissue, while maximizing the reparative potential of dentin-pulp complex[5]. These methods include laser ablation[6], air abrasion[7], sono-abrasion[8], and the chemomechanical agents (CMCR)[9].

BRIX 3000 (Brix medical science, S.R.L. of Argentina) is a papain-based gel with high enzyme activity (3.000 U/mg) due to utilizing the encapsulation buffer emulsion technology, that confers the stability of enzyme and thus reactivity[10]. The chemical method is considered to be effective in dissolving the infected tissues facilitating their removal while preserving the sound dentin structure[11].

The ultrasonic abrasion can remove carious lesions and unsupported hard structure when used at high frequency (20–40 kHz). It relies on the kinetic energy of water molecules that transferred into tooth surface by high-speed oscillated diamond-coated cutting tip accompanied with sonic air-scaler device[12]. However, Neves et al. (2011)[13] found that the sonic technique by using tungsten-carbide tips (Cariex system) is efficient to remove the caries at the cavity floor in a micro-CT study while still residual caries left at the walls, which agreed with a

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