UCLA Hawaii Symposium 2019

Direct pulp capping:
New paradigm in caries management

"To RCT or not to RCT"

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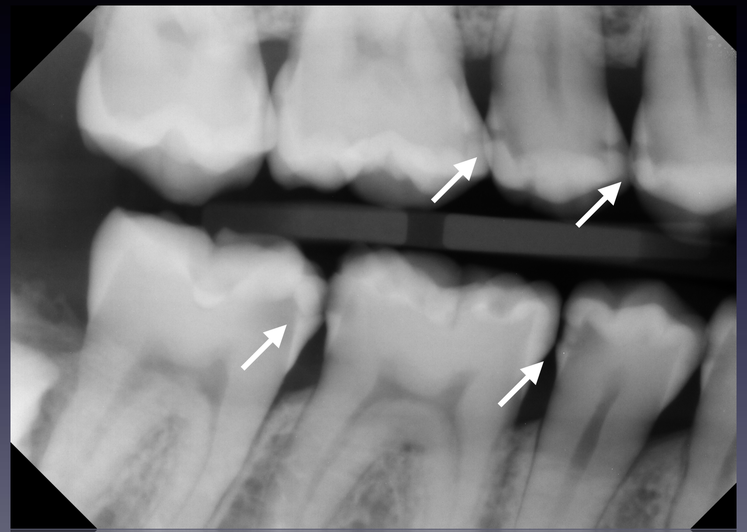
Professor and Chair
Section of Restorative Dentistry

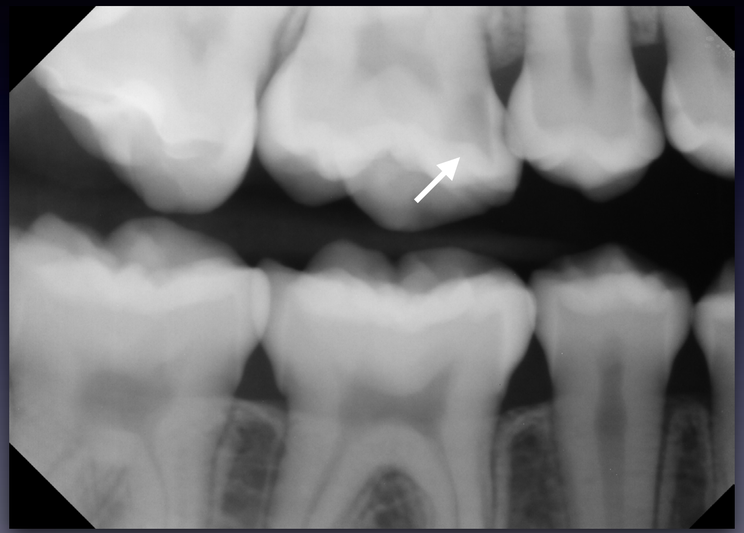
Disclosure Statement

- I have no relevant financial relationship(s) to disclose.
- I’m not an endodontist

What would you do?

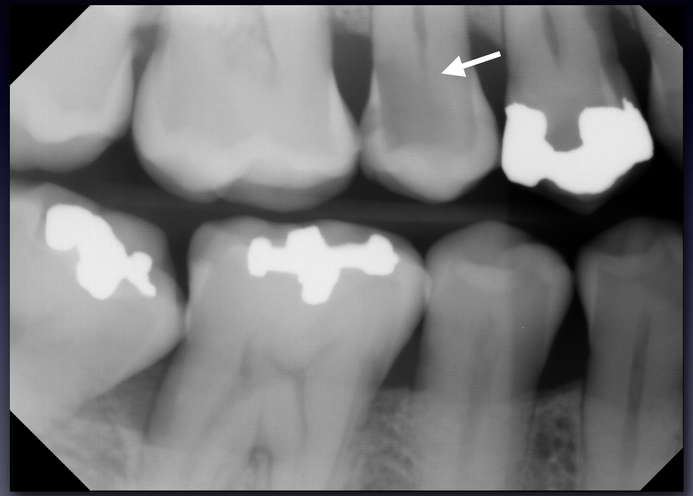


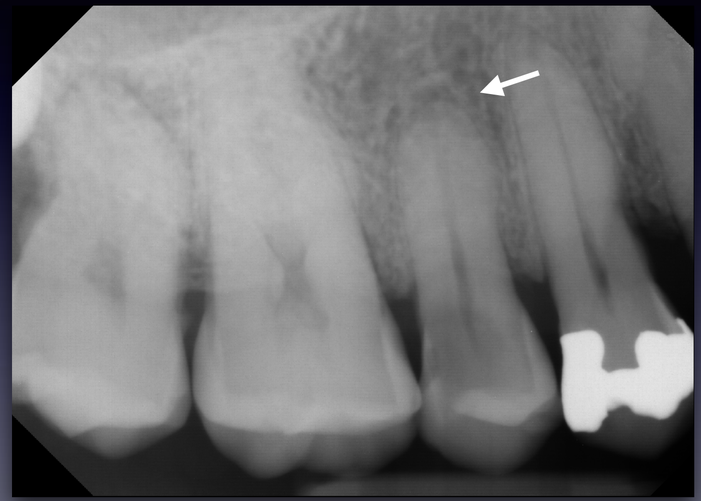
Clearly though the DEJ



Very close to the pulp

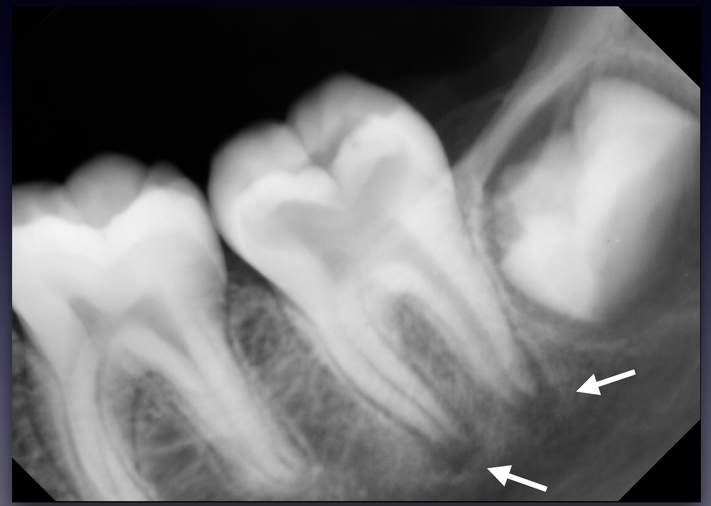
What would you do?





Normal pulpal response
No PARL

What would you do?



Incomplete root formation

“To do RCT or not to do RCT?”

Saving private pulp, Why?

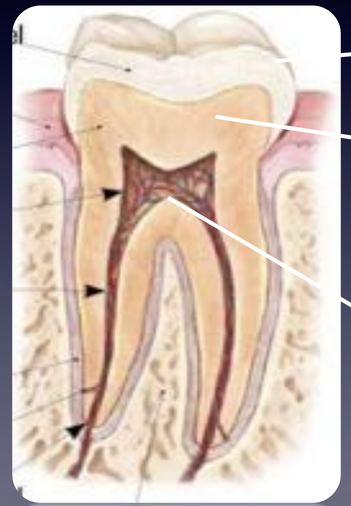
- Enable complete root formation
- Prevents the tooth from becoming brittle
- Prevents discoloration of the tooth
- Financially better option
- Prevent from traumatic fracture/damages from mechanical or thermal stresses (feedback mechanisms)
- Because they are still alive!

Outlines

- 1. Introduction: Saving private pulp, what would you do?
- 2. Historical perspectives
- 3. Managing deep caries/indirect pulp capping
- 4. Managing extreme deep caries/direct pulp capping
- 5. New paradigm

II. Historical perspective

A previous paradigm of caries control and pulpal management in restorative dentistry



Enamel → Sealants, PRR

Dentin → Shallow – simple fillings (Composite, amalgam)

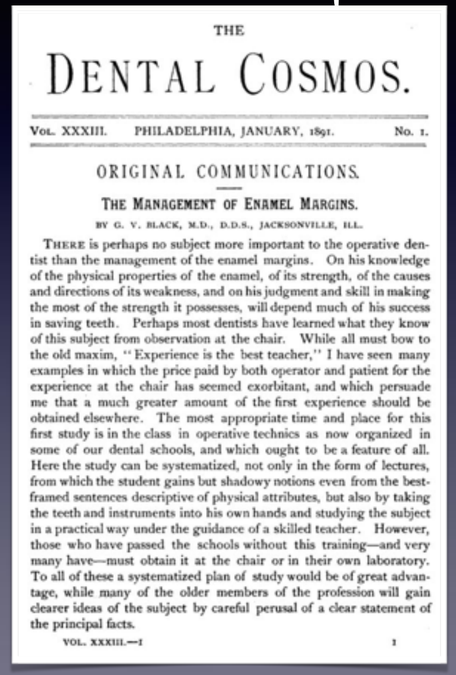
Deep – indirect pulp-capping (GI)

Pulp → Small exposure (< 1mm) – direct pulp-capping (CH, MTA)

Large exposure, iatrogenic → RCT

Large exposure, infected → RCT

1900 2000 Now



THE

DENTAL COSMOS.

Vol. XXXIII. PHILADELPHIA, JANUARY, 1891. No. 1.

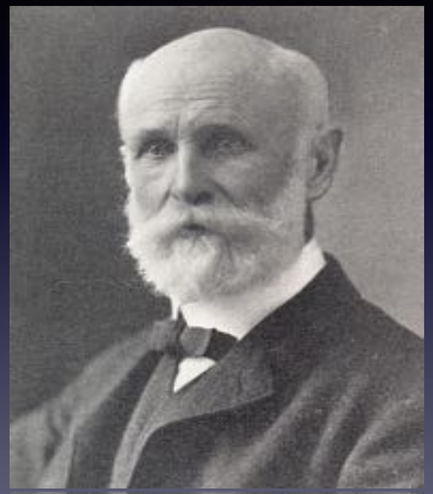
ORIGINAL COMMUNICATIONS.

THE MANAGEMENT OF ENAMEL MARGINS.

BY G. V. BLACK, M.D., D.D.S., JACKSONVILLE, ILL.

THERE is perhaps no subject more important to the operative dentist than the management of the enamel margins. On his knowledge of the physical properties of the enamel, of its strength, of the causes and directions of its weakness, and on his judgment and skill in making the most of the strength it possesses, will depend much of his success in saving teeth. Perhaps most dentists have learned what they know of this subject from observation at the chair. While all must bow to the old maxim, "Experience is the best teacher," I have seen many examples in which the price paid by both operator and patient for the experience at the chair has seemed exorbitant, and which persuade me that a much greater amount of the first experience should be obtained elsewhere. The most appropriate time and place for this first study is in the class in operative technics as now organized in some of our dental schools, and which ought to be a feature of all. Here the study can be systematized, not only in the form of lectures, from which the student gains but shadowy notions even from the best-framed sentences descriptive of physical attributes, but also by taking the teeth and instruments into his own hands and studying the subject in a practical way under the guidance of a skilled teacher. However, those who have passed the schools without this training—and very many have—must obtain it at the chair or in their own laboratory. To all of these a systematized plan of study would be of great advantage, while many of the older members of the profession will gain clearer ideas of the subject by careful perusal of a clear statement of the principal facts.

VOL. XXXIII.—1 1



Greene Vardiman Black (1836-1915)

Extension for Prevention

- "In no case should any decayed and softened material be left. It is better to expose the pulp of the tooth than leave it covered only with softened dentine"

=> Non-selective (complete) caries removal

1900 2000 Now

Prevention of Extension

- “Minimally invasive dentistry (MID)” as a new conservative philosophy in early 2000.

=> Selective (partial) caries removal

PRACTICAL SCIENCE

Minimally invasive dentistry

CAROL ANNE MURDOCH-KINCH, D.D.S., Ph.D.; MARY ELLEN McLEAN, D.D.S.

Preservation of a healthy set of natural teeth for each patient should be the objective of every dentist. All work in the health field is aimed basically at conservation of the human body and its function. ... The surgeon is so conservative that loss of even a small part of a finger or toe, not withstanding the fact that the patient will still have nine more, is considered a tragedy. Likewise, loss of even a part of a human tooth should be regarded as a serious injury, never to be considered lightly, and the tooth is certainly worthy of the most careful restoration."[1]

Miles Markley, one of several great leaders in preventive dentistry, summarized in this statement the central concept in the modern approach to the dentist's role in the treatment of dental caries: that the loss of even a part of a human tooth should be considered "a serious injury," and that dentistry's goal should be to preserve healthy, natural tooth structure. His words are perhaps even more relevant today than when he wrote them half a century ago, now that we have the scientific understanding and the means to realize his vision.

Emerging technologies will facilitate evolution to primary prevention of caries, though obstacles to full implementation in clinical practice now exist.

The "minimally invasive" approach to treating dental caries incorporates the dental science of detecting, diagnosing, intercepting and treating dental caries on the microscopic level.[2] This approach to treating dental caries includes many nonsurgical modalities, as well as the key concept that dental caries should be treated as an infectious disease.

It has been known for decades that dental caries is a communicable, infectious disease caused by dental plaque, an oral biofilm, and by exposure to fermentable carbohydrates. Plaque bacteria produce acid in the presence of fermentable carbohydrates. This acid dissolves the calcified component of dental hard tissues, leading to infection and progressive loss of tooth structure, pulpal disease and eventual tooth loss. In the past, dentistry's approach to treating caries has been surgical—removing diseased tissue and replacing it with a dental restorative material. This approach was necessary, given the prevalence of disease, our understanding of the disease process, the limitations of available materials and the lack of proven alternative therapies.

Over time, modern dentistry has evolved to a minimally invasive approach, in which caries is managed as an infectious disease, deferring operative intervention as long as possible. The focus is on maximum conservation of demineralized, noncavitated enamel and dentin. Once control of the infection is achieved, the patient's caries risk status and evidence of lesion demineralization

ABSTRACT

Background. During the past few decades, scientific developments in cariology, dental materials and diagnostic systems have changed dentistry's approach to diagnosis and management of dental caries. The authors summarize these developments.

Overview. Dental adhesives and restorative materials, new understanding of the caries process and remineralization, and changes in caries prevalence have catalyzed the evolution in caries management from G.V. Black's "extension for prevention" to "minimally invasive." The authors describe the scientific basis for early diagnosis; a modified classification of caries based on site and size of lesion remineralization; reduction of cariogenic bacteria; and minimally invasive cavity preparation design, techniques and material selection.

Conclusions and Practice Implications. Minimally invasive dentistry is based on advances in science. Emerging technologies will facilitate evolution to primary prevention of caries, though technical, cultural and economic obstacles to full implementation in clinical practice now exist.

- (Peters & McLean, JAD, 2001; Murdoch-Kinch & McLean, JADA, 2003)

1900 2000 Now

Adhesive Dentistry

Composites

Dentin adhesives

Glass ionomers

1900 — 2000 — Now

Complete vs. Partial removal

Results. The results of three randomized controlled trials, one of which followed up patients for 10 years, provide strong evidence for the advisability of leaving behind infected dentin, the removal of which would put the pulp at risk of exposure. Several additional studies have demonstrated that cariogenic bacteria, once isolated from their source of nutrition by a restoration of sufficient integrity, either die or remain dormant and thus pose no risk to the health of the dentition.

Clinical Implications. There is substantial evidence that removing all vestiges of infected dentin from lesions approaching the pulp is not required for caries management.

Treatment of deep carious lesions by complete excavation or partial removal

A critical review

Van Thompson, DDS, PhD; Ronald G. Craig, DMD, PhD; Fredrick A. Curro, DMD, PhD; William S. Green, AB; Jonathan A. Ship, DMD

ABSTRACT

Background. The classical approach to treatment of deep carious lesions approaching the pulp mandates removing all infected and affected dentin. Several studies call this approach into question.

Types of Studies Reviewed. A search of five electronic databases using selected key words to identify studies relating to partial versus complete removal of carious lesions yielded 1,059 reports, of which the authors judged 23 to be relevant. Three articles reported the results of randomized controlled trials.

Results. The results of three randomized controlled trials, one of which followed up patients for 10 years, provide strong evidence for the advisability of leaving behind infected dentin, the removal of which would put the pulp at risk of exposure. Several additional studies have demonstrated that cariogenic bacteria, once isolated from their source of nutrition by a restoration of sufficient integrity, either die or remain dormant and thus pose no risk to the health of the dentition.

Clinical Implications. There is substantial evidence that removing all vestiges of infected dentin from lesions approaching the pulp is not required for caries management.

Key Words. Deep caries; deep carious lesions; partial caries removal; indirect pulp capping; pulpal exposure; stepwise excavation; alternative restorative treatment.

JADA 2008;139(6):705-712.

The treatment of deep carious lesions approaching a healthy pulp presents a significant challenge to the practitioner. The traditional management of carious lesions of any kind dictates the removal of all infected and affected dentin to prevent further cariogenic activity and provide a well-mineralized base of dentin for restoration. When the procedure risks exposing or even breaching the pulp, however, the course of treatment becomes less predictable and may require such measures as indirect pulp capping (typically using a protective material such as a calcium hydroxide–based preparation), pulpotomy or, in the most extreme cases, pulpectomy. Choosing among these options can be daunting for the dentist—as well as for the patient, who is advised of the risks and asked to share in the decision.

To preclude or at least minimize the potential complications of com-

Van Thompson *et al.*, *JADA*, 2008

INTERNATIONAL ENDODONTIC JOURNAL

doi: 10.1111/iej.13308

European Society of Endodontology position statement: Management of deep caries and the exposed pulp

European Society of Endodontology (ESE) developed by:

H. F. Duncan[1], K. M. Galler[2], P. L. Tomson[3], S. Simon[4], I. El-Karim[5], R. Kundzina[6], G. Krastl[7], T. Dammaschke[8], H. Fransson[9], M. Markvart[10], M. Zehnder[11] & L. Bjørndal[10]

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Abstract

European Society of Endodontology (ESE) developed by: Duncan HF, Galler KM, Tomson PL, Simon S, El-Karim I, Kundzina R, Krastl G, Dammaschke T, Fransson H, Markvart M, Zehnder M., Bjørndal L. European Society of Endodontology position statement: Management of deep caries and the exposed pulp. *International Endodontic Journal*, 52, 923–934, 2019.

This position statement on the management of deep caries and the exposed pulp represents the consensus of an expert committee, convened by the European Society of Endodontology (ESE). Preserving the pulp in a healthy state with sustained vitality, preventing apical periodontitis and developing minimally invasive biologically based therapies are key themes within contemporary clinical endodontics. The aim of this statement was to summarize current best evidence on the diagnosis and classification of deep caries and caries-induced pulpal disease, as well as indicating appropriate clinical management strategies for avoiding and treating pulp exposure in permanent teeth with deep or extremely deep caries. In presenting these findings, areas of controversy, low-quality evidence and uncertainties are highlighted, prior to recommendations for each area of interest. A recently published review article provides more detailed information and was the basis for this position statement (Bjørndal et al. 2019, *International Endodontic Journal*, doi:10.1111/iej.13123). The intention of this position statement is to provide the practitioner with relevant clinical guidance in this rapidly developing area. An update will be provided within 5 years as further evidence emerges.

Keywords: caries, dental pulp, pulp capping, pulpitis, pulpotomy, stepwise excavation, tertiary dentinogenesis, vital pulp treatment.

Received 14 January 2019; *accepted* 24 January 2019

2000 — Now

Management of deep caries and exposed pulp

"Preserving the pulp in a healthy state with sustained vitality, preventing apical periodontitis and developing minimally invasive biologically based therapies are key themes within contemporary clinical endodontics"

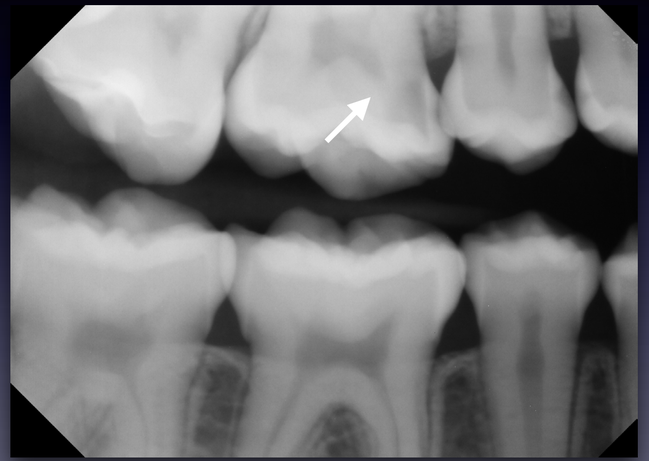
Ducan *et al.*, *Int. End. J*, 2019

Managing Caries vs. Carious lesion

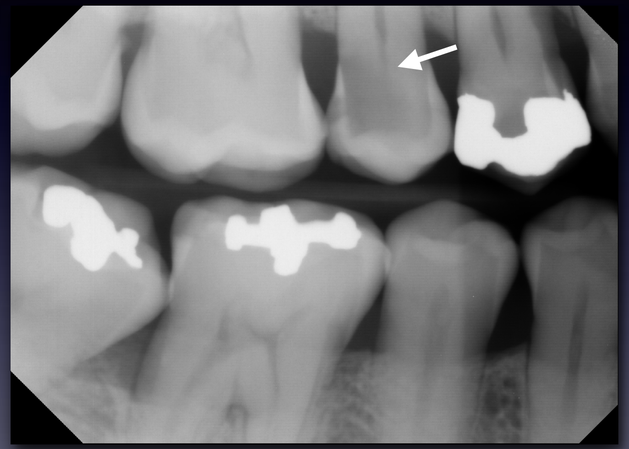
- **Caries management**
  - The actions taken <u>at the patient level for prevention</u>
  - CAMBRA
  - Personality, habit, medical issues, etc.

- **Carious lesion management**
  - The actions taken <u>at the tooth level for intervention</u>
    - Non-invasive (Silver diamine fluoride, SDF)
    - Invasive

Definitions

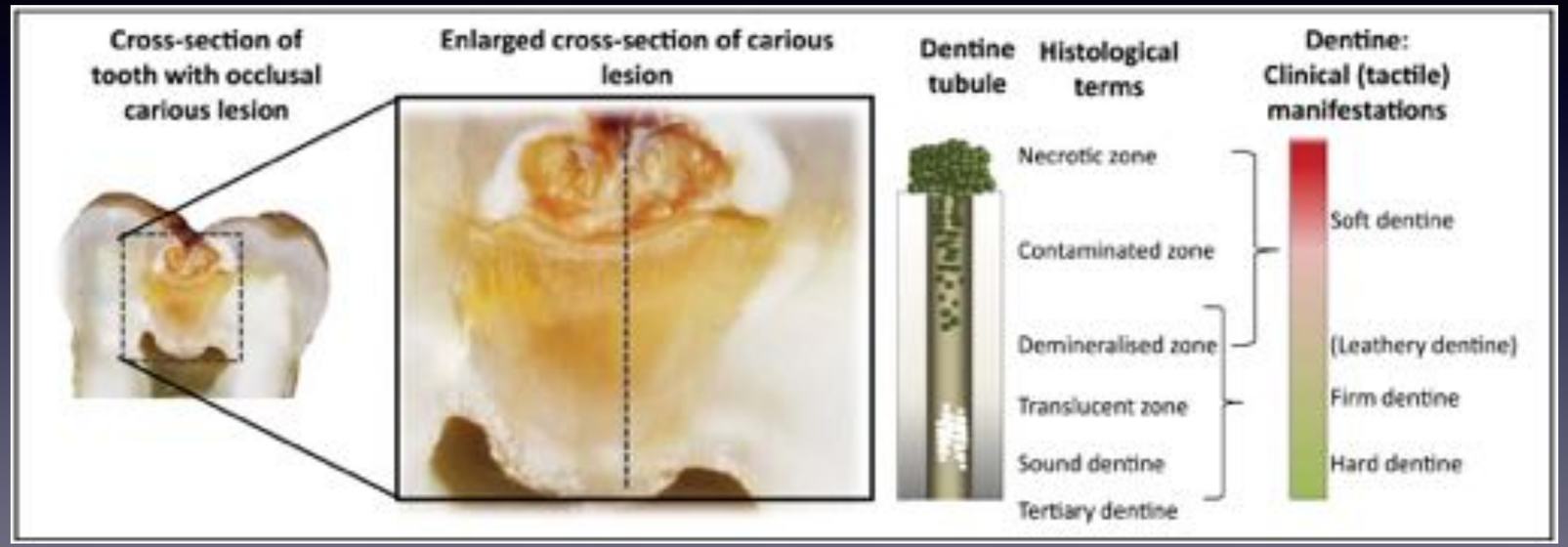


- **Deep caries:**
- Caries reaching the inner quarter of dentine, but with a zone of hard or firm dentine between the caries and the pulp, which is radiographically detectable when located on an interproximal or occlusal surface. There is a risk of pulp exposure during operative treatment.



- **Extremely deep caries:**
- Caries penetrating the entire thickness of the dentine, radiographically detectable when located on an interproximal or occlusal surface. Pulp exposure is unavoidable during operative treatment.

Definitions

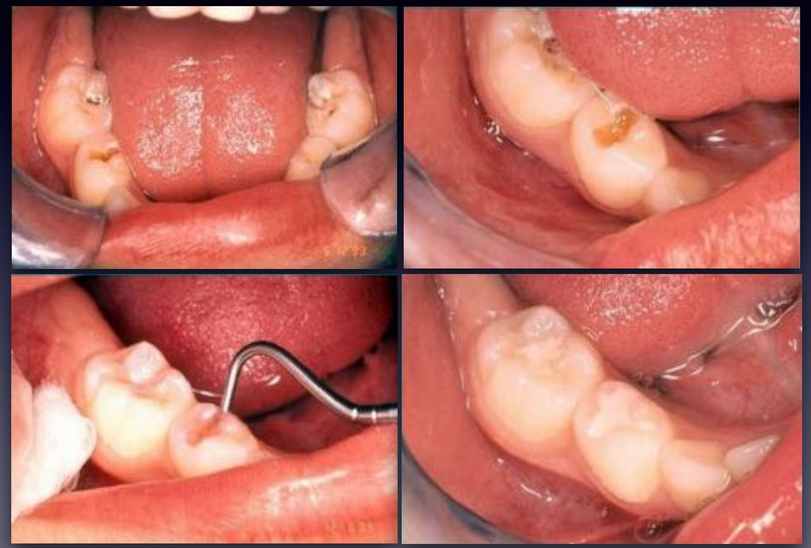


- **Soft dentin (infected):** Can be excavated with minimum resistance using hand instruments.
- **Firm dentin (affected):** Resistant to excavation using hand instruments.
- **Hard dentin:** Sound and resistant to probe penetration and scratching.

Types of carious tissue removal

- Atraumatic restorative treatment (ART)
- Selective removal
- Stepwise removal
- Nonselective removal

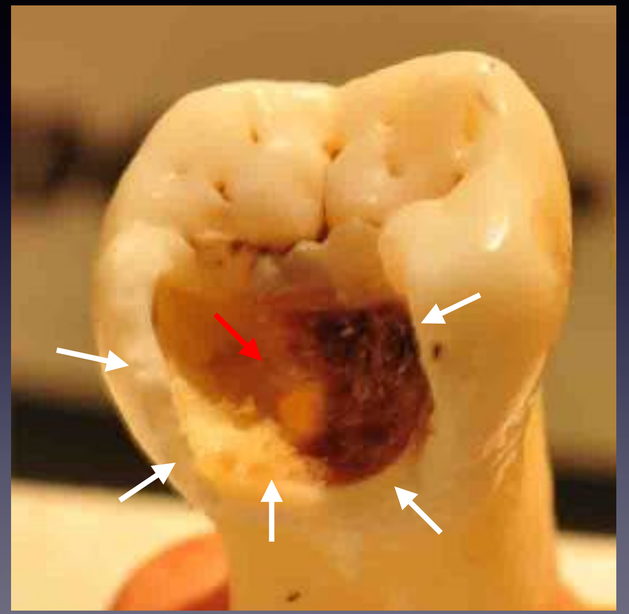
Atraumatic Restorative Treatment (ART)



- Caries removal using hand instrument only
- Remove soft, completely demineralized enamel and dentine until firm resistance is felt
- Usually filled with GI cement

Selective (partial or incomplete) removal

- Also known as partial or incomplete caries removal
- **Peripheral dentine (peripheral walls)** - should be hard and free of infected dentin (no soft and firm dentin)
  - A scratching noise when scraping the surfac with a hsarp hand excavator or dental probe
  - It allows to have complete sealing with bonding
- **Inner dentin (pulpal or axial walls)** - Remove soft dentin but may leave firm dentin



Step-wise removal

- Two-steps to remove caries completely

- **Stage I:** Selective removal to soft dentin
  - Remove soft dentin and leave firm dentin behind
  - The periphery of the cavity should be hard
  - A provisional restoration is placed

- **Stage II:** Selective removal to firm dentin
  - 6 to 12 mo later
  - Remove firm dentin
  - Place the definitive restoration

RESEARCH REPORTS
Clinical

M. Maltz[1]*, R. Garcia[1], J.J. Jardim[1], L.M. de Paula[2], P.M. Yamaguti[2], M.S. Moura[1], F. Garcia[2], C. Nascimento[1], A. Oliveira[2], and H.D. Mestrinho[2]

[1]Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil; and [2]Brasília University, Brasília, DF, Brazil; *corresponding author, marisa.maltz@gmail.com

J Dent Res 91(11):1026-1031, 2012

Randomized Trial of Partial *vs.* Stepwise Caries Removal: 3-year Follow-up

ABSTRACT

This randomized, multicenter clinical trial evaluated the effectiveness of 2 treatments for deep caries lesions — partial caries removal (PCR) and stepwise excavation (SW) — with respect to the primary outcome of pulp vitality for a 3-year follow-up period. Inclusion criteria were as follows: patients with permanent molars presenting deep caries lesions (lesion affecting ≥ 1/2 of the dentin on radiographic examination), positive response to a cold test, absence of spontaneous pain, negative sensitivity to percussion, and absence of periapical lesions (radiographic examination). Teeth randomly assigned to PCR (test) received incomplete caries removal and filling in a single session. Outcome success was evaluated by assessment of pulp vitality, determined by pulp sensitivity to a cold test and the absence of periapical lesions. Data were analyzed by a Weibull regression model with shared frailty term (survival analysis). At baseline, 299 treatments were executed: PCR, 152 and SW, 147. By the end of the 3-year follow-up period, 213 teeth had been evaluated. Adjusted survival rates were 91% for PCR and 69% for SW ($p = 0.004$). These results suggest that there is no need to re-open a cavity and perform a second excavation for pulp vitality to be preserved (Clinical trials registration NCT00887952).

KEY WORDS: dental caries, clinical trial, permanent dentition, survival analysis, permanent dental restoration, dental pulp.

DOI: 10.1177/0022034512460403

Received April 5, 2012; Last revision August 8, 2012; Accepted August 8, 2012

INTRODUCTION

The treatment of asymptomatic teeth presenting deep caries lesions is usually based on traditional techniques that involve the complete removal of the soft, demineralized dentin. In these cases, it is common to have the pulp exposed during the operative procedure (Magnusson and Sundell, 1977; Leksell *et al.*, 1996; Ricketts *et al.*, 2006). Previous investigations have shown that conservative treatments of the exposed pulp resulted in a poor prognosis in follow-up trials (Barthel *et al.*, 2000; Bjørndal *et al.*, 2010).

Stepwise excavation (SW) is an option for the treatment of deep lesions. It involves initial excavation, in which the necrotic and disorganized tissue is removed, leaving soft tissue over the pulp wall. The cavity is then temporarily sealed, allowing the pulp to react and produce tertiary dentin (Bjørndal, 2008). The cavity is subsequently re-opened, and the remaining demineralized dentin is removed. This technique involves less pulp exposure compared with complete caries removal during a single session (Magnusson and Sundell, 1977; Leksell *et al.*, 1996). One-year evaluation of SW revealed a survival rate of 74 to 91% (Bjørndal and Thylstrup, 1998; Bjørndal *et al.*, 2010). However, SW requires 2 sessions for treatment completion, resulting in additional costs and discomfort to the patient; further, there is a probability of pulp exposure during the second procedure (Bjørndal and Thylstrup, 1998; Bjørndal *et al.*, 2010).

Because of these problems and the evidence pertaining to lesion arrest after sealing of the cavity (Bjørndal and Larsen, 2000; Maltz *et al.*, 2002; Alves *et al.*, 2010), there is discussion in the literature concerning the necessity for cavity re-opening (Ricketts *et al.*, 2006). Three clinical trials have studied partial caries removal (PCR) on permanent teeth: Two of these trials included lesions reaching the outer half of dentin (Mertz-Fairhurst *et al.*, 1998; Bakhshandeh *et al.*, 2011), and the third involved lesions reaching the inner half of dentin (Maltz *et al.*, 2011). All of these studies reported no detrimental effects when demineralized tissue was left in the cavity. Despite these, there are no long-term randomized, controlled trials that support a 1-step partial excavation followed by the immediate placement of a filling on permanent teeth.

The aim of this randomized, multicenter trial was to compare PCR and SW with respect to the primary outcome of pulp vitality for a 3-year follow-up period.

Partial caries removal vs. step-wise caries removal

- 2012 report:
  - 3-year single center RCT
    - Survival rate of 91% PCR vs. 69% SW
- 2018 report:
  - 5 -year multicentrer RCT
  - Survival rate of 80% PCR vs. 56% SW

PCR as a single-visit technique to manage deep caries lesions in permanent teeth

Maltz *et al., JDR*, 2012; Maltz *et al., Clin Oral Investig*, 2018

Non-selective removal

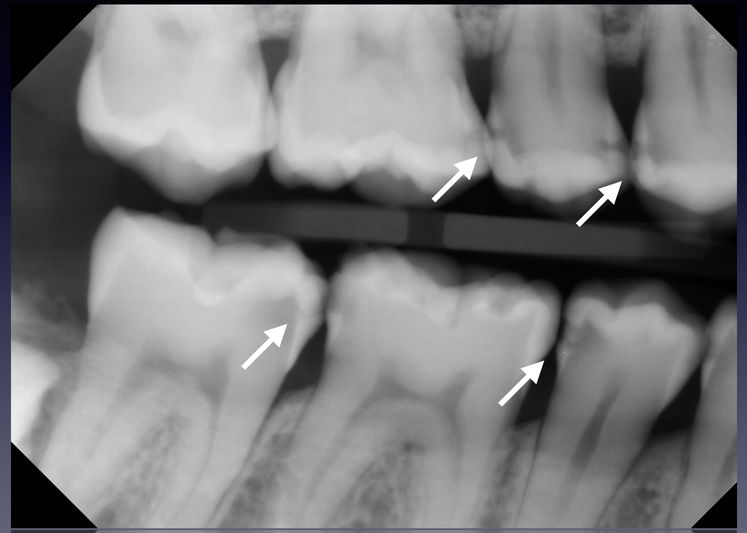
- Also known as complete excavation or complete caries removal
- Popular concept before but now considered overtreatment
- Removal of both soft and firm dentin (leaving only hard dentin behind)
- **Not recommended any longer**

Summary

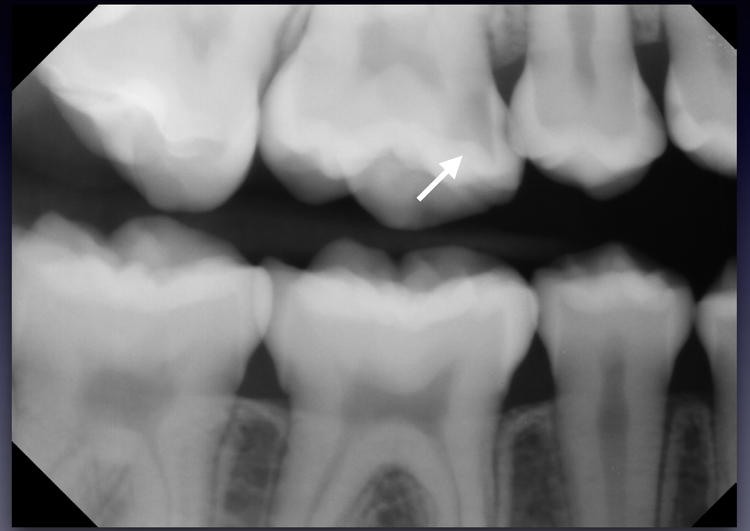
- Atraumatic restorative treatment (ART)
  - Only in limited cases (caries control, elderly individuals, pediatrics, etc.)
- **Selective removal**
  - Recommended practice
- Stepwise removal
- ~~Nonselective removal~~

II. Managing deep caries:
Indirect pulp capping

What would you do?: Deep caries

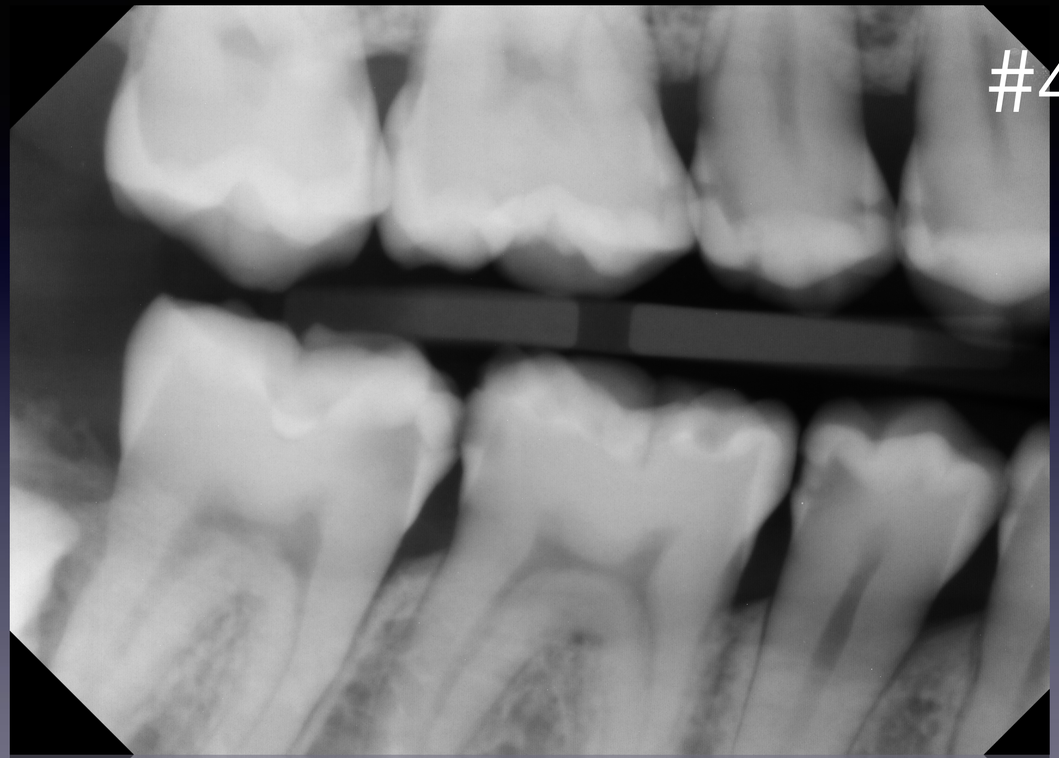


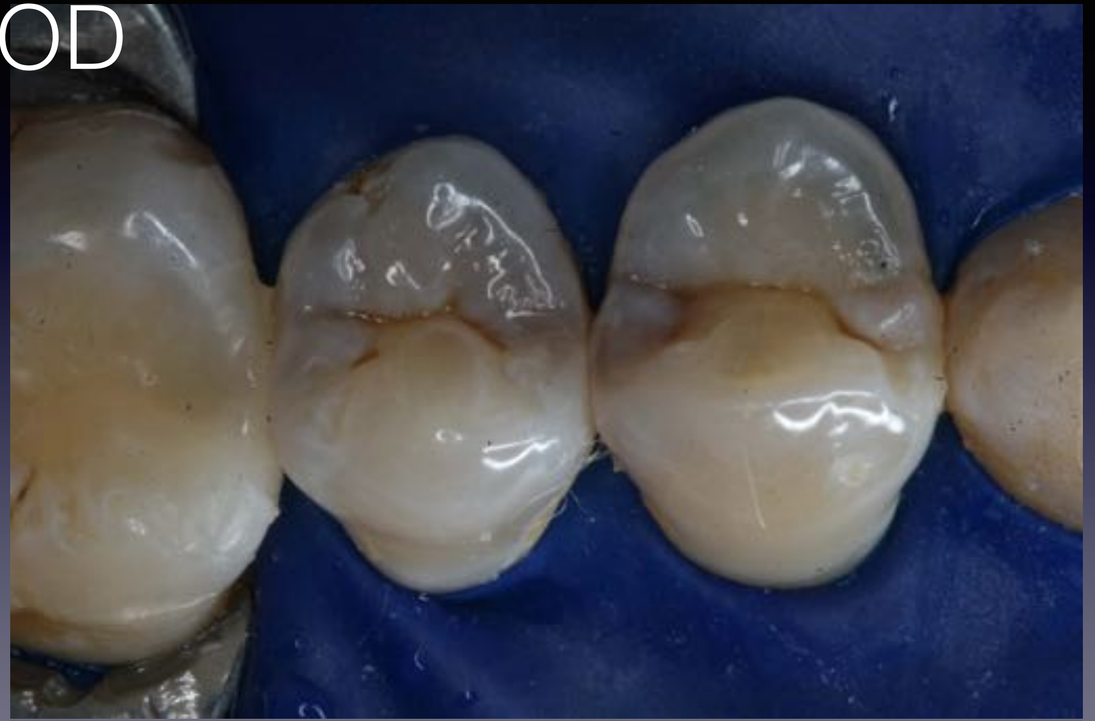
Clearly though the DEJ

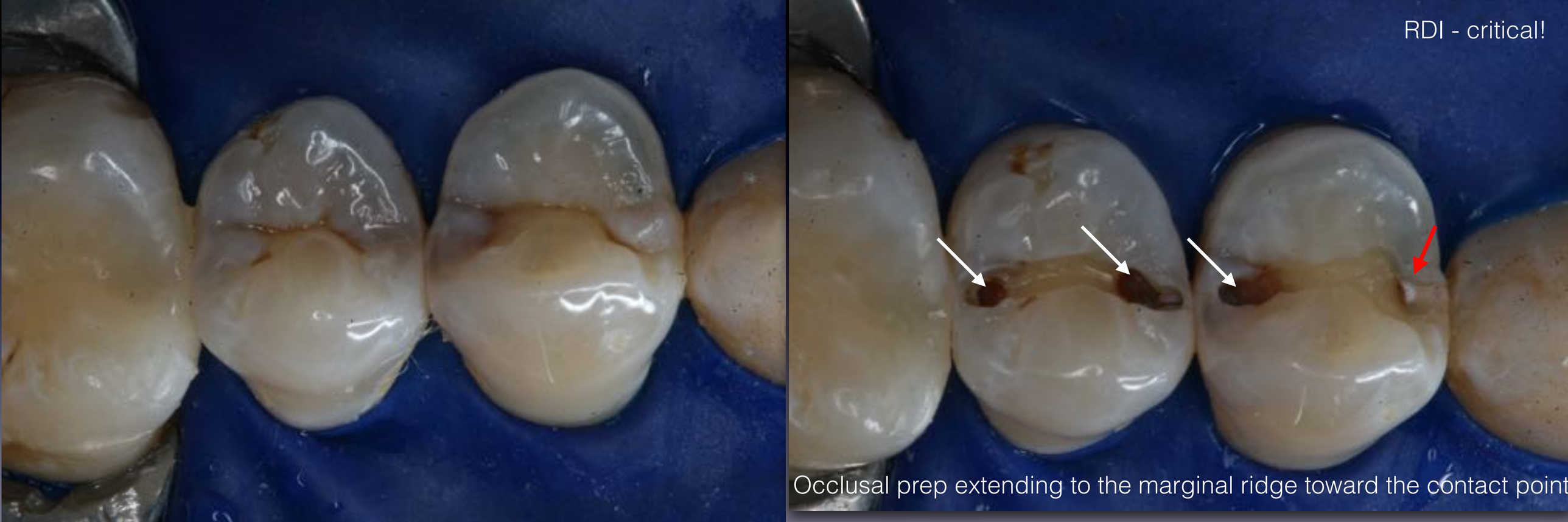


Very close to the pulp

#4 and 5 MOD

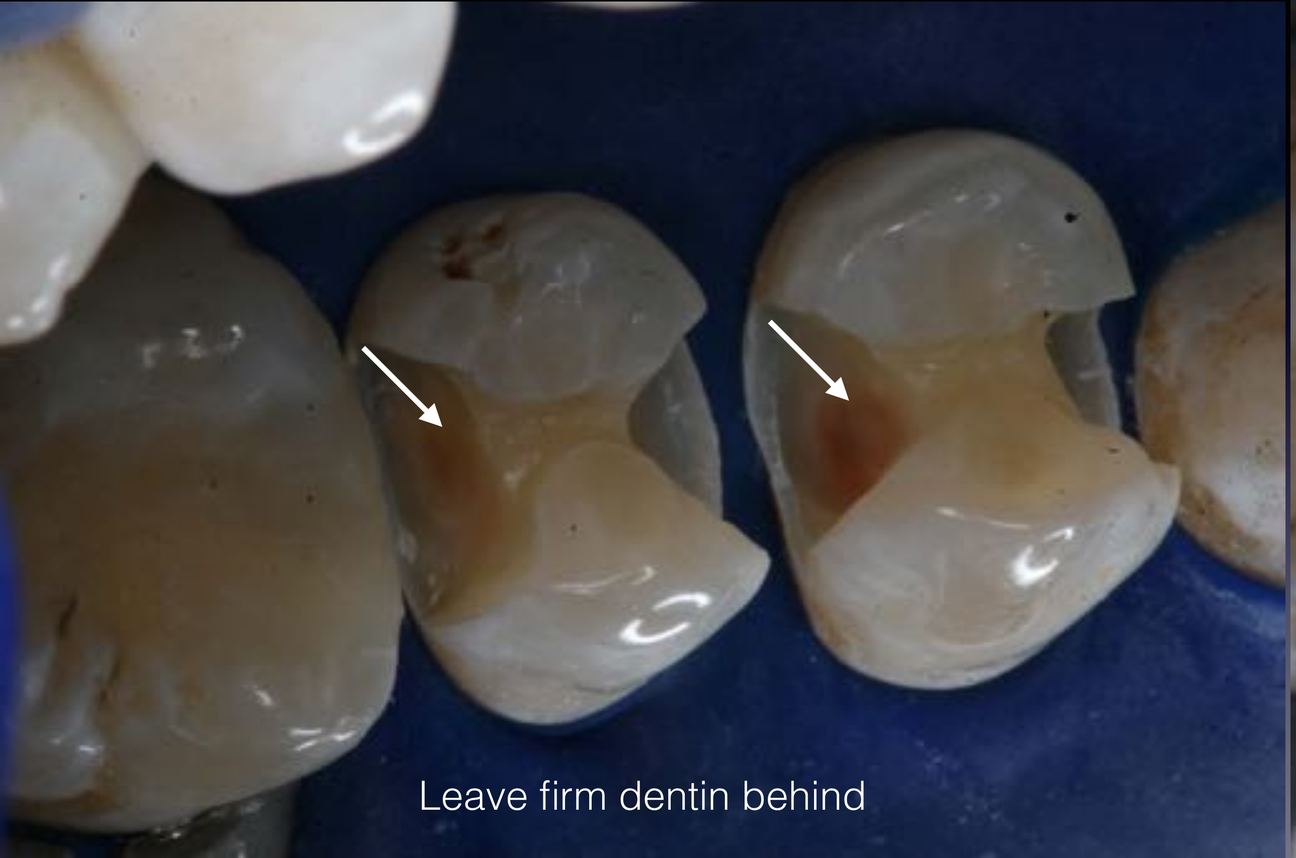


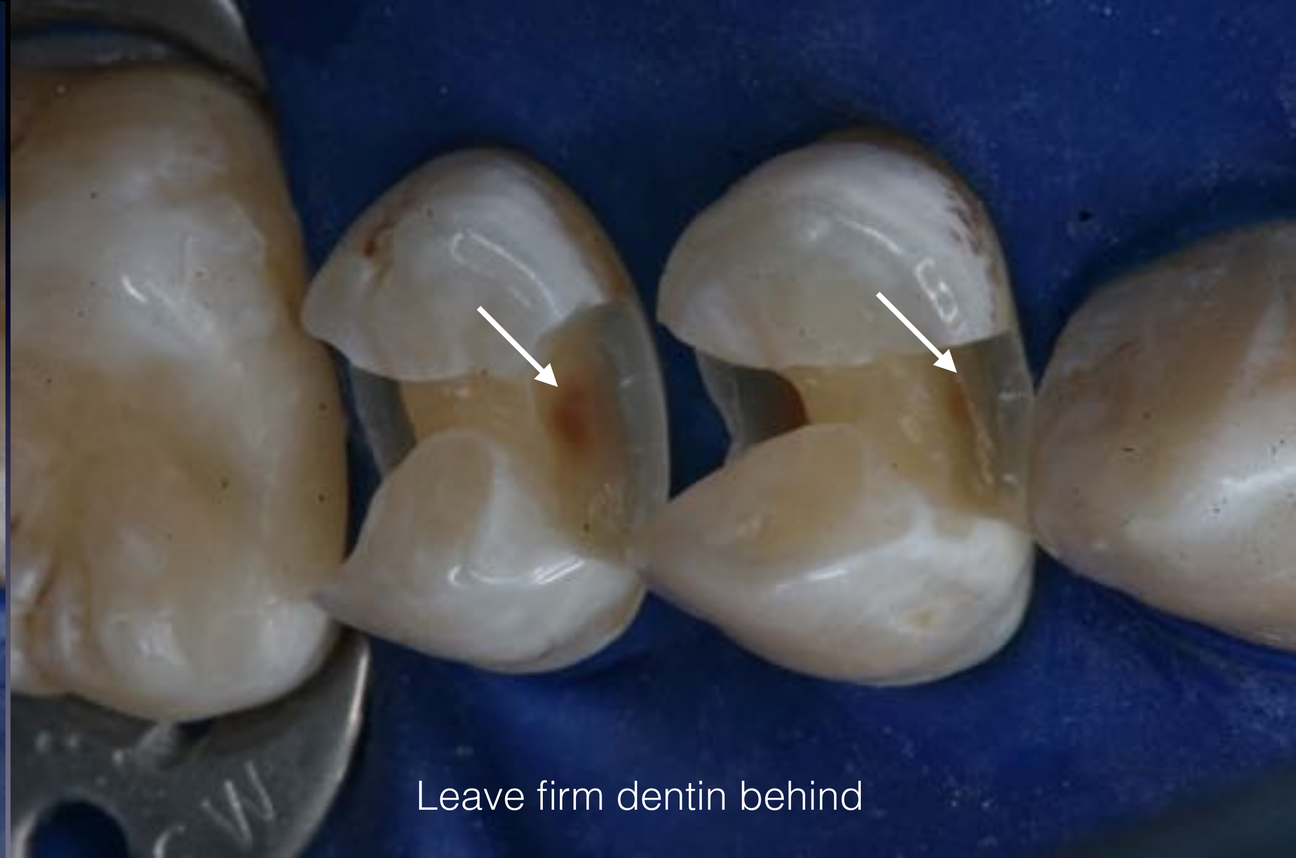



RDI - critical!
Occlusal prep extending to the marginal ridge toward the contact point


Do ideal prep


Use the biggest available round bur to remove soft dentin and leave firm dentin behind


Leave firm dentin behind


Leave firm dentin behind

Follow the outer contour of the adjacent teeth to make it esthetic
(not as significant for composite restoration)

Indirect pulp capping with GI lining cement

Alternative: TheraCal

Short ring (Blue) | Tall ring (Orange) | Wide ring (Green)

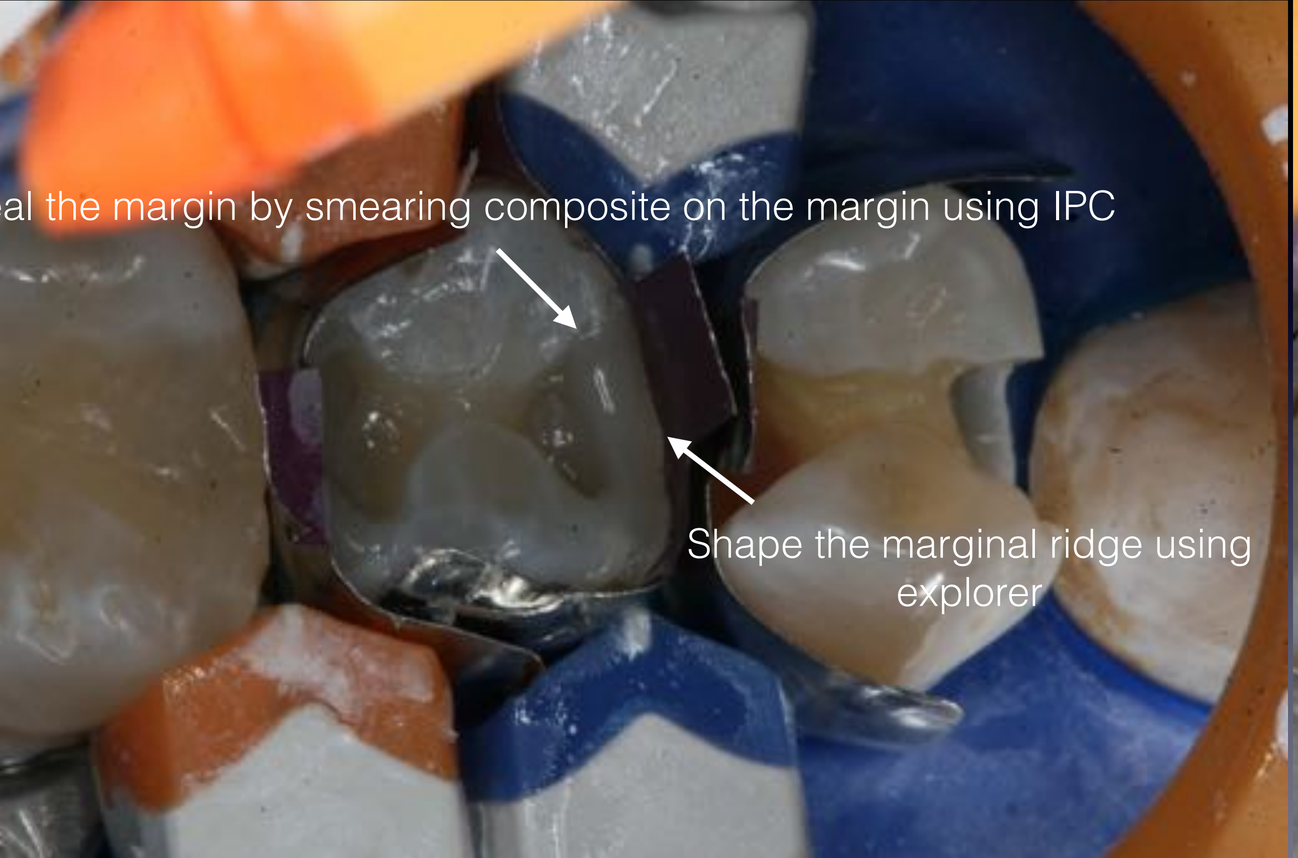
Short ring on the M

Tall ring on the D

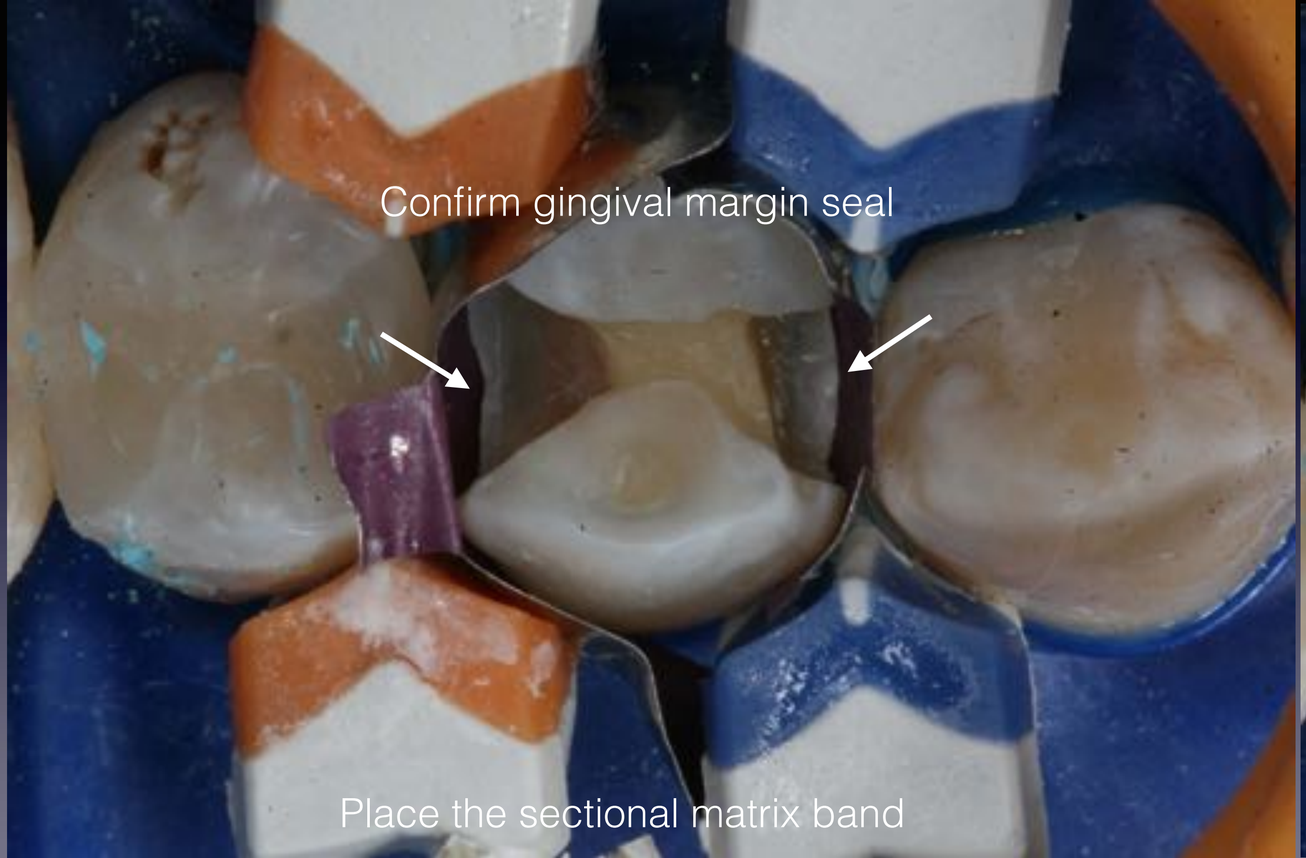
Confirm gingival margin seal


First layer on the ginigval floor,
focusing on adapting composite in all margins


Develop walls and the marginal ridges using the side of condenser


al the margin by smearing composite on the margin using IPC
Shape the marginal ridge using explorer

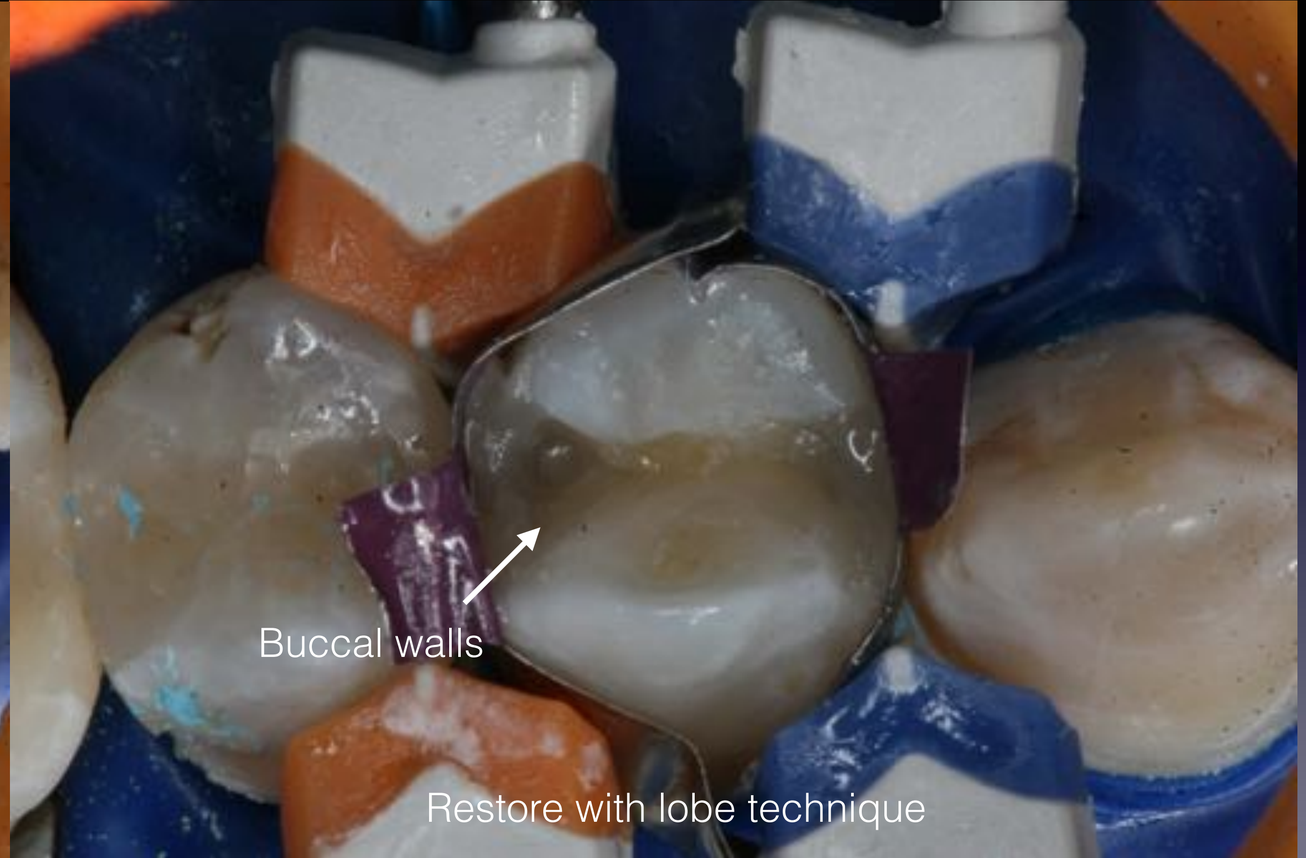

Restore with lobe technique

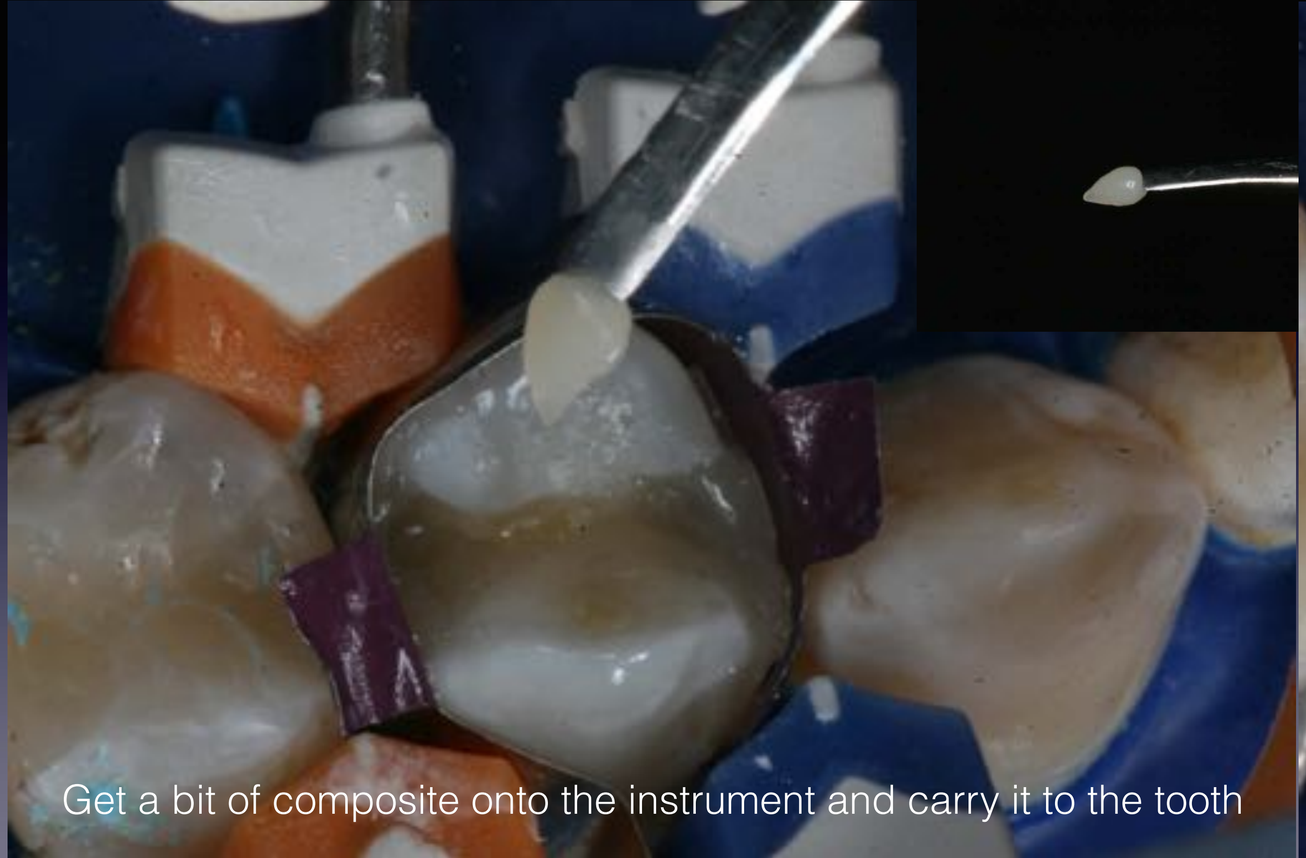

Confirm gingival margin seal
Place the sectional matrix band


First layer on the ginigval floor,
focusing on adapting composite in all margins

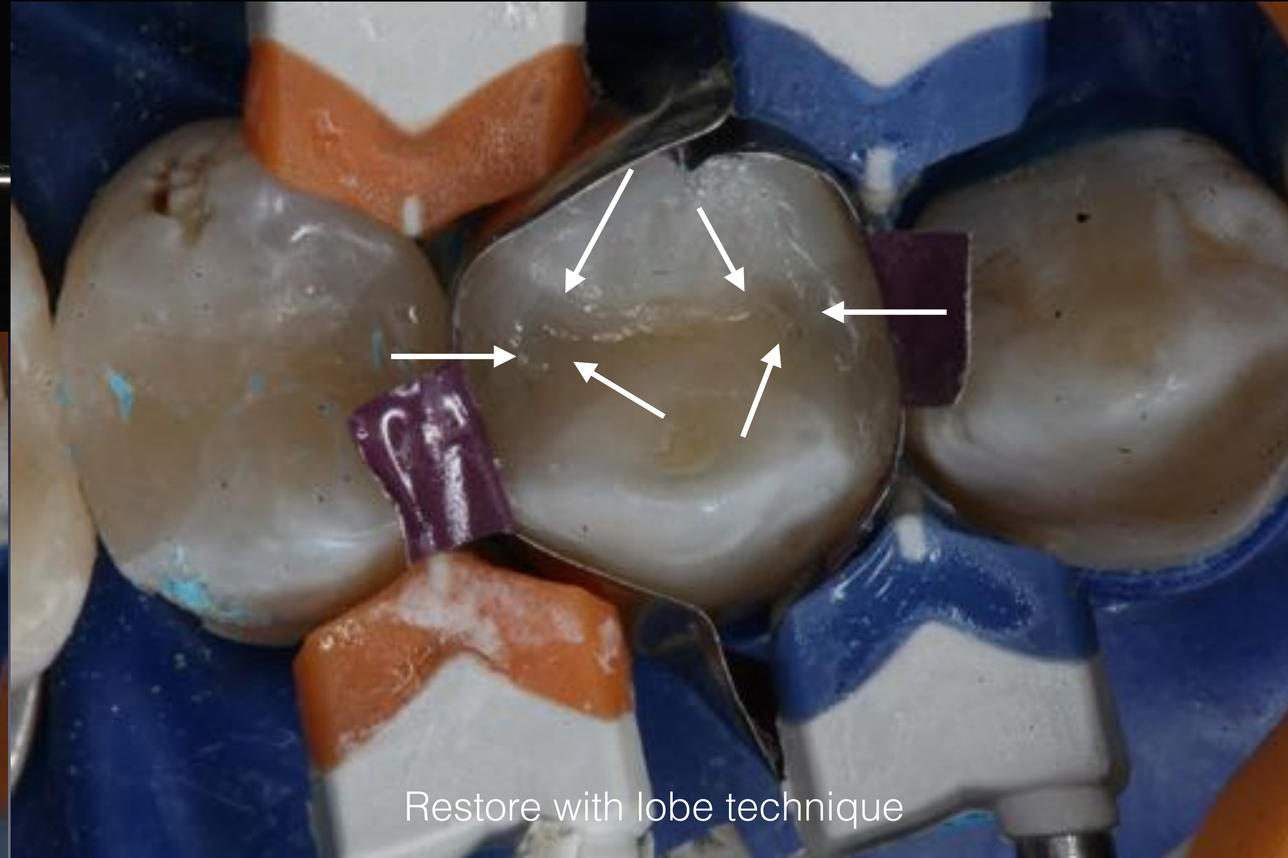
First layer on the ginigval floor,
focusing on adapting composite in all margins


Seal the margin by smearing composite on the margin using IPC
Shape the marginal ridge using explorer


Buccal walls
Restore with lobe technique

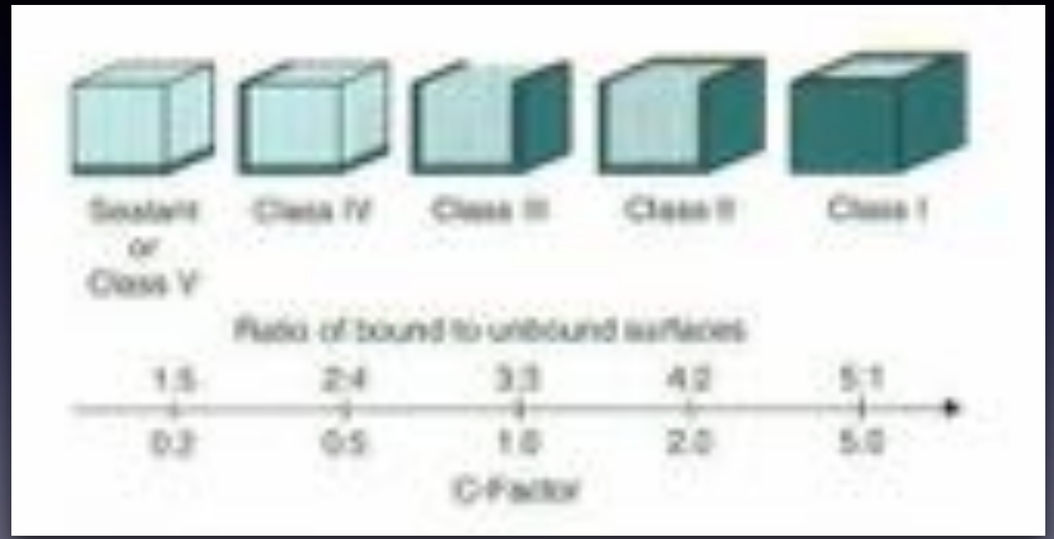


Get a bit of composite onto the instrument and carry it to the tooth

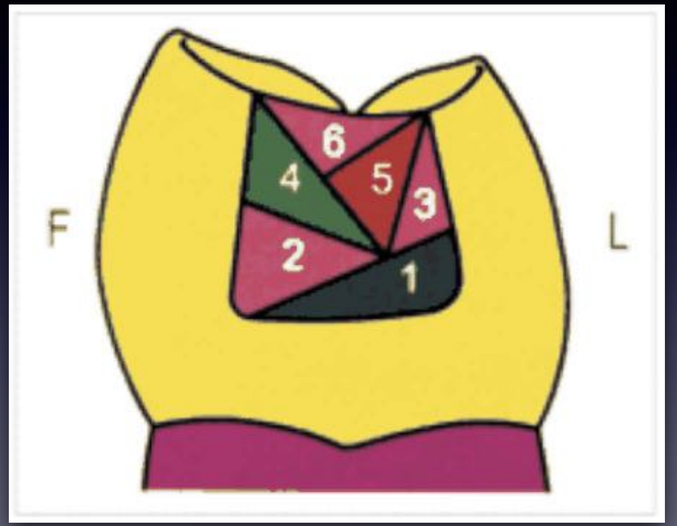


Restore with lobe technique

C-factor and composite shrinkage



Higher C-factor means greater contraction at the bonded surfaces



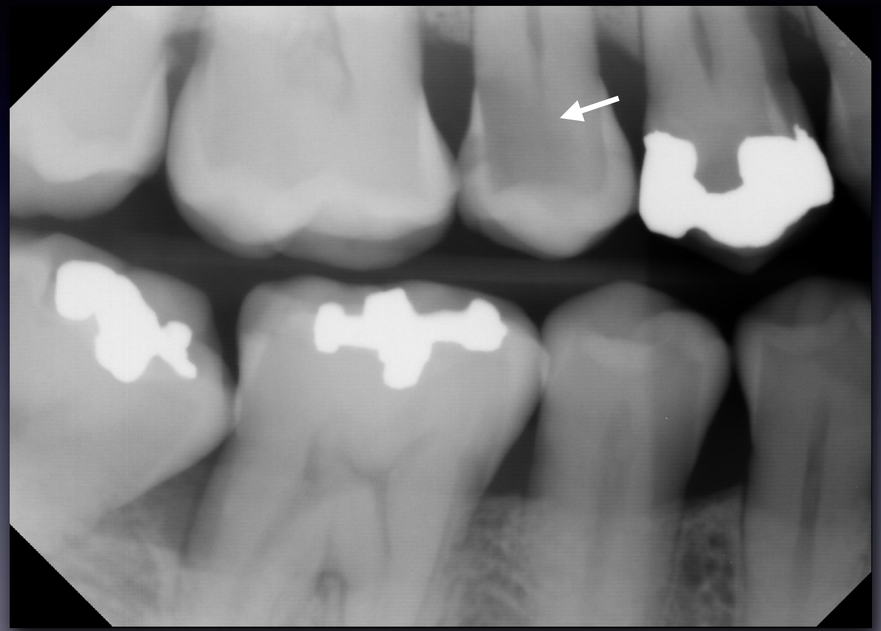
Lobe technique allows for minimal composite shrinkage

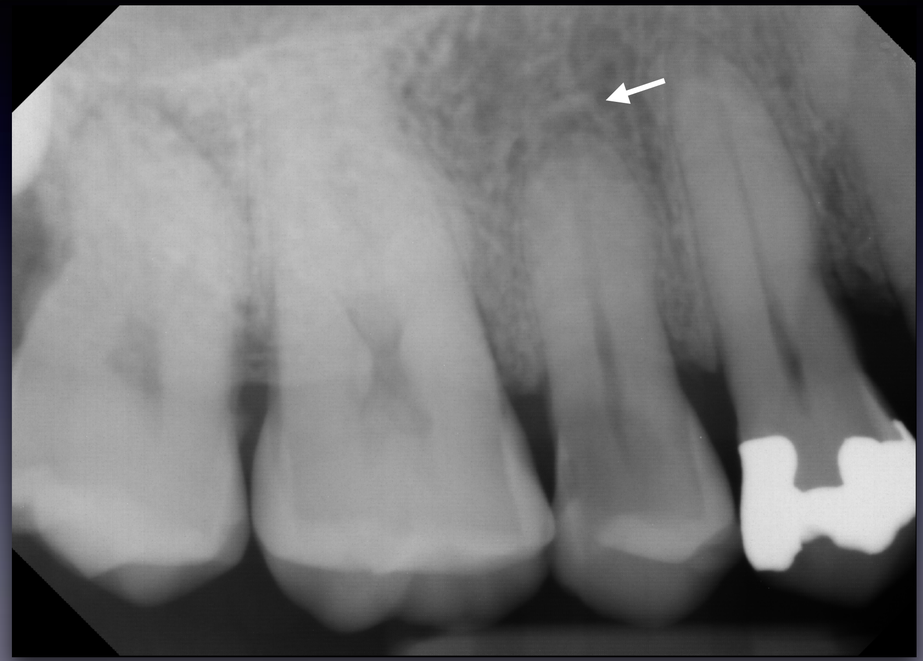
Minimal finishing and polishing

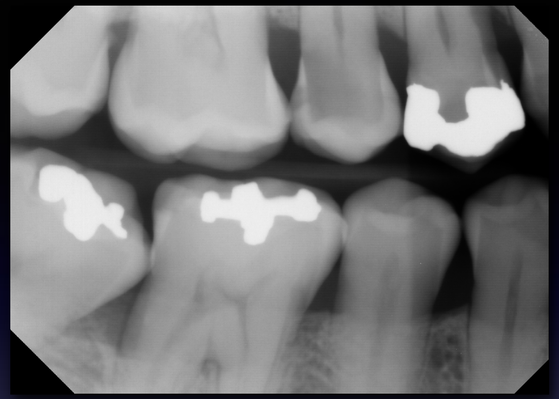
confirm tight sealing of the proximal walls and gingival walls

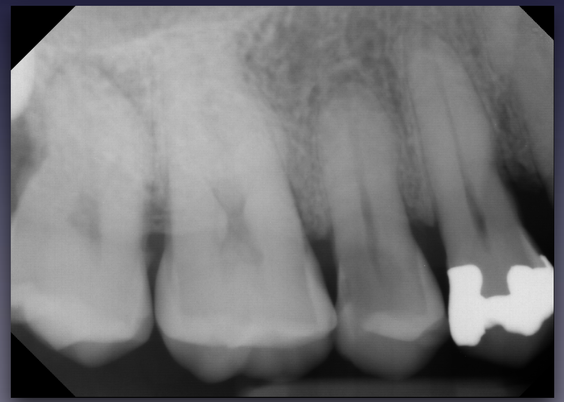
II. Managing extremely deep caries:
Direct pulp capping

What would you do?: Deep caries









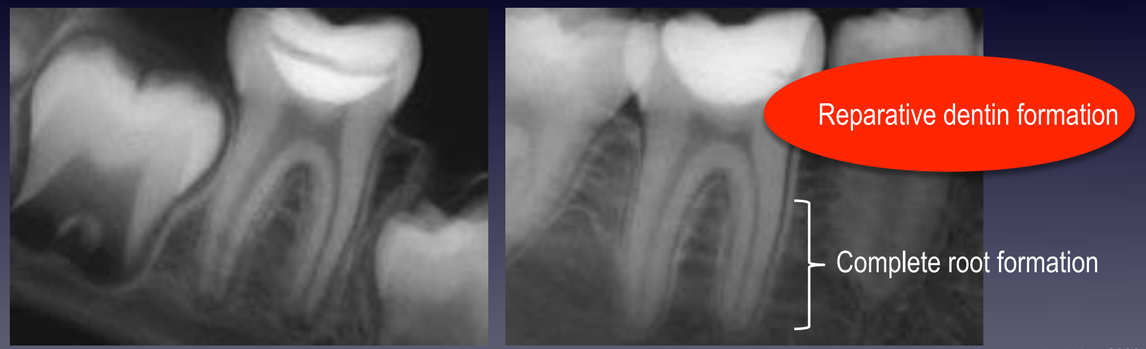
Pre-op: Pulp diagnosis

- Patient history
  - Throbbing pain, dull pain, spontaneous pain
- Endo testing
  - PA, Vitality test (Cold and EPT), Percussion test, Palpation test, Mobility test, and Probing depth
- In case with extreme deep caries with no endo symptoms, direct pulp capping can be performed

What is "no endo symptoms?" - not irreversible pulpitis

- no Hx of throbbing, dull aching, and spontaneous pain
- + cold test without lingering pain (> 15sec)
- + EPT test (vital tooth)
- WNL probing depth (no suden drop in depth)
- - to percussion, palpation, and mobility

Vital pulp therapy (VPT)



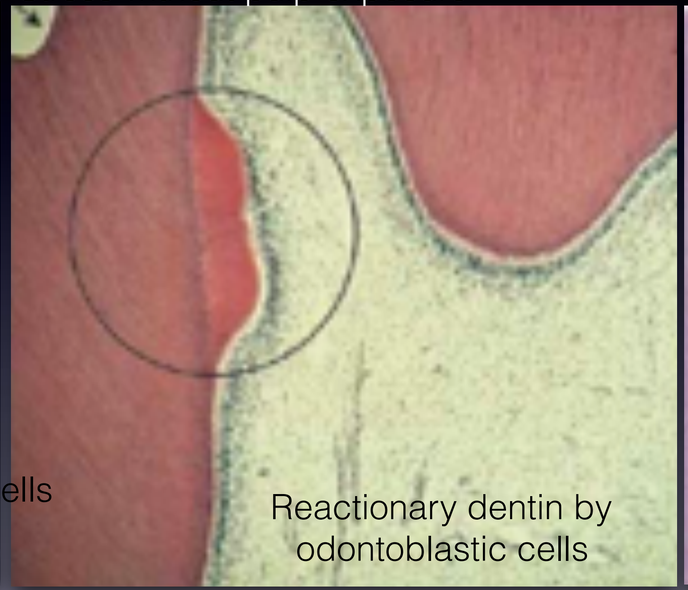
Bogen et al., JADA, 2008

- To preserve entire or partial pulp tissues that are otherwise diseased, traumatized, and damaged.
- The most conservative restorative procedure for protecting the pulp from further insult (Aguilar et al., JOE, 2011).
- Only after non-selective carious-tissue removal
- RDI absolutely required

Goal of VPT

Normal

Stress without pulp exposure



Stress with pulp exposure

- To regenerate reparative dentin (Dentinal bridge), which functions as a "biological seal" to protect the underlying pulp.

Sloan & Smith, 2007; Waddington et al. 2009; Simon et al. 2009

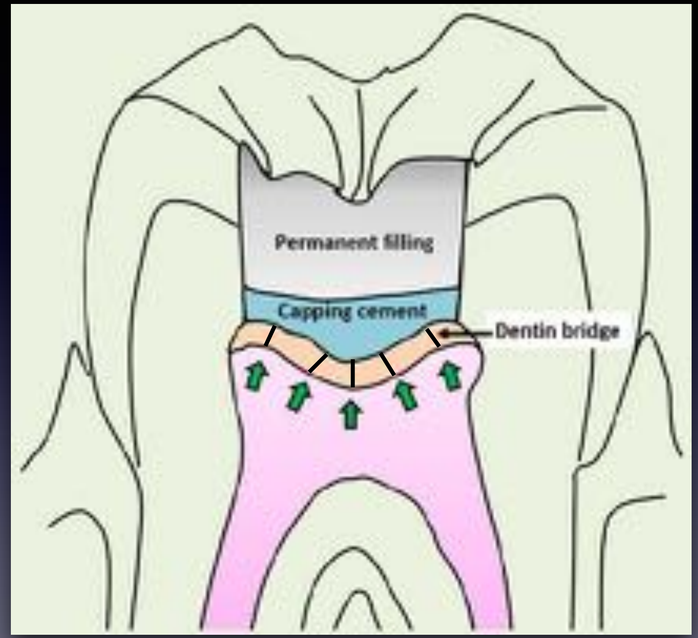
Calcium hydroxide (CH)

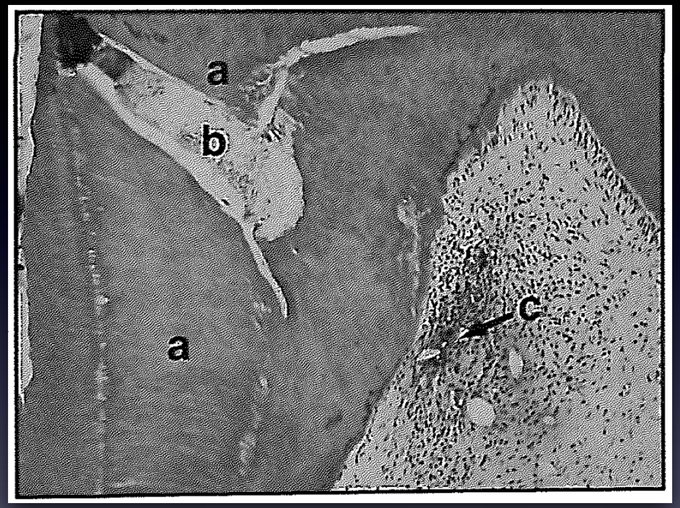
- Gold standard for direct pulp capping for many decades
- Long history (~90 years)
- Produce hydroxyl anions (OH-)
  - Creates alkaline environment which is favorable for mineralization process

Hilton *et al.,* Oper Dent, 2009, Cox *et al., Adv Dent Res,* 2001, Kitasako *et al., Dent Tromatol,* 2008, Prosser *et al., J Dent Res,* 1982, Anusavice *et al., S Dent Mat* 2012

Major drawbacks of CH

- Pulp Surface Inflammation and Necrosis
- Tunnel defects in dentin bridge. 89% of dentin bridges formed by calcium hydroxide cement in monkeys contained tunnel defects. (Cox *et al.* 2001)
- Does not provide hermetic seal against micro leakage
- Lack of adhesion and degradation over time.
- High solubility - “tunnel defects”
  - The success rate: 80.1% after 1 year, 68.0% after 5 years, and 58.7% after 9 years. (Willershausen *et al*. 2001)



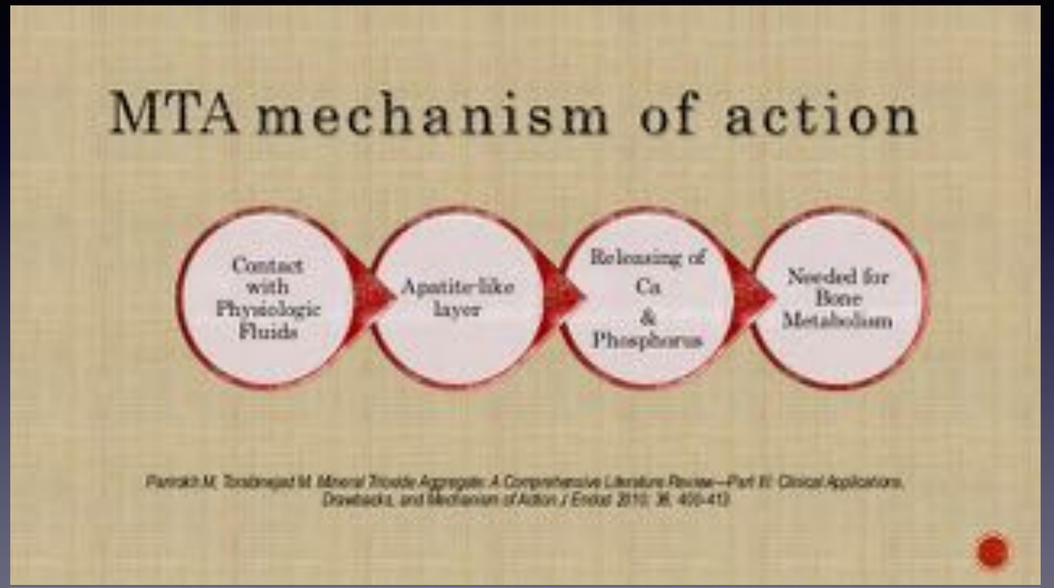


a = Dentin bridge;
b = tunnel defect;
c = Dycal-ingested inflammatory cells

Cox *et al.*, 1985

Hydraulic calcium silicate cements (HCSCs)

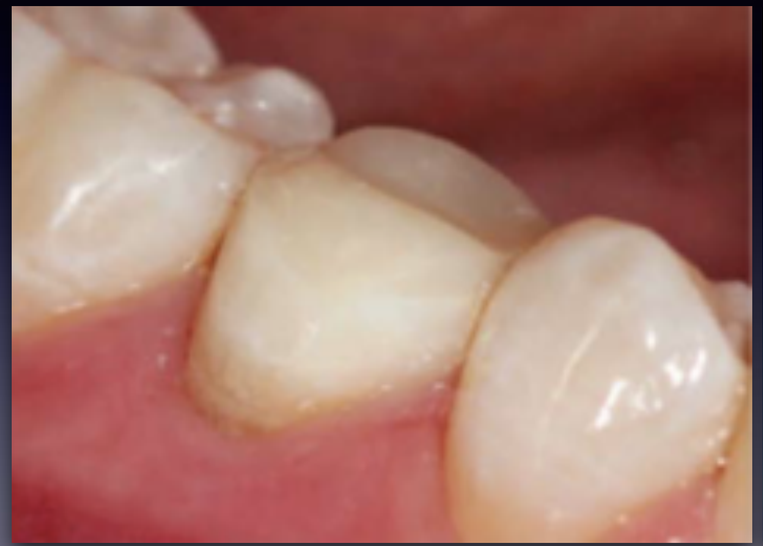
- Derivatives of the prototype, Mineral trioxide aggregate (MTA)
  - First introduced in early 1990s by Torabinejad and his coworker.
- Hydraulic - requires H2O for activation
- Main constituents are dicalcium silicates and tricalcium silicates

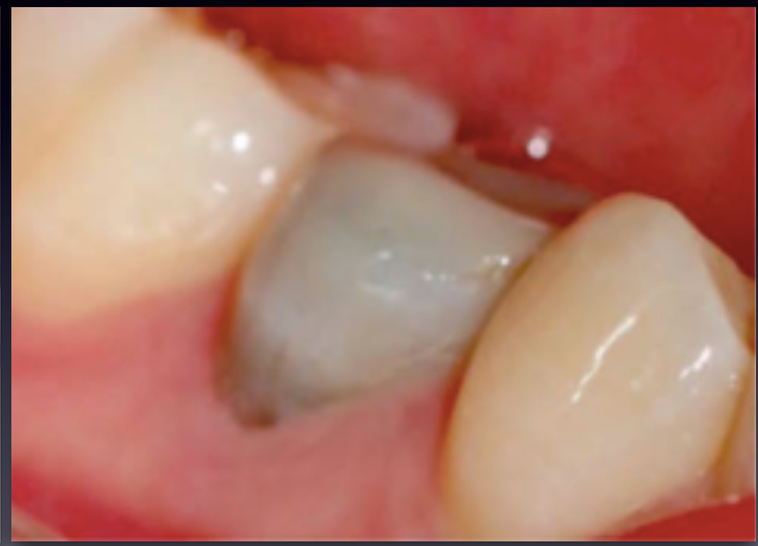


- (Ford *et al*., J Endo 1996; Torabinejad *et al*., J Endo 1993)

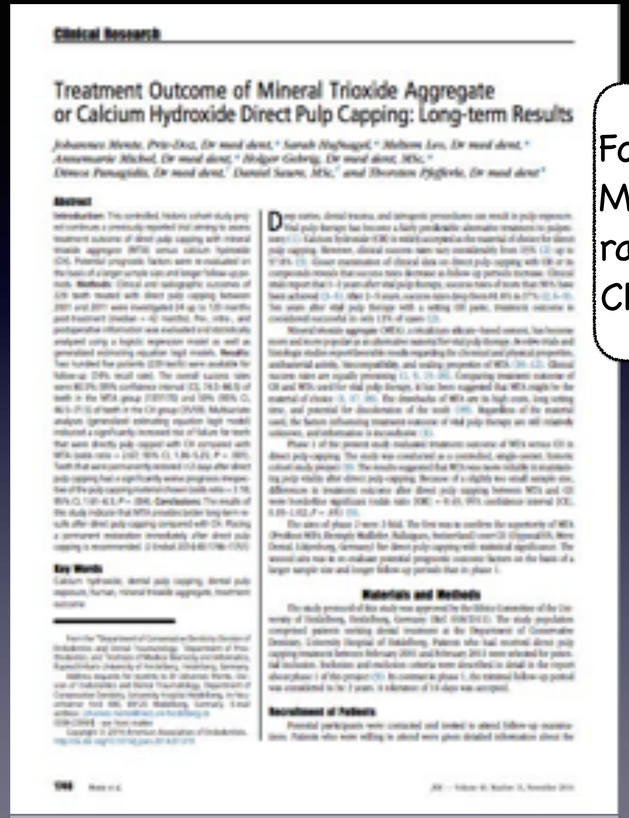
Major drawbacks of MTA

- Long setting time
- Potential to cause tooth discoloaration
- Difficult handling properties
- Expensive to purchase
- No known solvent





Fridland et al., 2003



Clinical Research

Treatment Outcome of Mineral Trioxide Aggregate or Calcium Hydroxide Direct Pulp Capping: Long-term Results

Follow-up = 123 months
MTA = 80.5 % success rate.
CH = 59% success rate.

Follow-up = nine years
MTA = 97.96 % success rate.
15/15 teeth with open species showed complete root closure.

RESEARCH

Direct pulp capping with mineral trioxide aggregate

An observational study

ABSTRACT

HCSCs showed high long-term success rate in direct pulp capping

Which components in CH and HCSCs are responsible for dentinal bride formation?

Ca^{2+}

- Many bone grafting materials are enriched with Ca^{2+}
- Calcium alone can induce odontogenic differentiation *in vitro*

OH^-

- pH of 12-13 (Staehle et al., 1989; Tanomaru-Filho et al., 2009; Fridland et al., 2005)
- Alkaline environment promote bone formation.
- Akaline phosphatase activity, an important enzyme for mineralization, is optimal in 7.37 (Monfoulet et al., 2014; Fliefel et al., 2016)
- pH above 8.0 is shown to inhibit mineralization process both in vitro and in vivo (Monfoulet et al., 2014; Fliefel et al., 2016)
- Excellent microbial activity

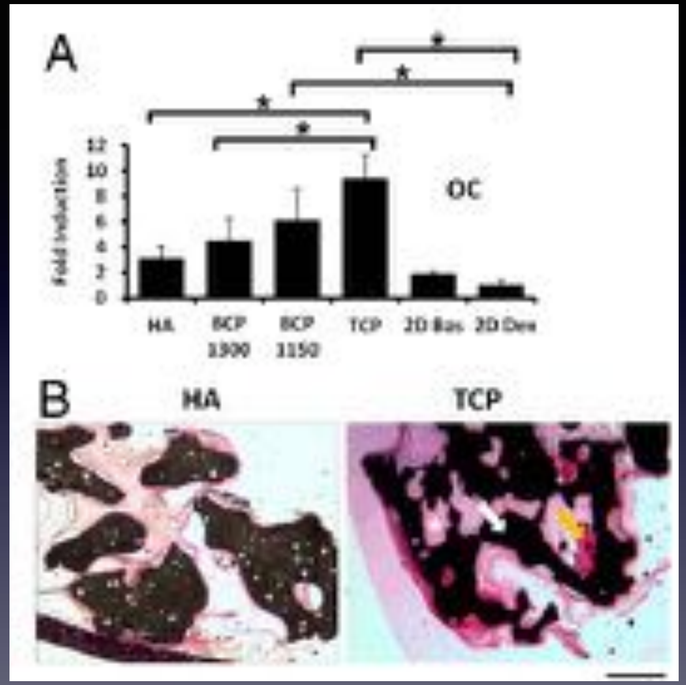
Osteoinductive ceramics as a synthetic alternative to autologous bone grafting

Huipin Yuan[a,1], Hugo Fernandes[b,1], Pamela Habibovic[b], Jan de Boer[b], Ana M. C. Barradas[b], Ad de Ruiter[c], William R. Walsh[d], Clemens A. van Blitterswijk[b], and Joost D. de Bruijn[a,2]

Table 1.

	HA	TCP	BCP1150	BCP1300
Chemistry	HA	5HA + 95TCP	20TCP/80HA	20TCP/80HA
Particle size, mm	1–2	1–2	1–2	1–2
Specific surface, m^2/g	0.1	1.2	1	0.2
Percentage of materials, %	46.4 ± 2.4	49.9 ± 1.8	45.6 ± 2.2	44.6 ± 1.9
Microporosity, %*	3.1	48.7	41.1	8.7
Ca release, ppm	0.9 ± 0.1	15.3 ± 0.2	5.4 ± 0.1	4.2 ± 0.4

*Volume percentage of micropores smaller than 10 μm within the ceramic.



Calcum release: TCP > BCP1150 > BCP1300 > HA

More calcium release from the scaffolds means more bone formation

Hydraulic Calcium Silicate Cements (HCSCs)

TABLE 3

Commercially Available Calcium Silicate-Based Cements

Commercial brand	Company	Working time	Setting time
BioAggregate	Innovative Bioceramix, Vancouver, B.C.	5 min	2.5-6 h
Biodentine	Septodont, Saint-Maur-des-Fosses, France	6 min	12 min
Calcium Enriched Mixture	Bionique Dent, Tehran, Iran	5 min	<1 h
Capasio	Primus Consulting, Bradenton, FL	N/A	150 min
Cerkamed MTA plus	Wojciech Pawlowski, Nisko, Poland	6-10 min	10 min
Choroxis MTA	Insight Endo, Henry Schein, New York	10 min	15 min
DiaRoot BioAggregate	DiaDent Group International, Burnaby, B.C.	>5 min	4 h
Endocem MTA	Maruchi, Wonju, Korea	2 min	4 min
Endosequence	Brasseler USA, Savannah, Ga.	4 h	4-10 h
GenexxA	Dentsply, Tulsa, Okla.	N/A	75 min
Grey MTA Plus	Avalon Biomed Inc. Bradenton, FL	12-20 min	1.25 h
Harvard MTA	Harvard Dental International GmbH, Hoppegarten, Germany	>2 min	5 min
iRoot BP Plus	Innovative Bioceramix, Vancouver, B.C.	Premixed	5-7 d
MM-MTA	MicroMega, Besançon, France	2 min	20 min
MTA Angelus, MTA Bio	MTA-Angelus, Londrina PR, Brazil	10 min	10-15 min
MTA Plus	Prevest Denpro, Jammu, India	12 min	< 1h
MTA-Cops	Acteon, Merignac, France	N/A	20 min
MTA-CPM	EGEO SRL Buenos Aires, Argentina	N/A	15 min
NeoMTA Plus	Avalon Biomed Inc. Bradenton, FL	20 min	<1 h
Odontocem	ADM, Brisbane, Australia	10 min	24 h
OrthoMTA	BioMTA, Seoul, Korea	3 min	5 h 30 min
ProRoot MTA	Dentsply, Tulsa, Okla.	78 min	261 min
RetroMTA	BioMTA, Seoul, Korea	2.5 min	6 h

Cao et al., 2016

Which one is should I use?

Modeling direct pulp capping in animals

-There are several animal model previously used (Koliniotou-Koumpia *et al., J Dent*, 2005; Tarim *et al., Quintessence Int*. 1998; Tziafa *et al., J Endod*. 2014).

-Among them, rats are most frequently used due to its small in size but large enough to overcome technical difficulties.

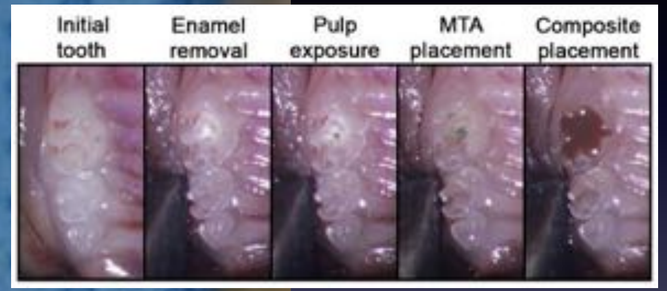
-However, these large animals are observational in nature.

-Genetically engineered mice (transgenic or knockout) would help expedite our understanding of these processes at the molecular level.

-Recent studies demonstrated direct pulp capping procedure in mice (Saito *et al., JDR*, 2016; Hunter *et al, JBMR*, 2015; Goldberg *et al., Front Biosci*. 2011).

However, there are no mouse models to demonstrate clinically relevant direct pulp capping procedure.

Establishment of direct pulp capping model in mice



jove Journal of Visualized Experiments www.jove.com

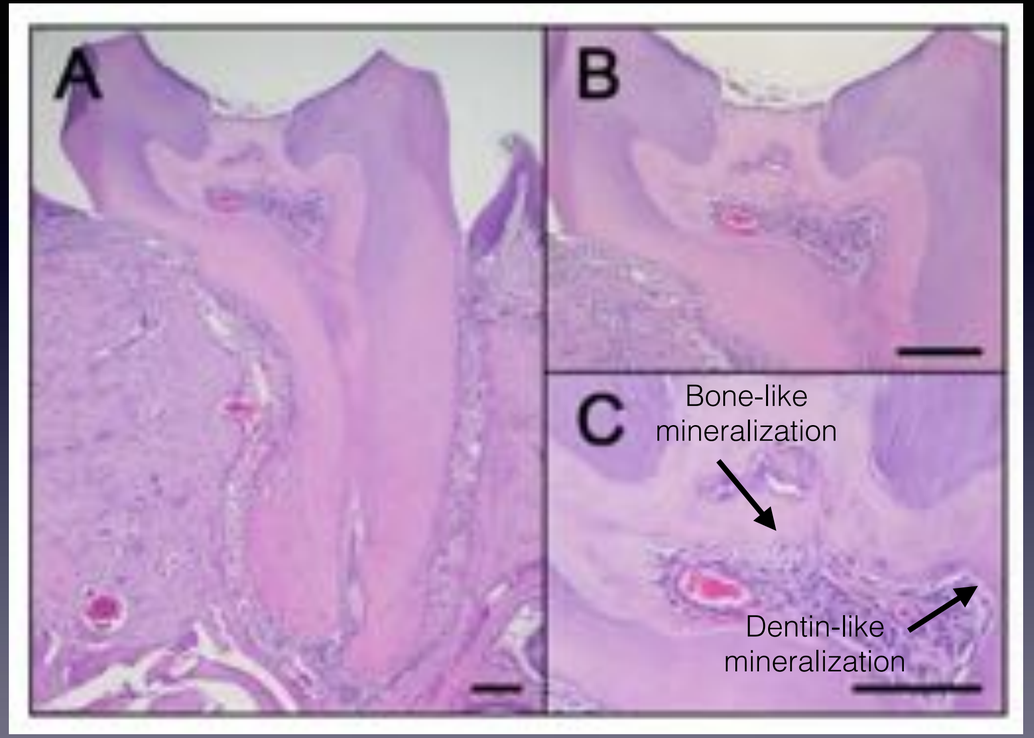
Video Article

Development of a Direct Pulp-capping Model for the Evaluation of Pulpal Wound Healing and Reparative Dentin Formation in Mice

Minju Song[1], Sol Kim[1], Terresa Kim[1], Sil Park[1], Ki-Hyuk Shin[1,2], Mo Kang[1,2], No-Hee Park[1,2,3], Reuben Kim[1,2]

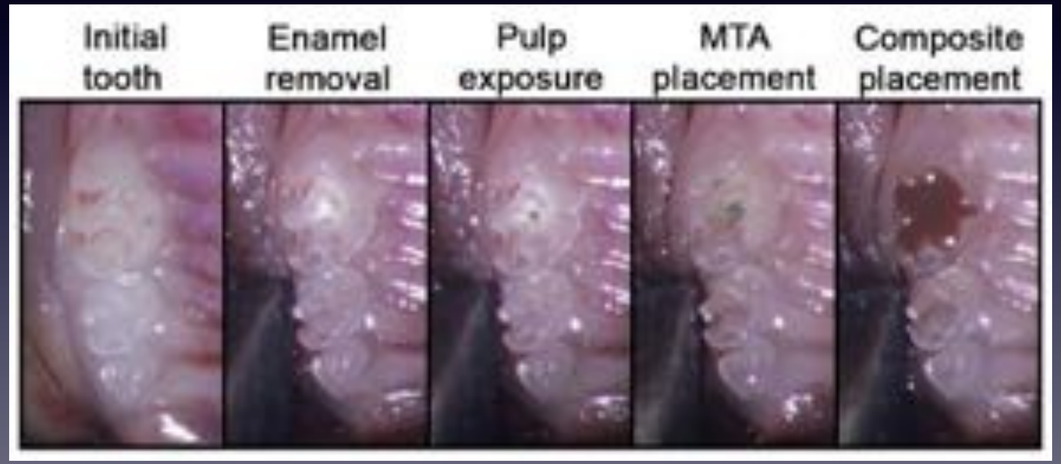
[1]The Shapiro Family Laboratory of Viral Oncology and Aging Research, The UCLA School of Dentistry
[2]UCLA Jonsson Comprehensive Cancer Center
[3]David Geffen School of Medicine at UCLA

Correspondence to: Reuben Kim at rkim@dentistry.ucla.edu



Song et al., JOVE, 2016

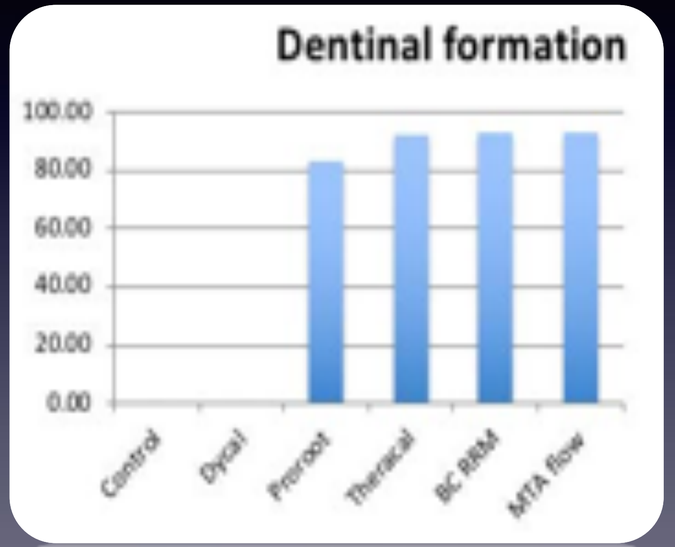
Comparison among different HCSCs

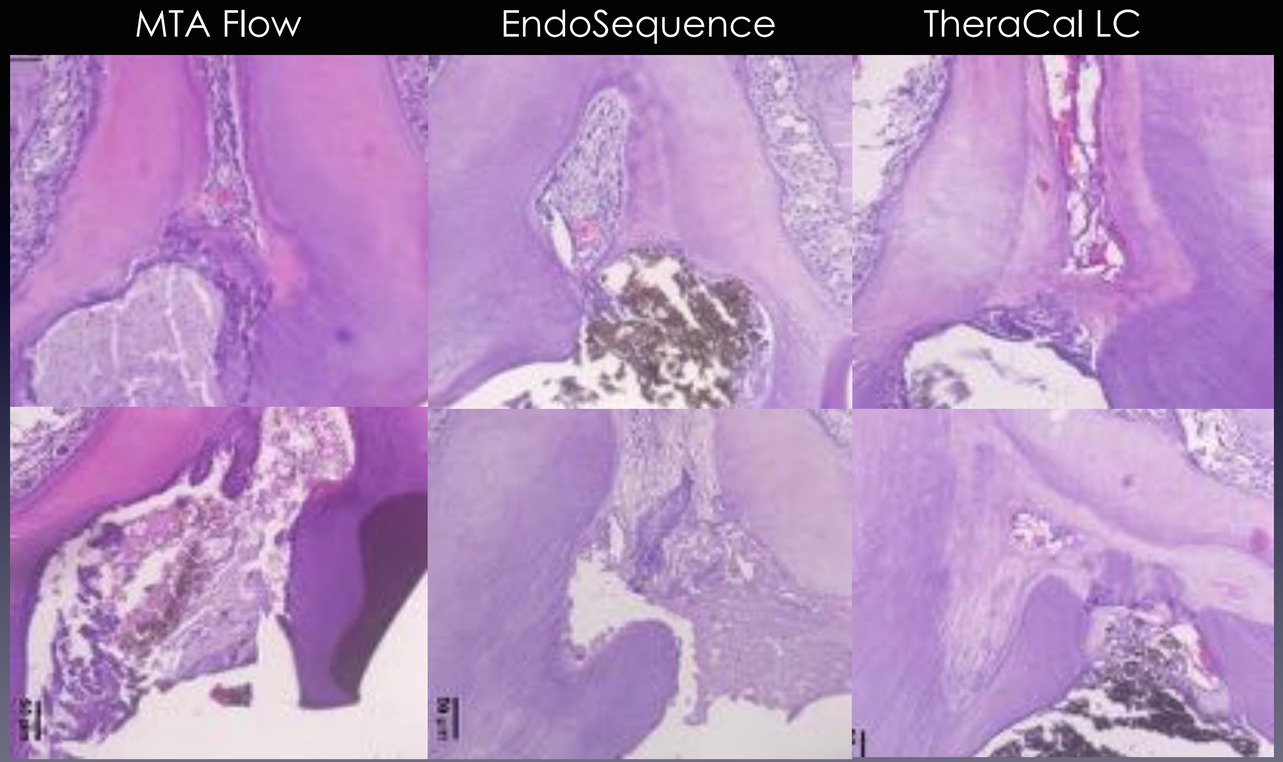


- Methods:
  - Direct pulp capping on C57/BL6 mice and left it for 6 weeks
  - Samples (n = 14 per group):
    - Composite (control)
    - Dycal (control)
    - Proroot MTA (Dentsply)
    - TheraCal LC (Bisco)
    - EndoSequence BC RRM (Brasseler)
    - MTA FLOW (Ultradent)

Dentinal bridge formation

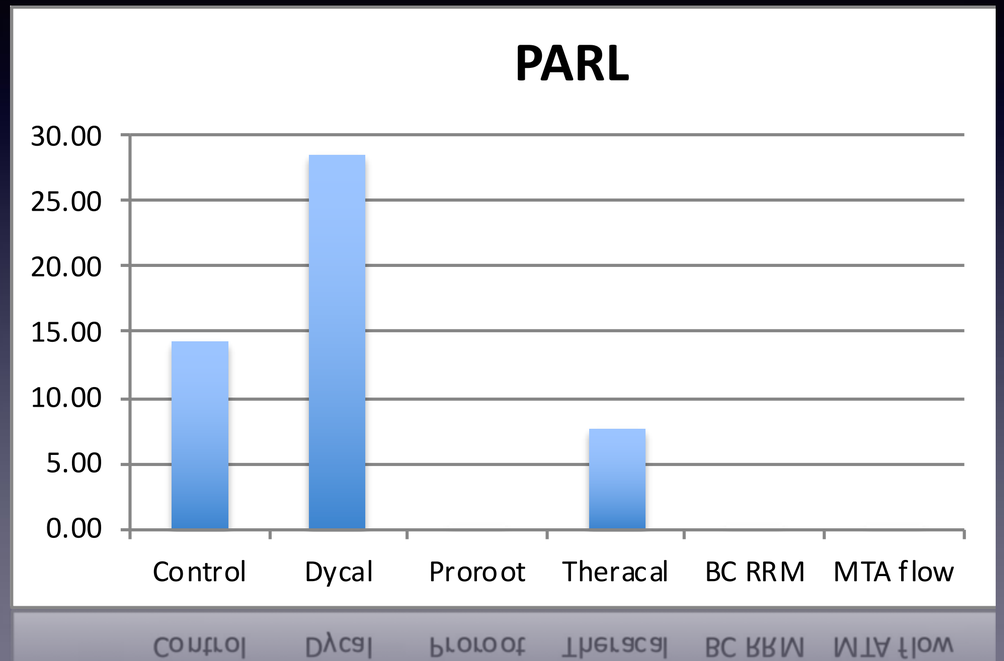
PCM Type	Dentinal Bridge Formation
PROROOT® MTA	10/12
TheraCal LC	12/13
EndoSequence BC RRM	13/14
Endo-Eze™ MTAFlow	13/14
UltraCal® XS	0/14
Control	0/14




MTA Flow
EndoSequence
TheraCal LC
Dycal
Composite
Proroot MTA

PARL development

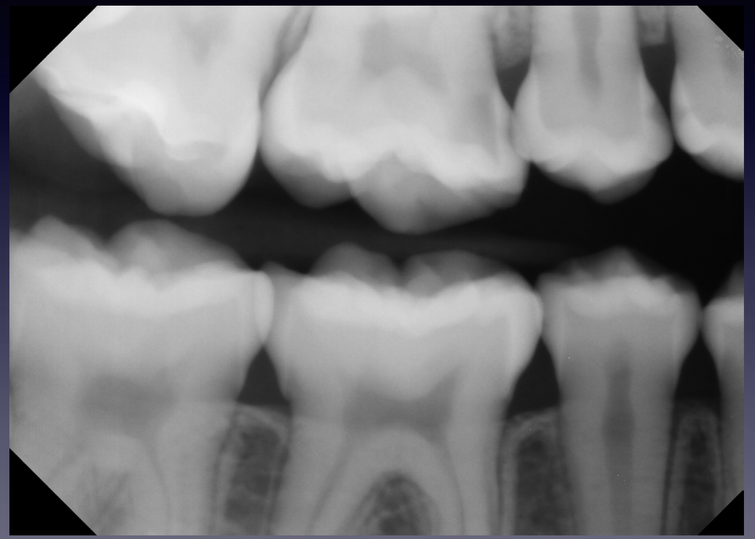
PMC Type	Number of Teeth with PARL
ProRoot MTA	0/14
Theracal	1/14
BC RRM	0/14
MTA Flow	0/14
Dycal	4/14
Control	2/14

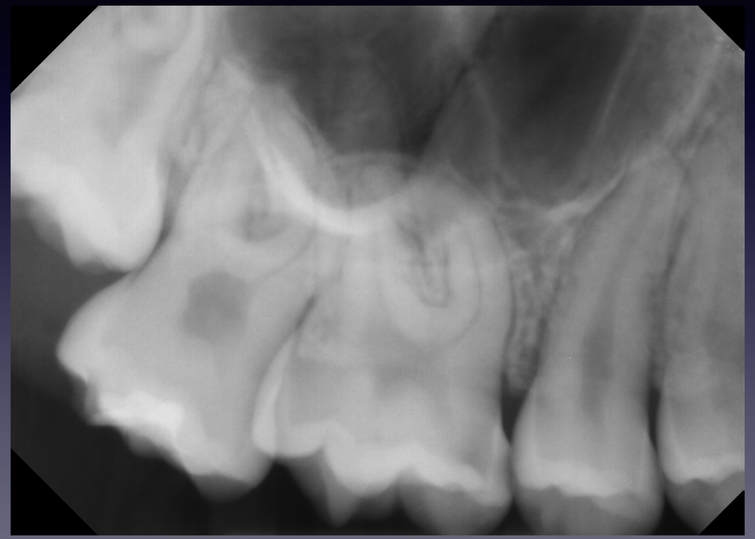


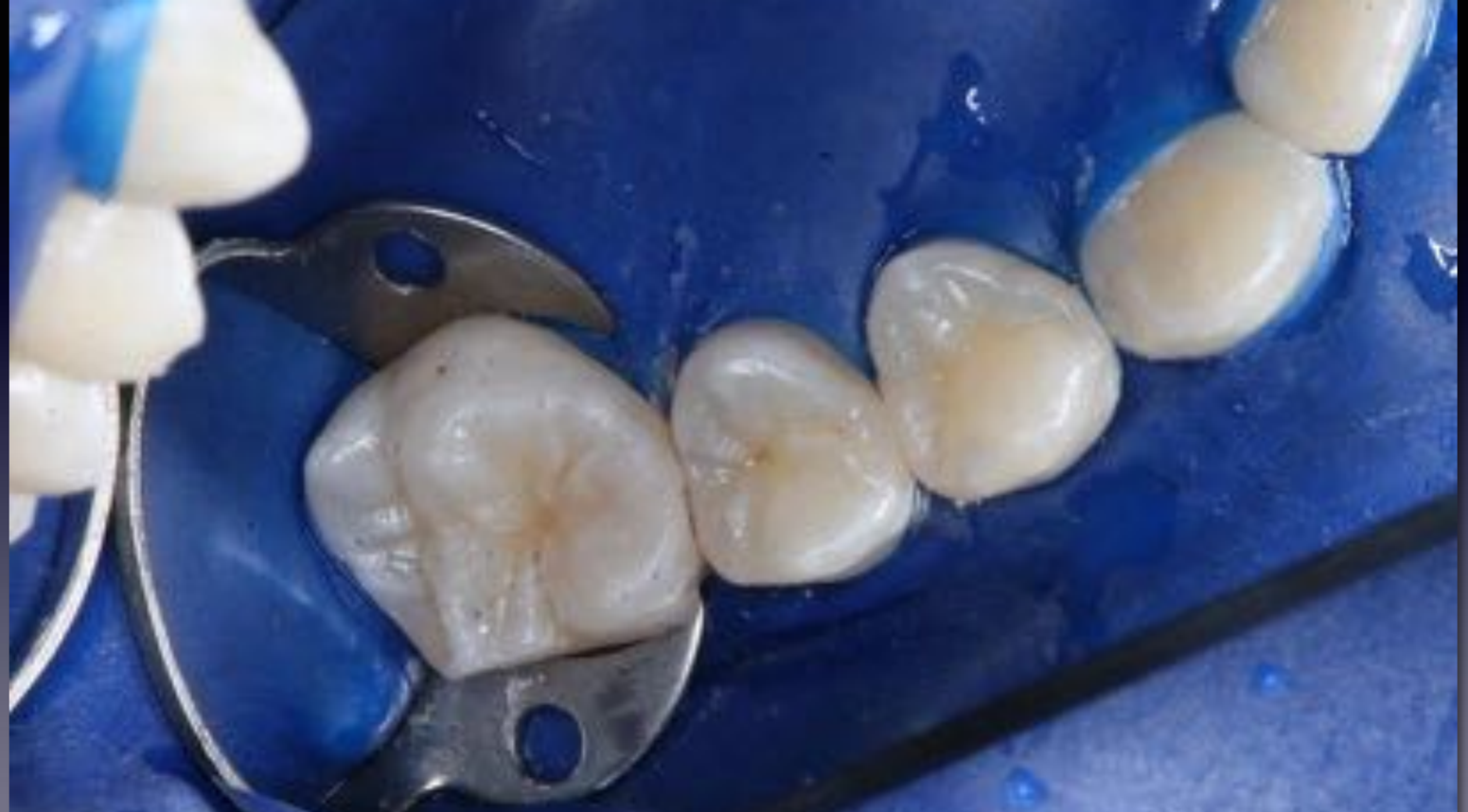
Clinical procedures

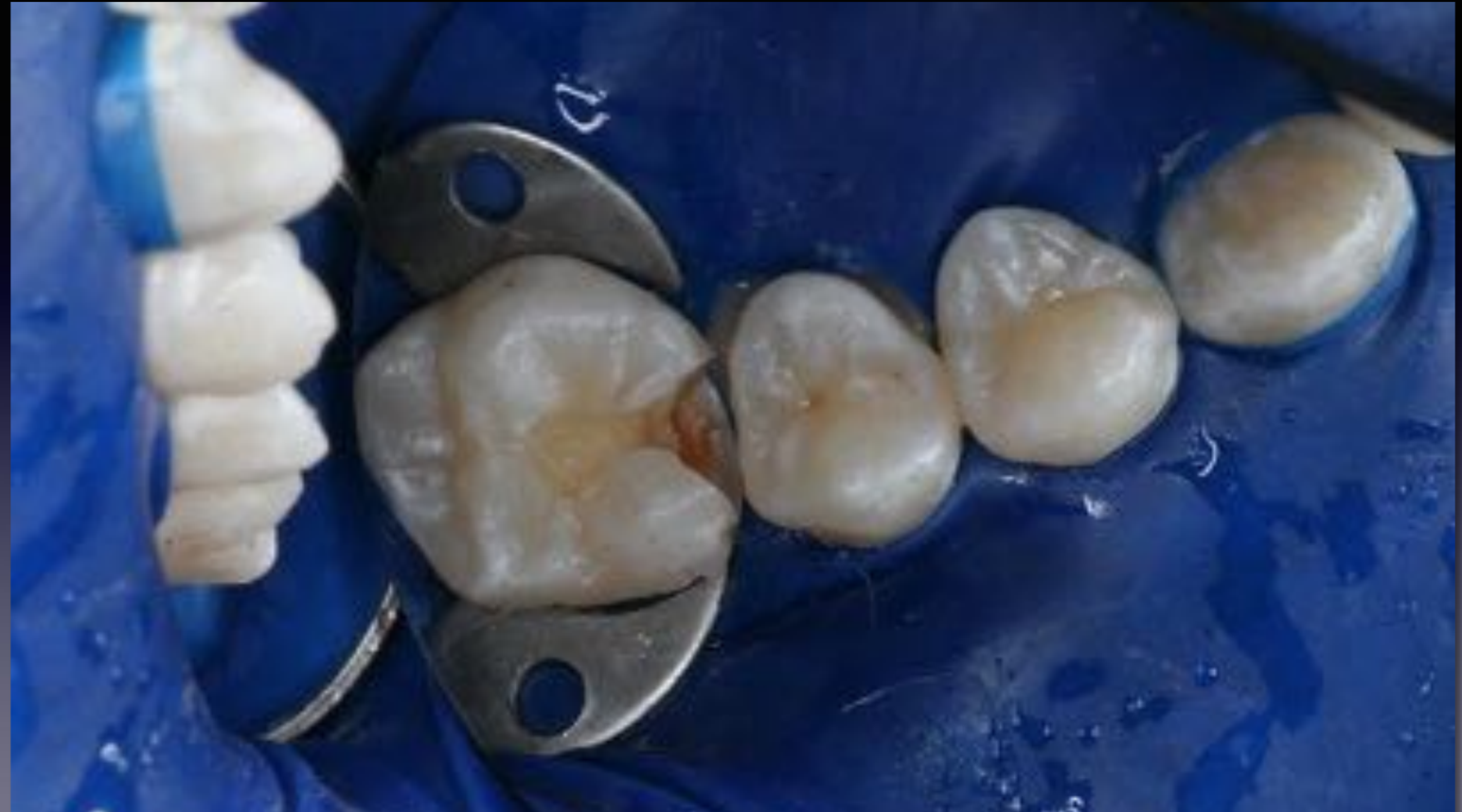
Steps	Clinical procedures	Rationales
1	Apply rubber dam	To isolate the working environment
2	Use the high-speed large round burs to remove all decay peripherally first ("High-speed zone")	To assess whether the tooth is clinically restorable
3	Use the low-speed large round burs to carefully remove all decay pulpally and axially ("Low-speed zone")	To establish the exposed pulp opening
4	Apply 3.5% NAOCl-soaked cotton pellets onto the exposed pulp for 2 min	To stop the bleeding
5	Place the hydraulic calcium silicate cement (HCSC) materials	To seal the exposed pulp opening
6	Apply conditioner (10% polyacrylic acid)	To increase the binding capacity of RMGI
7	Apply RMGI-based liners (e.g., Fuji II LC)	To seal the pulp-capping materials
8	Apply etchant/primers/adhesives	To increase the binding capacity of composite
9	Composite (3-step, total-etch)	To restore the tooth

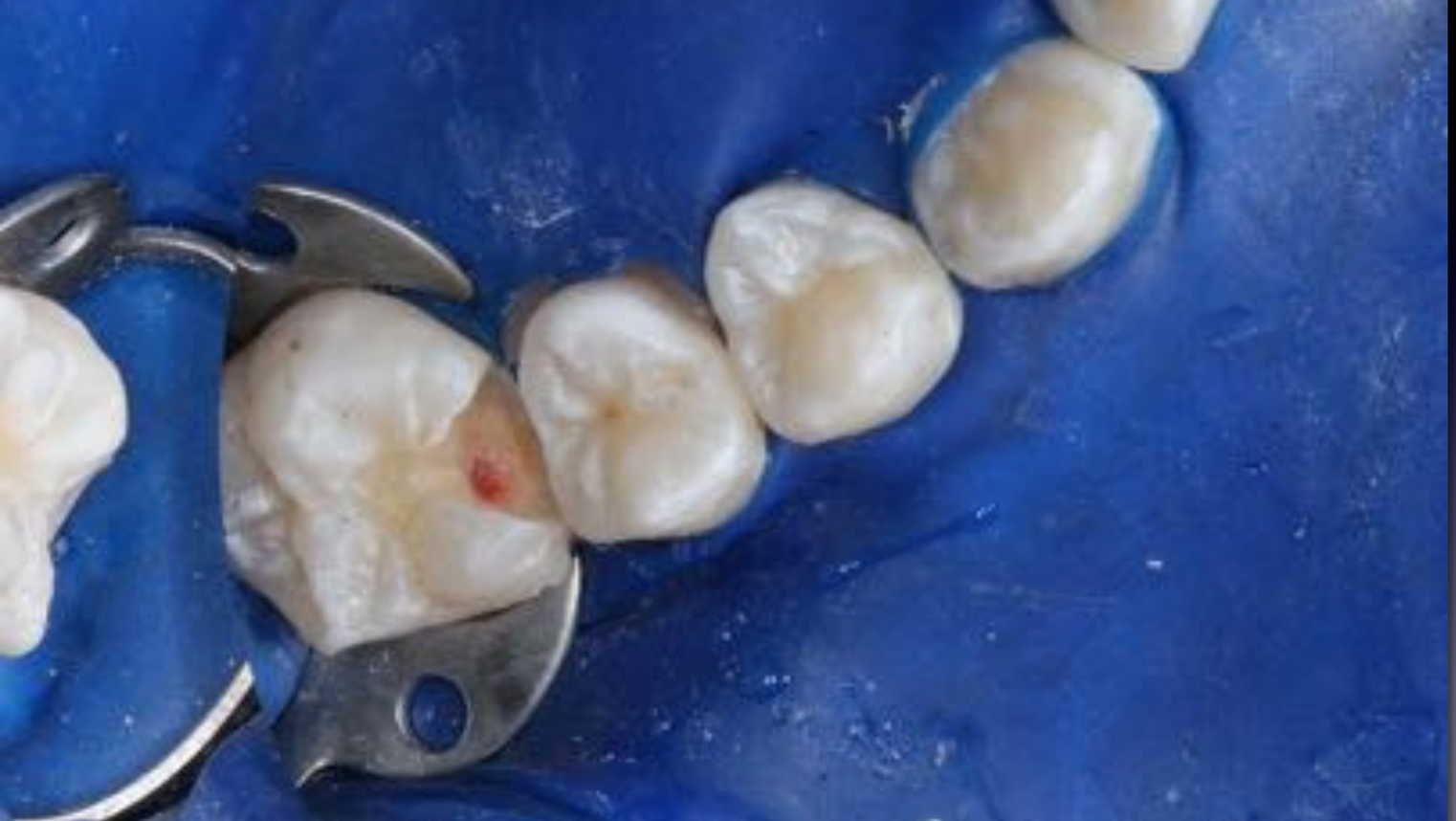
Case 1: #3 MO

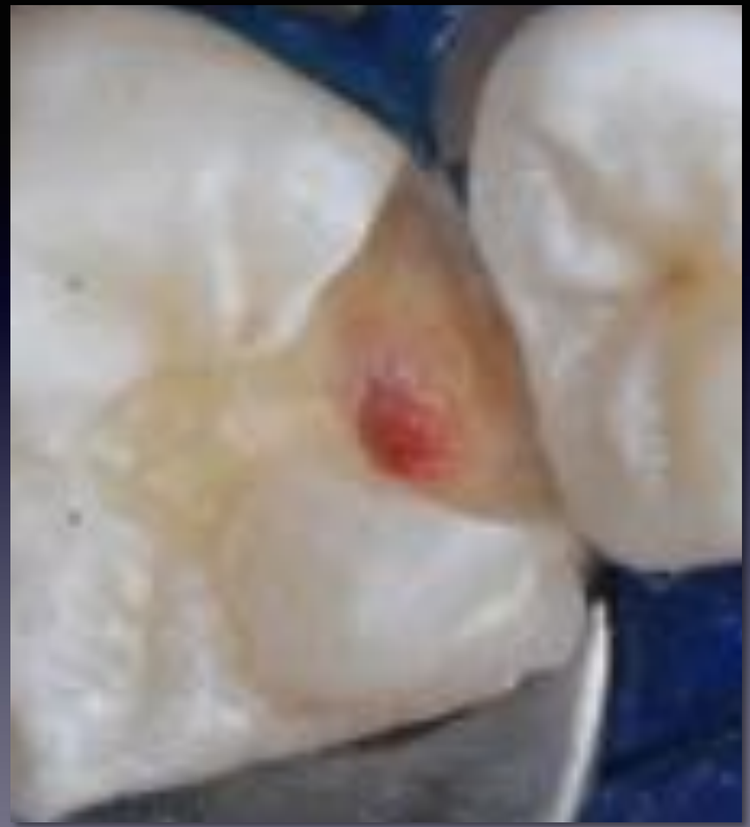


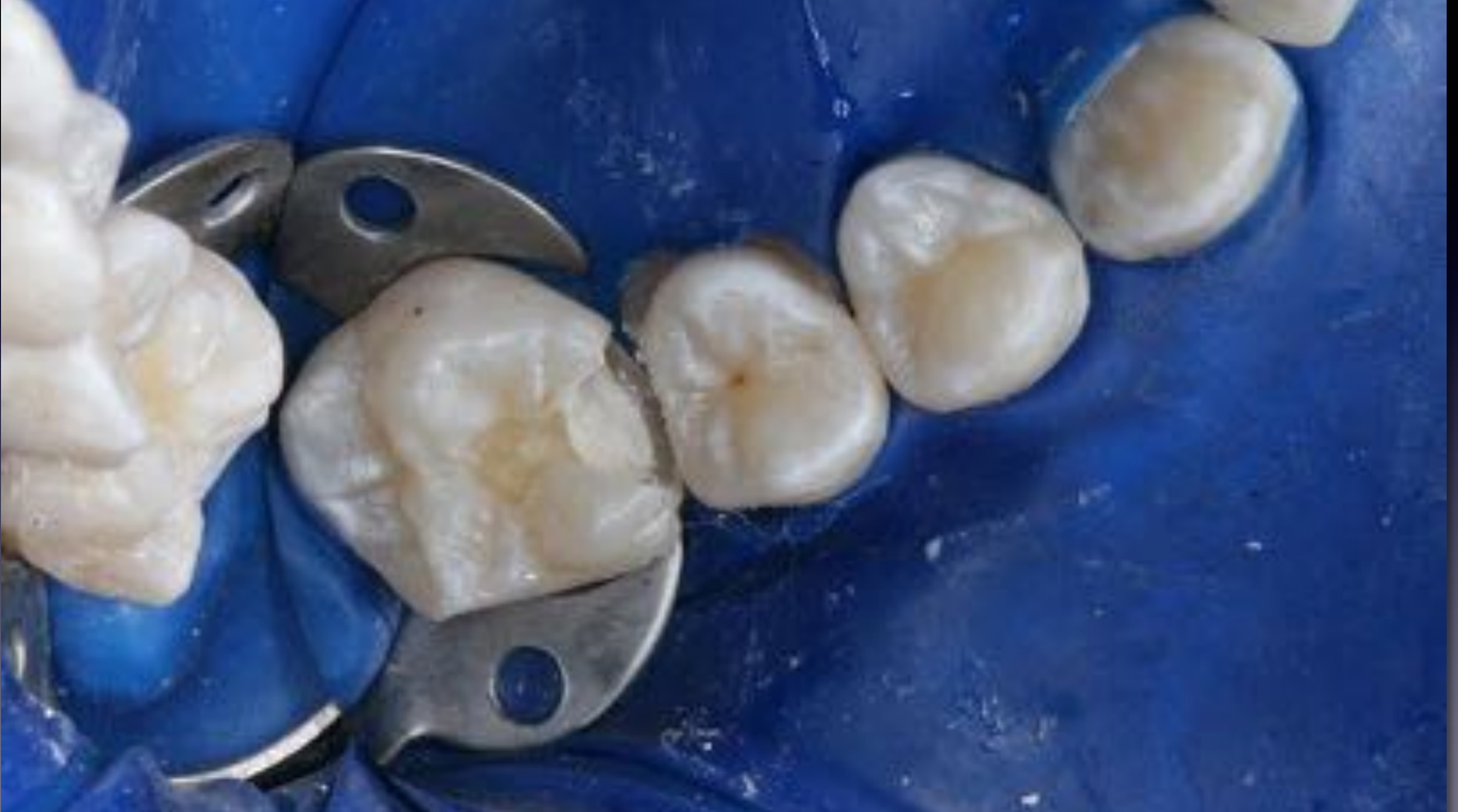


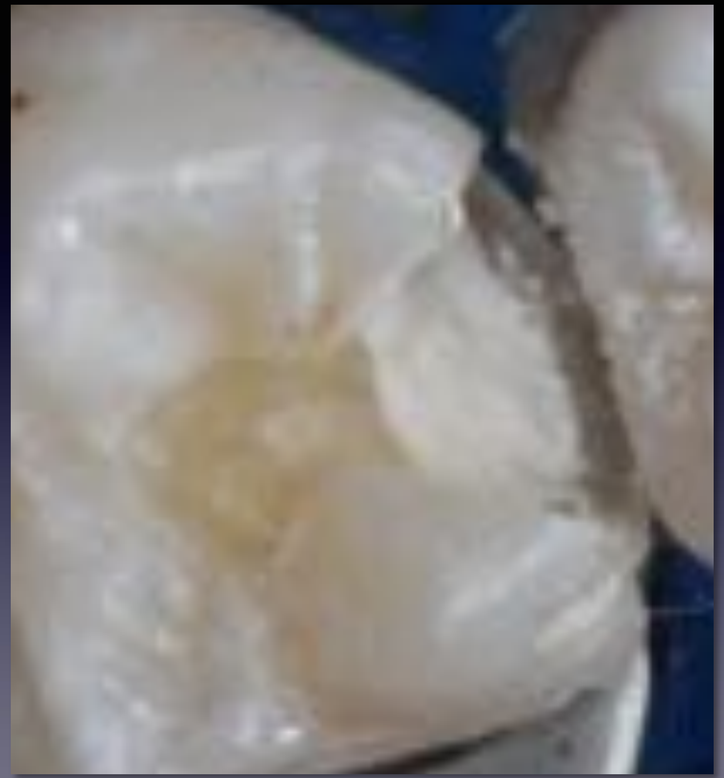


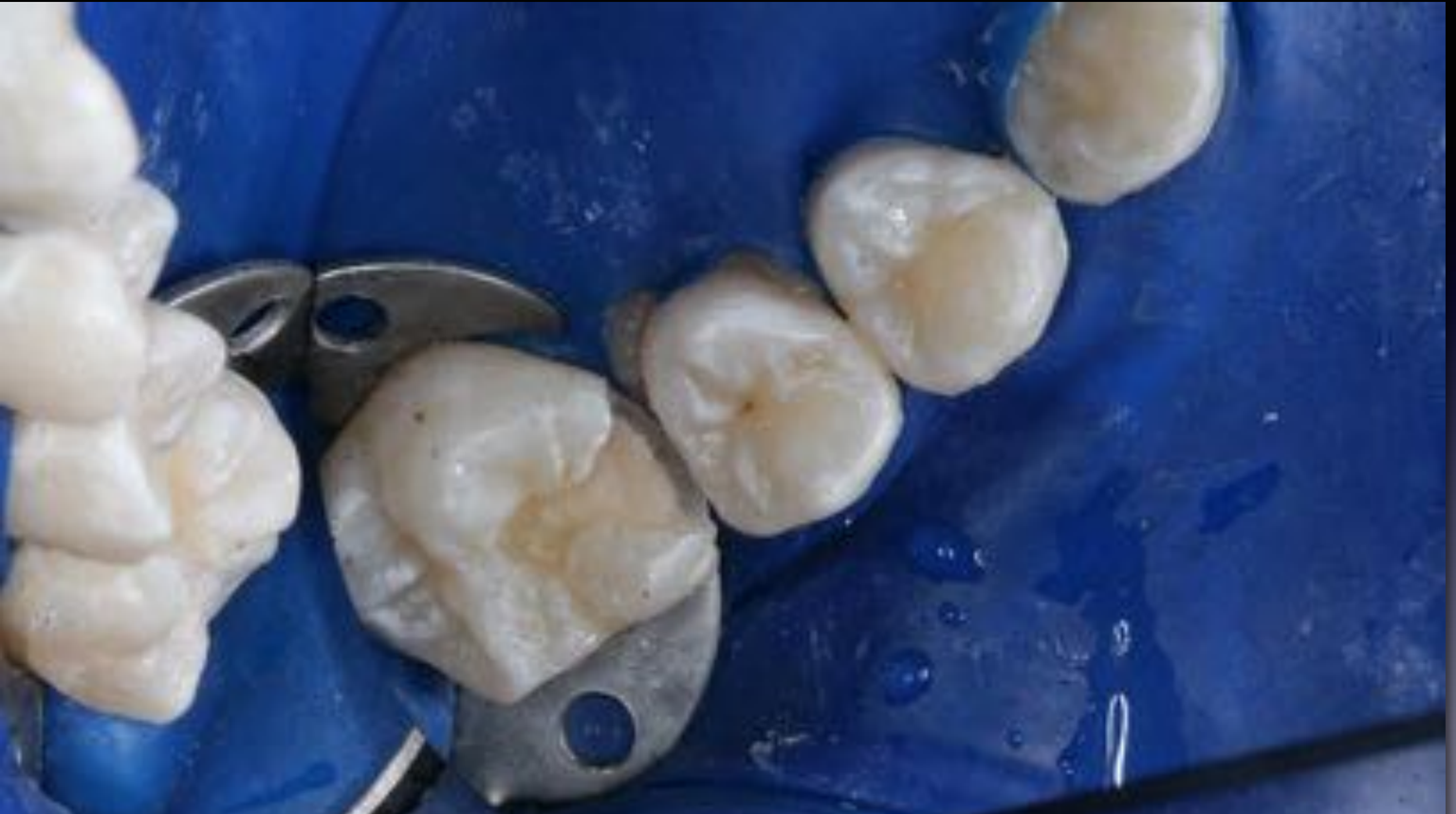






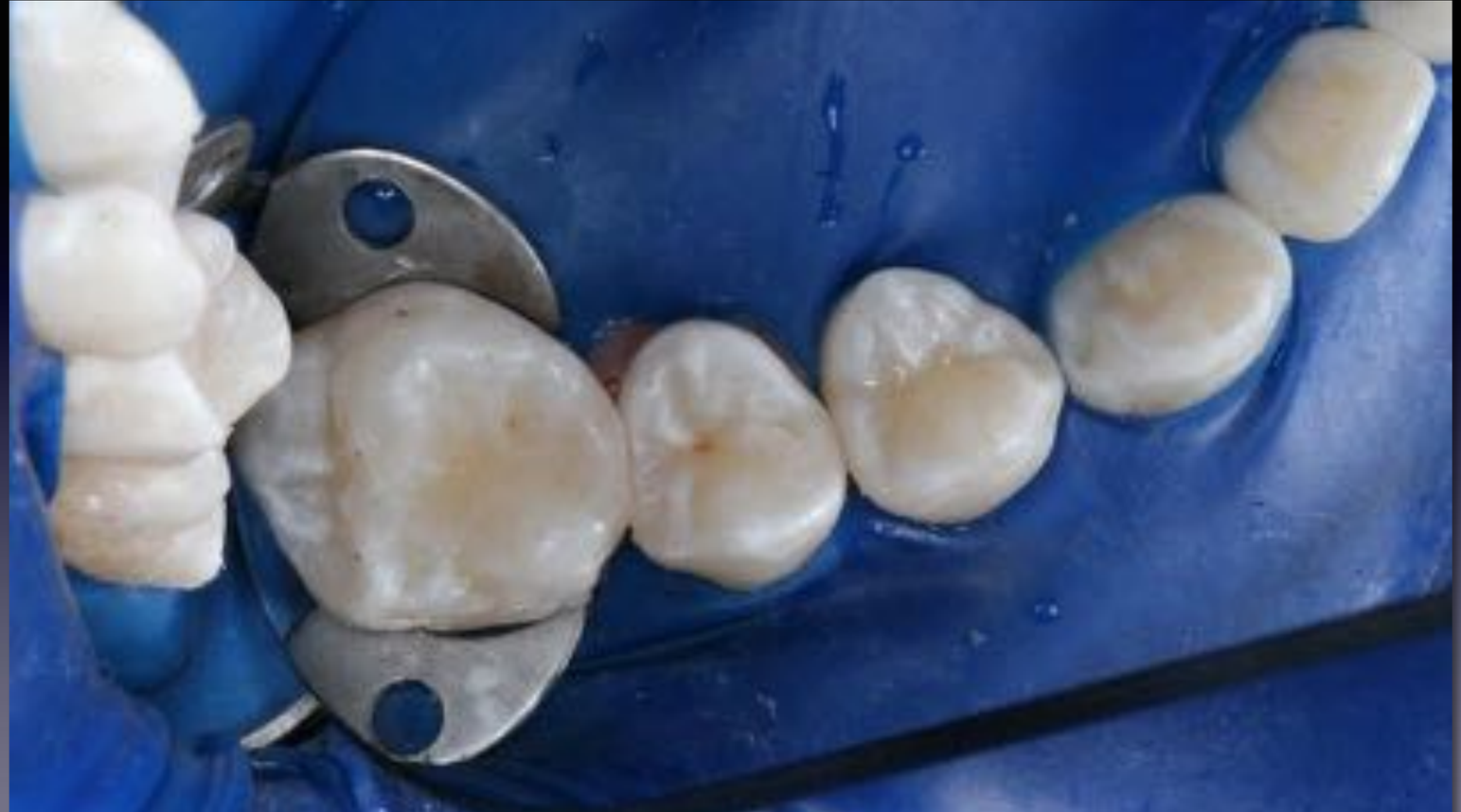




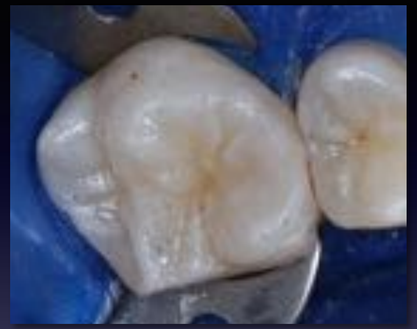


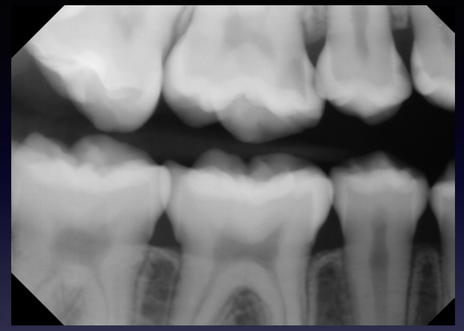
Resin-modified Glass Ionome (RMGI)

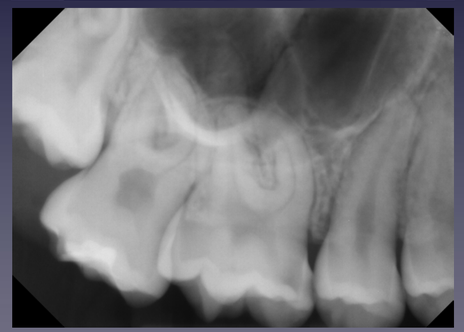
Conditioner (10% polyacrylic acid) removes smear layer without stripping tooth of calcium ions. This allows chemical bond between GI and calcium ions (not micromechanical as in composite resin)



Before







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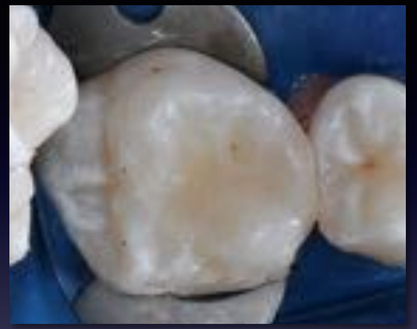
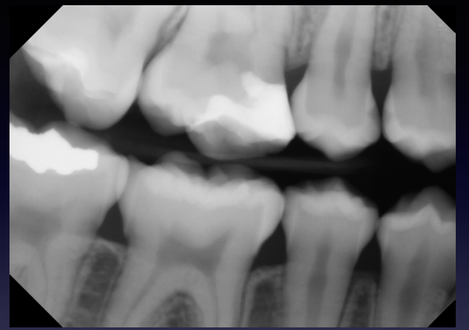
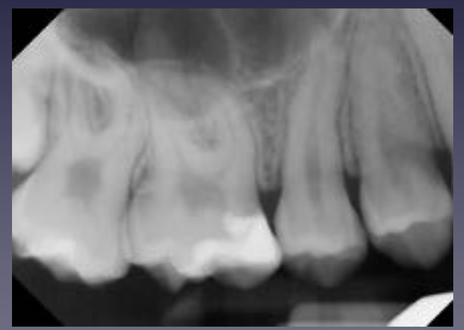
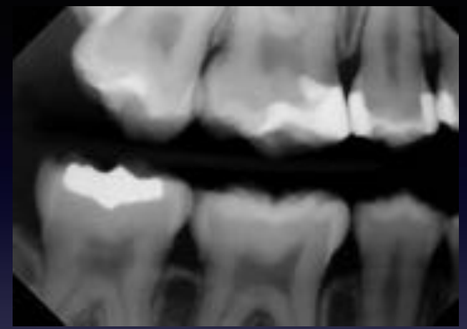
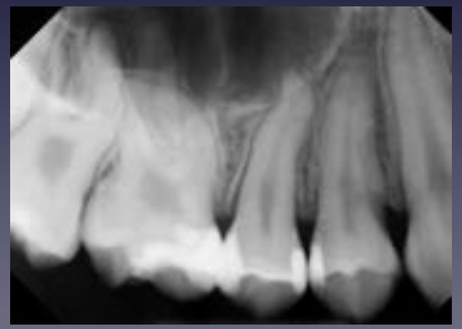




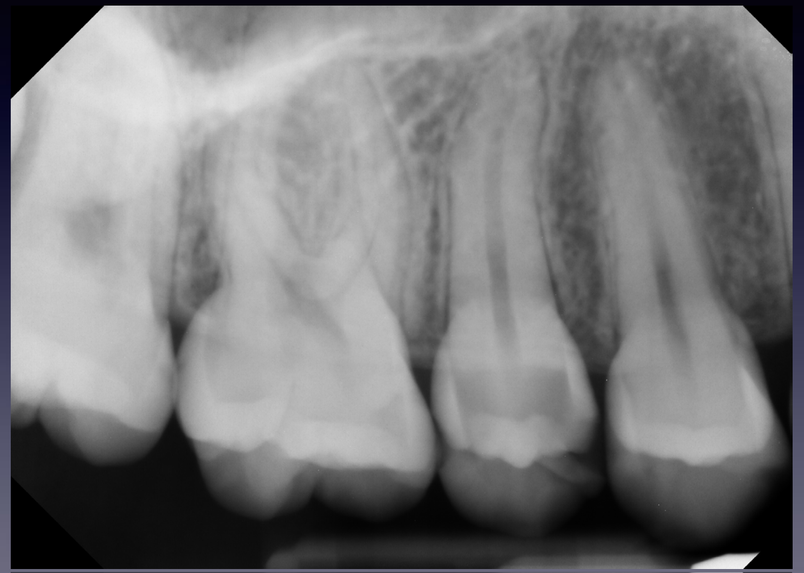


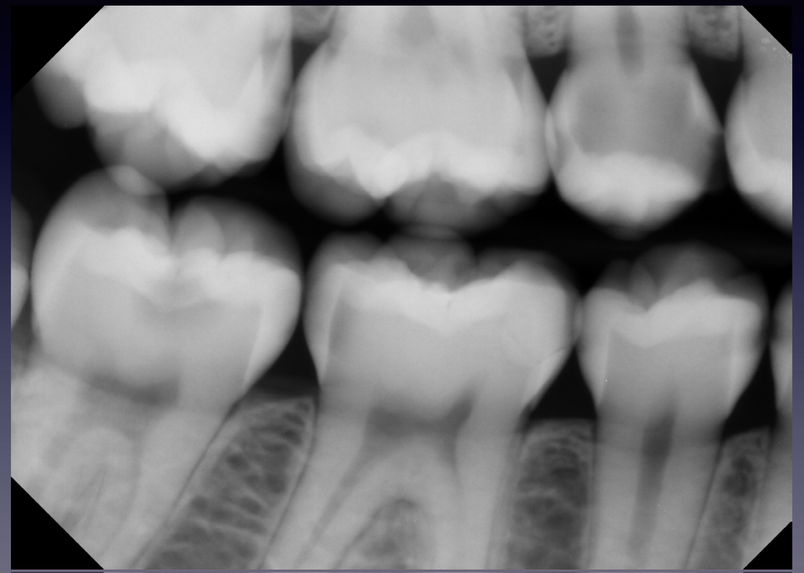
1 year after

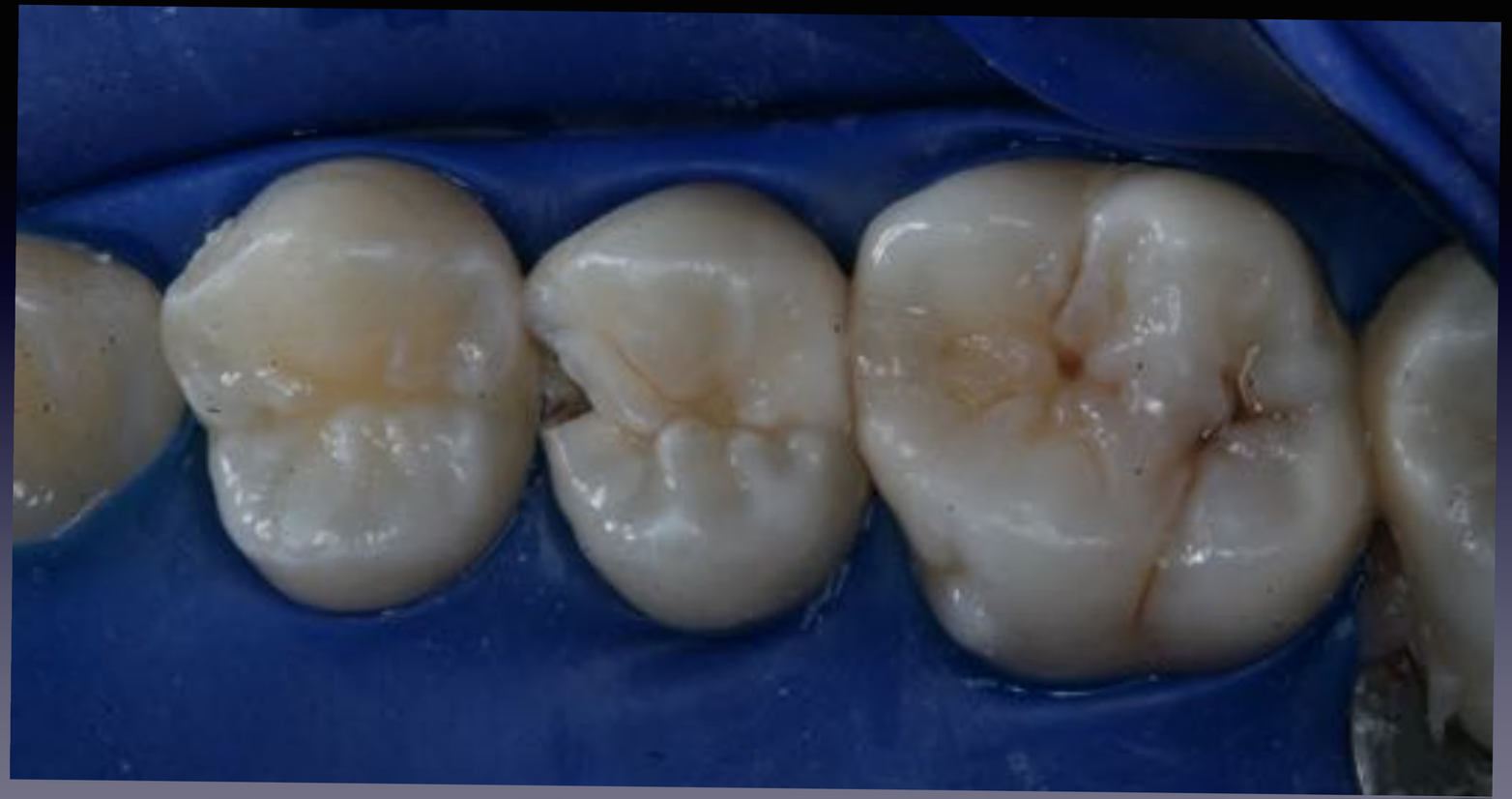


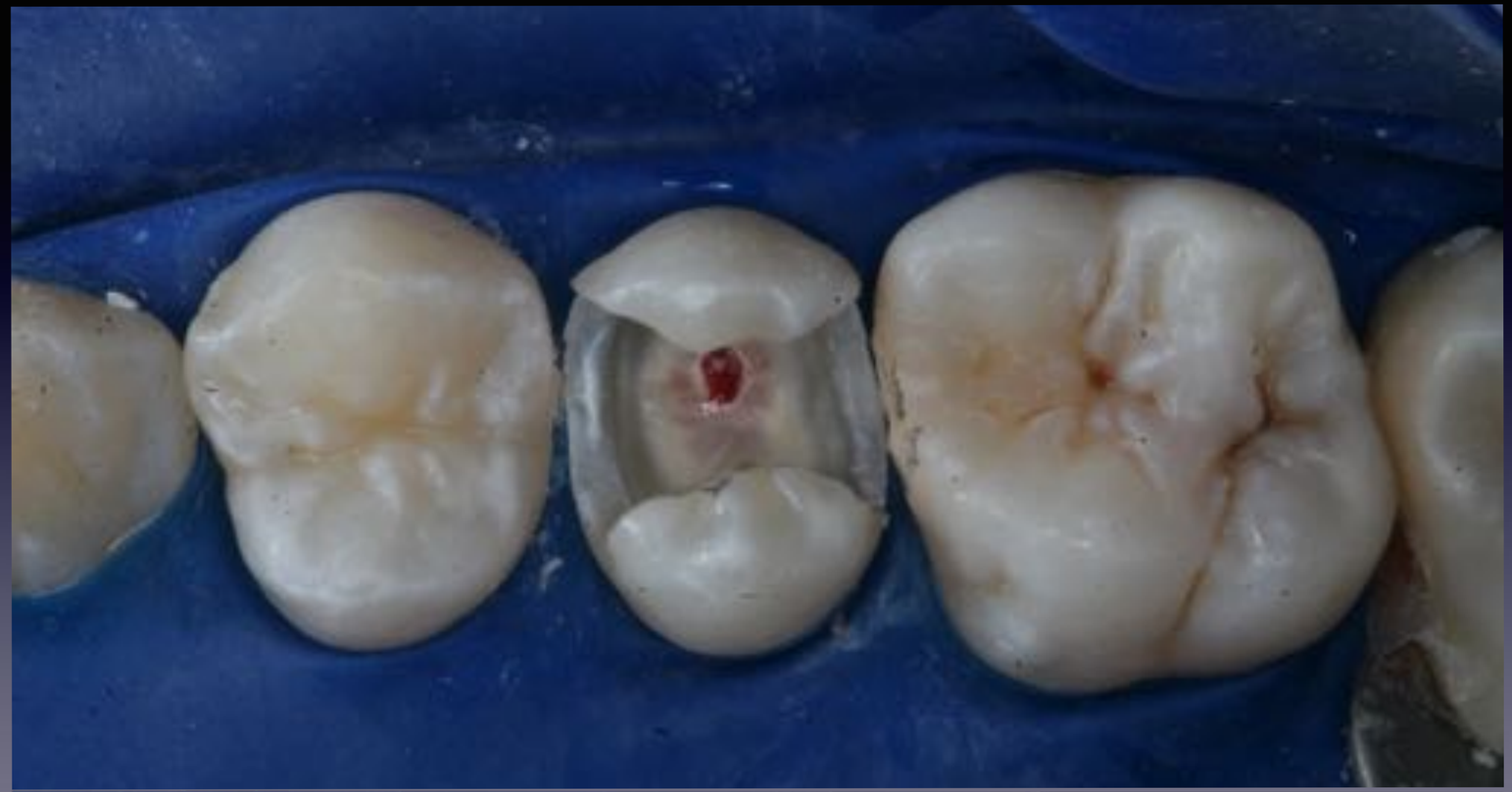


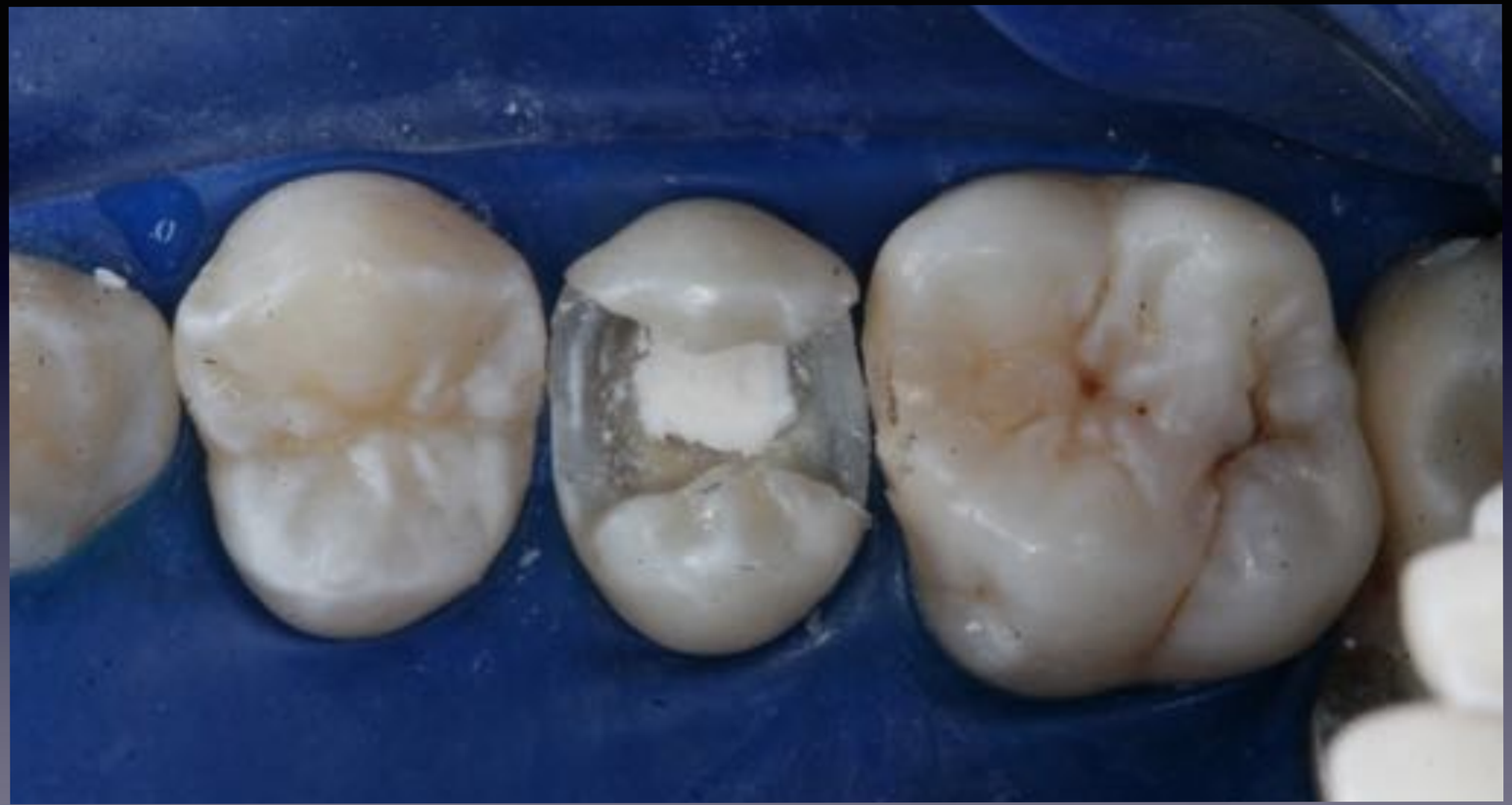
Case 2: #4 MOD

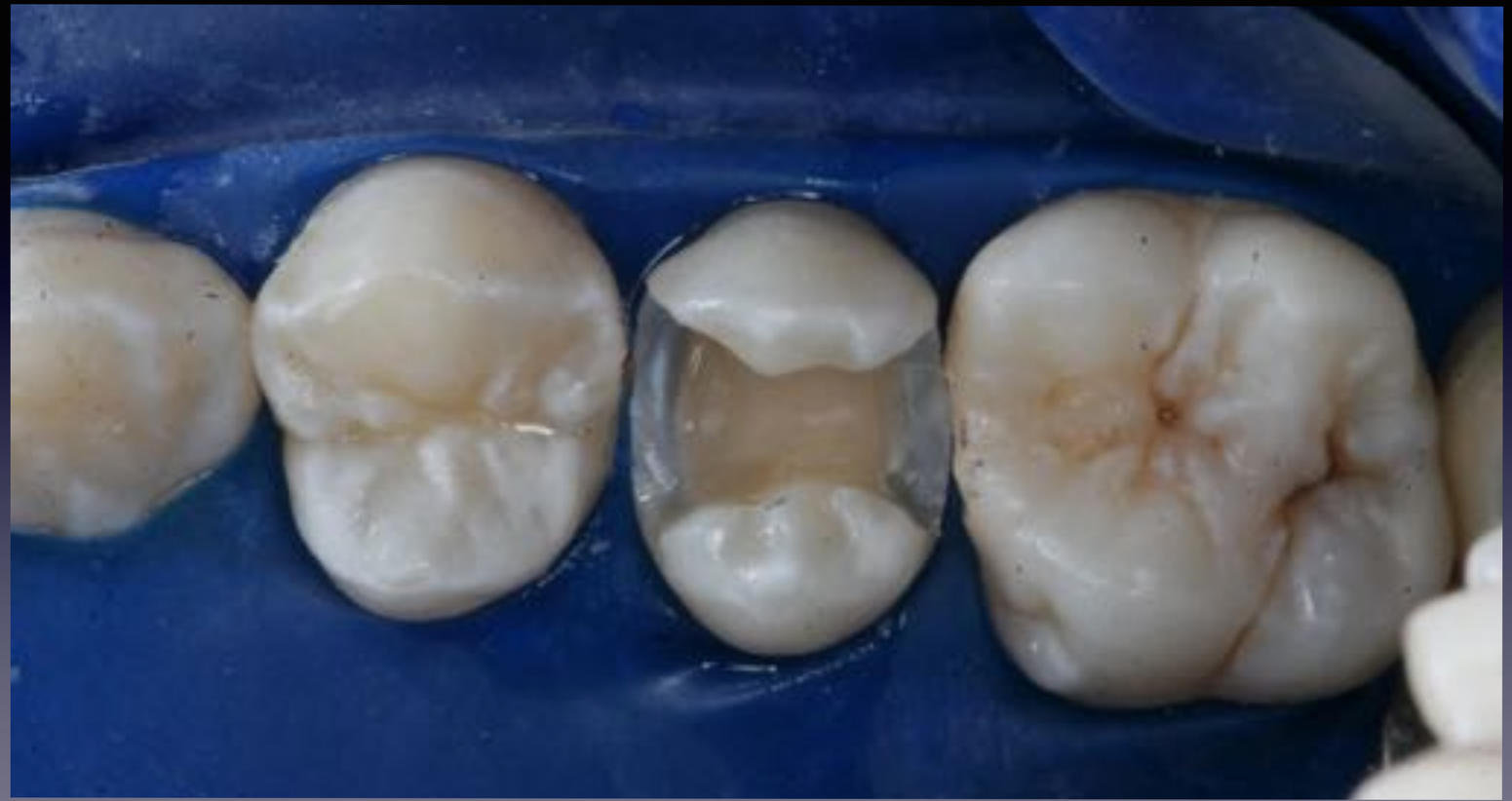


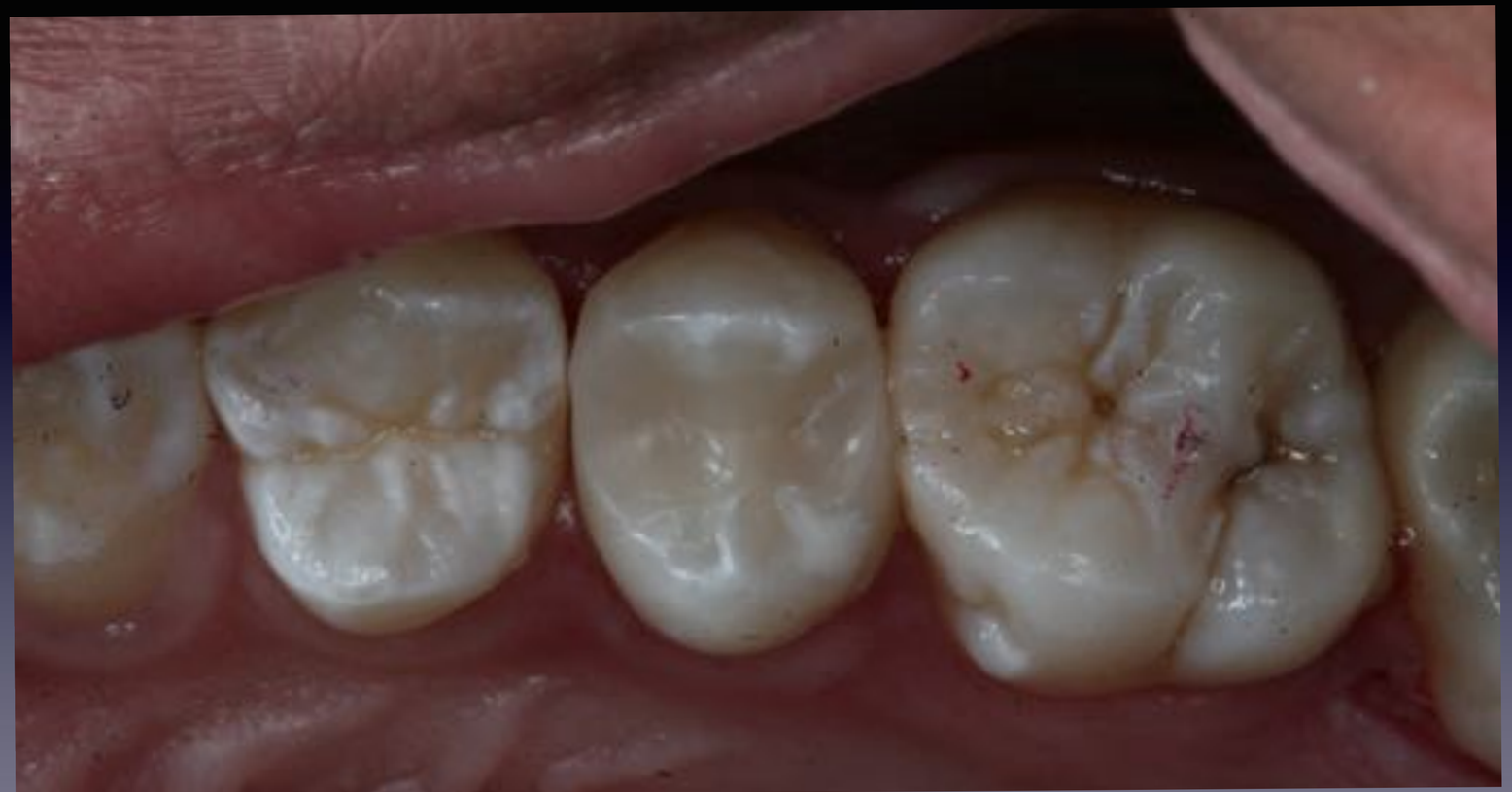












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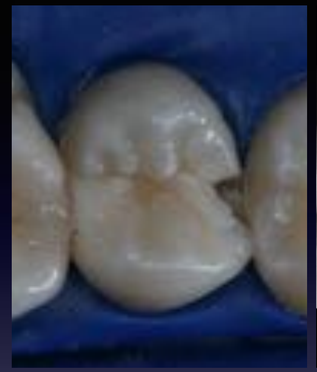

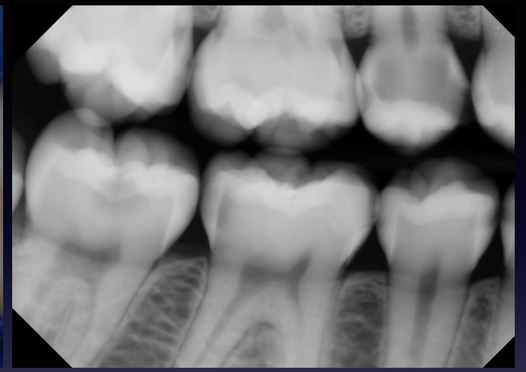

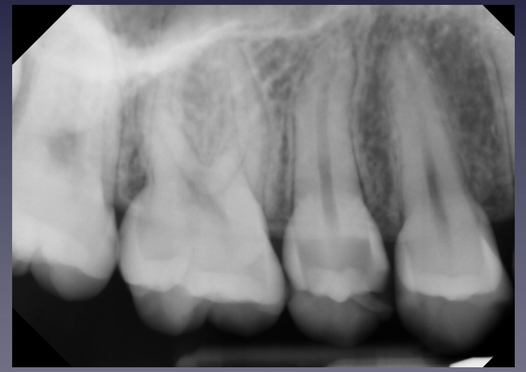

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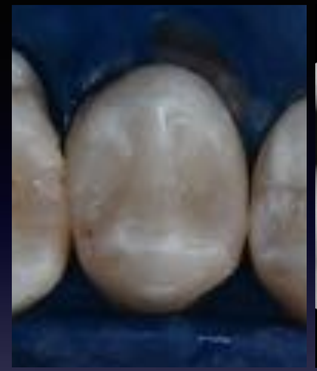
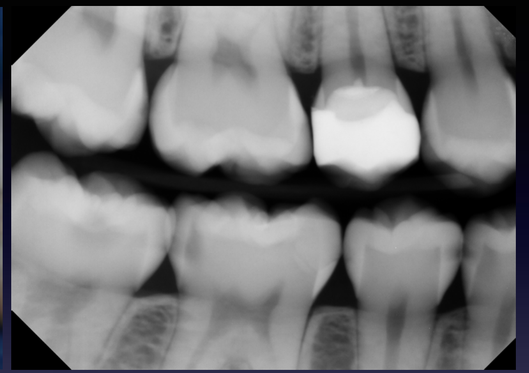
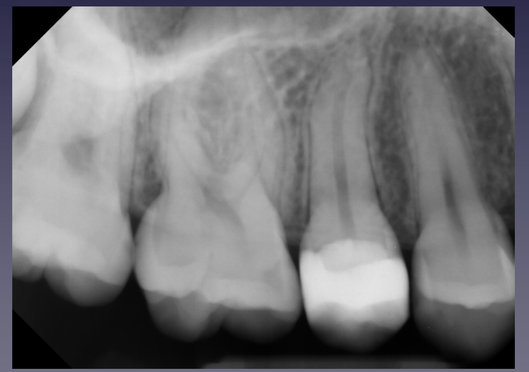
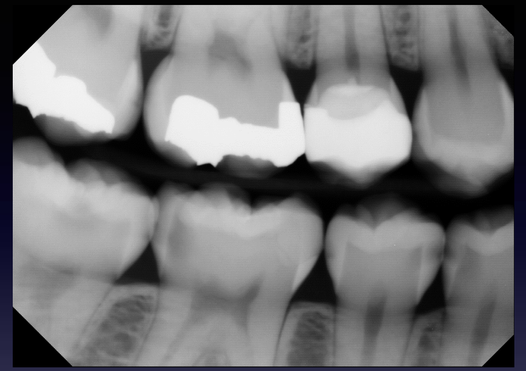
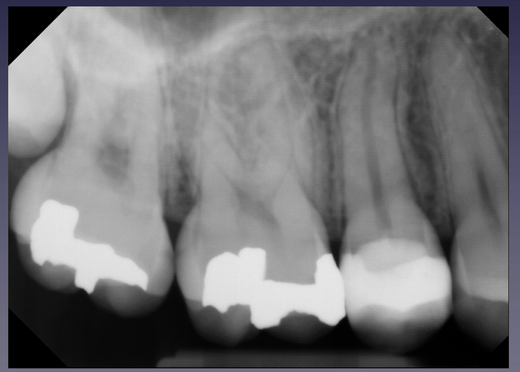


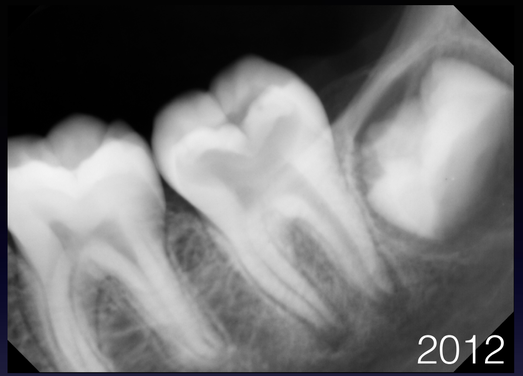


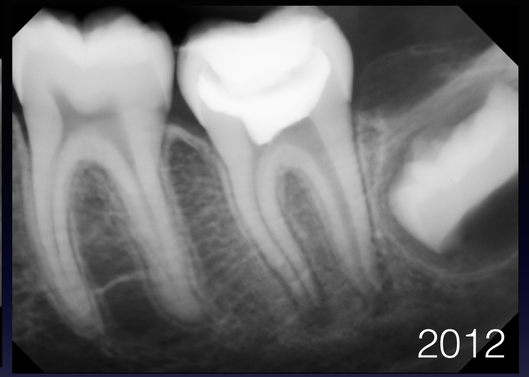


1 year after

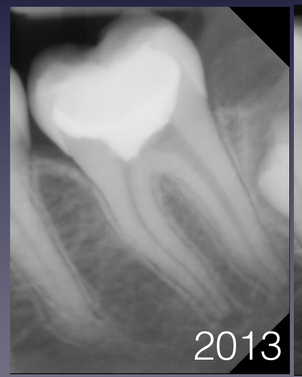


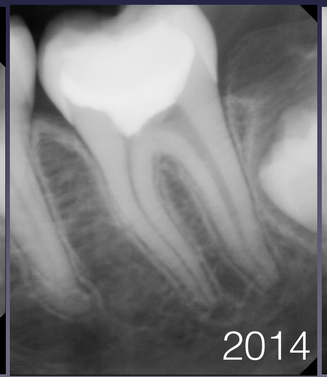


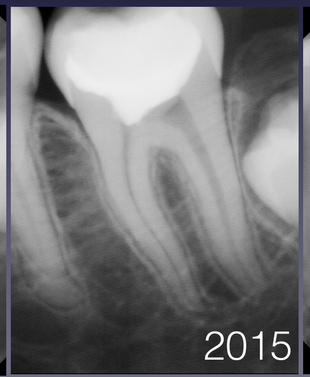


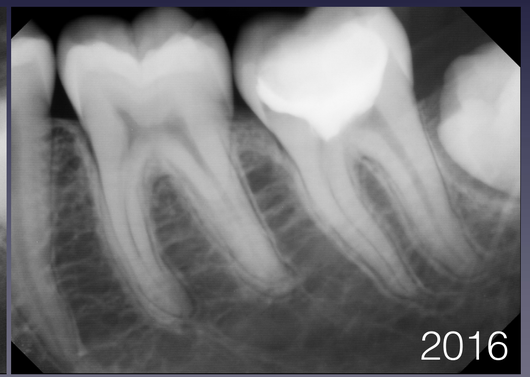


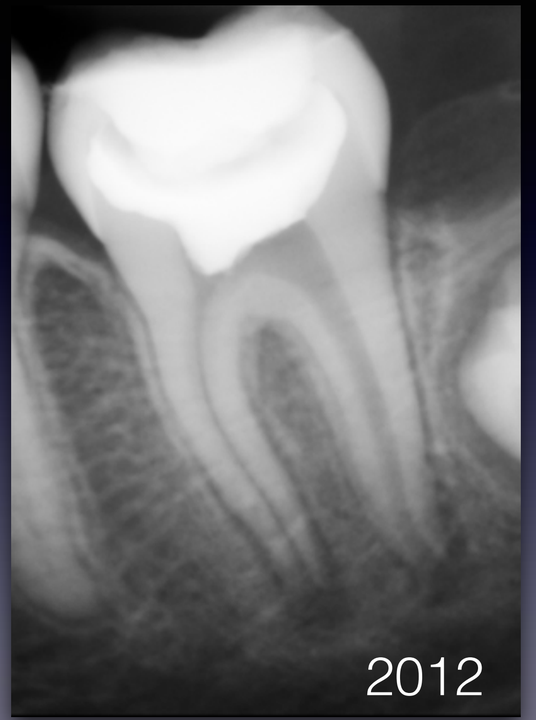
#19 pulpotomy

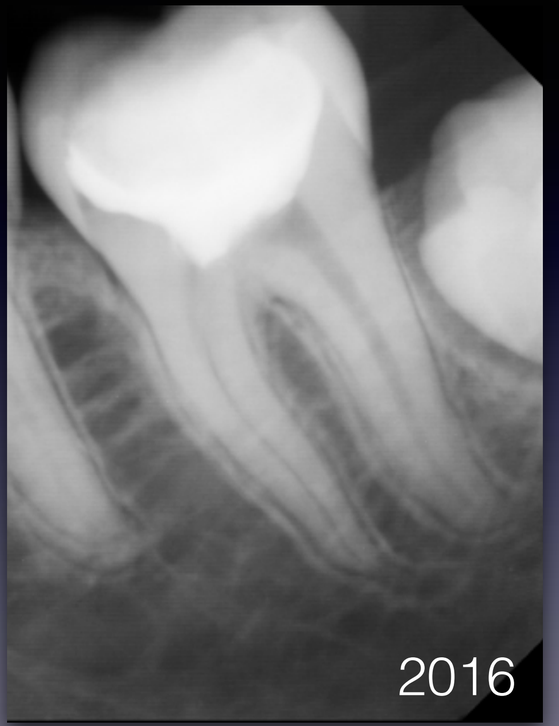




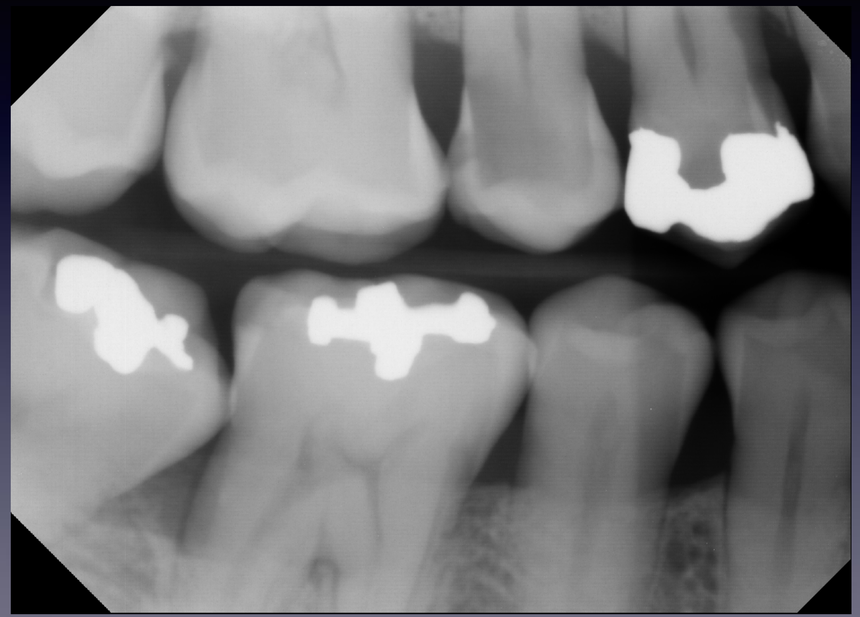


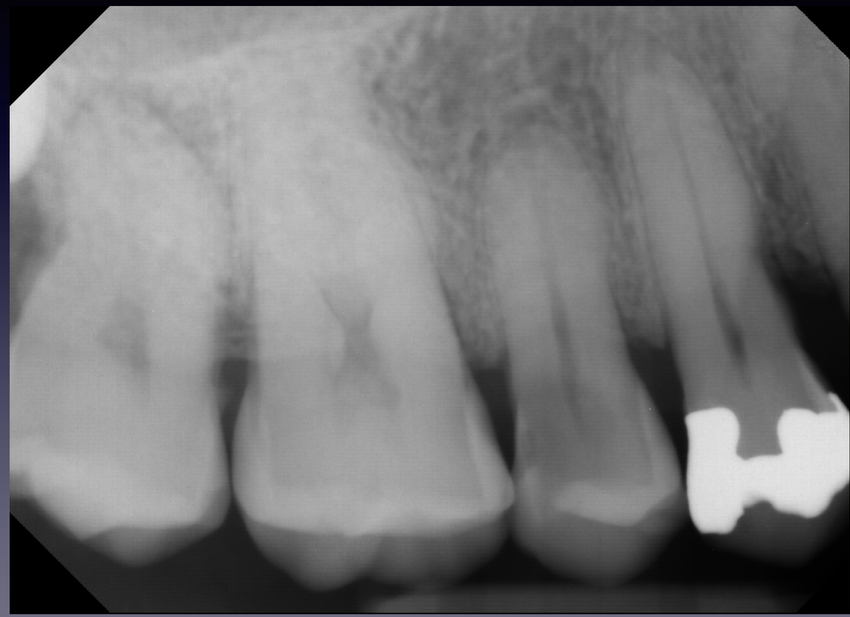


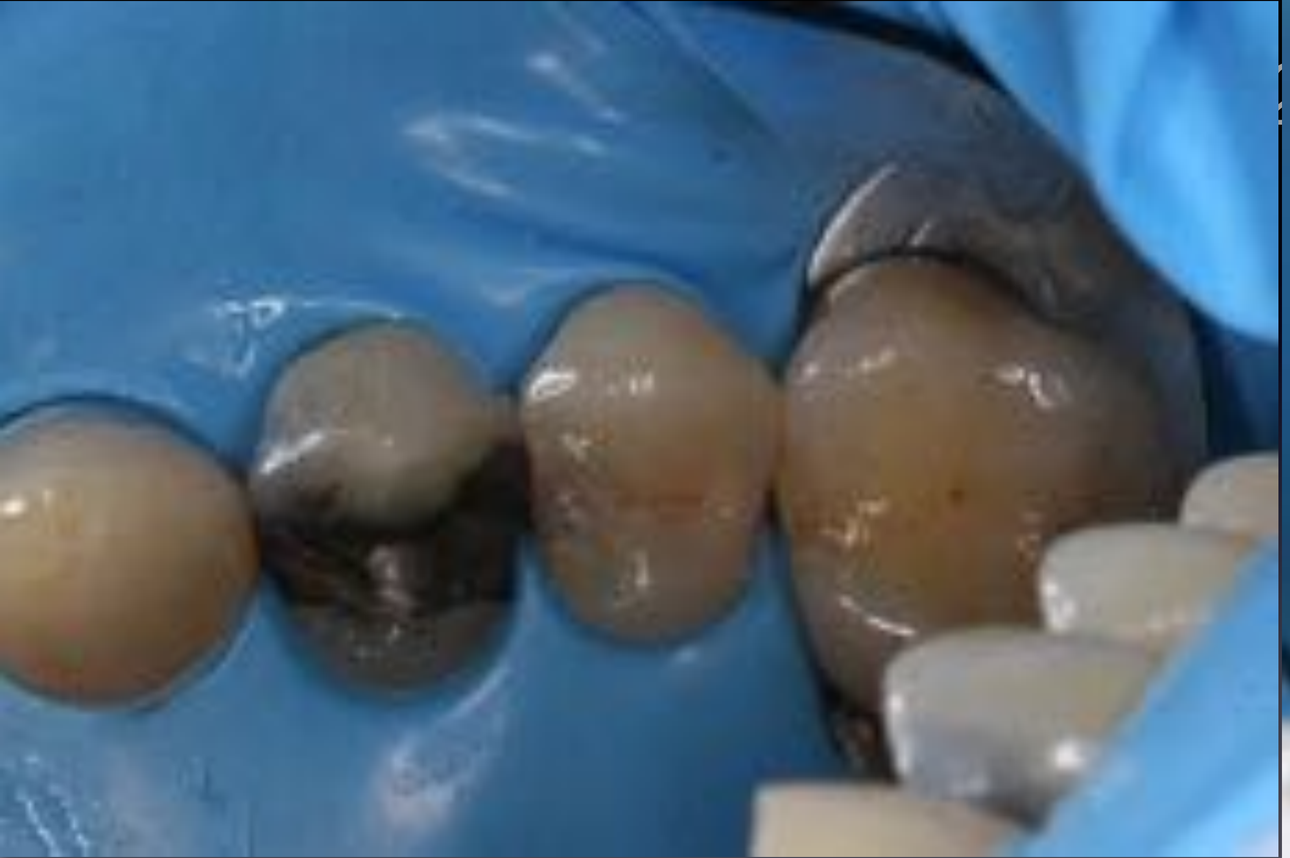


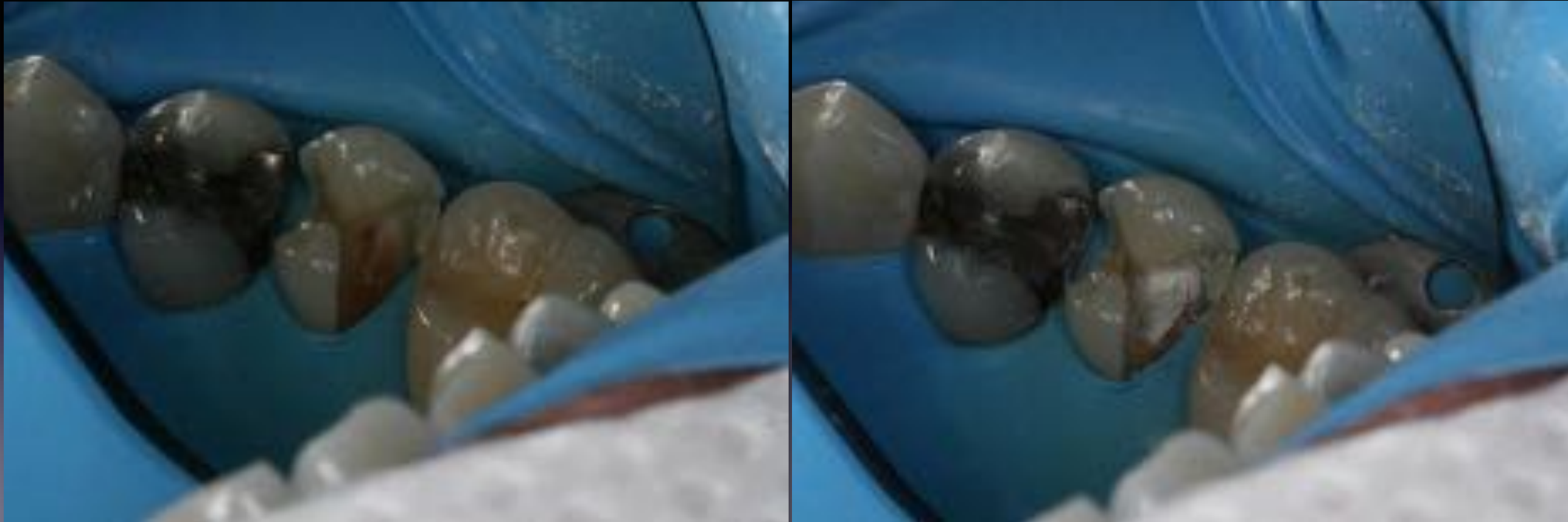


Case 3: #4 D decay



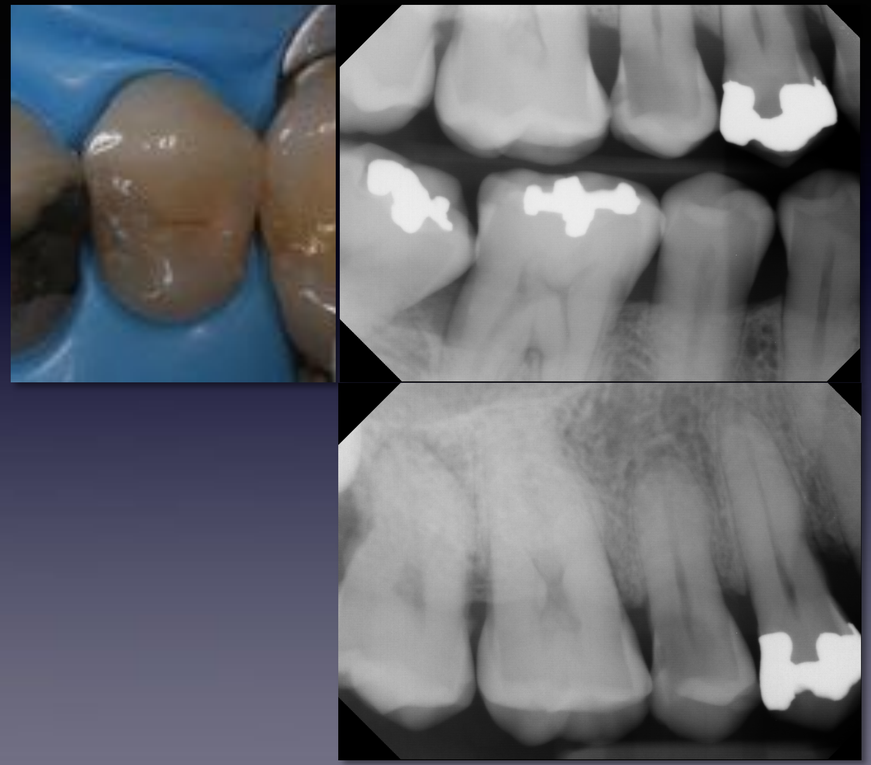


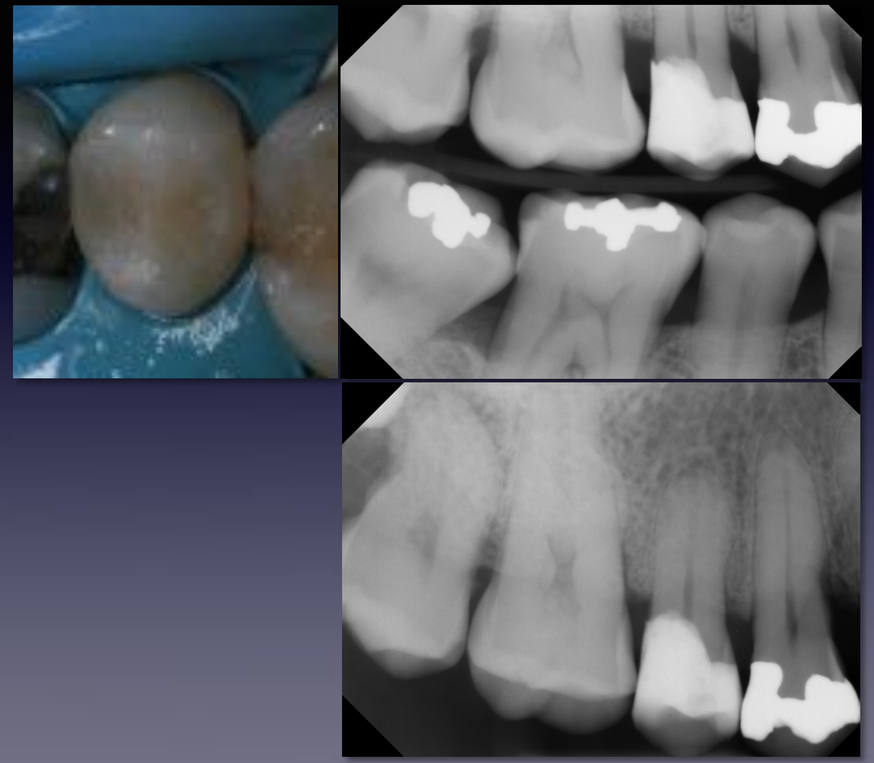


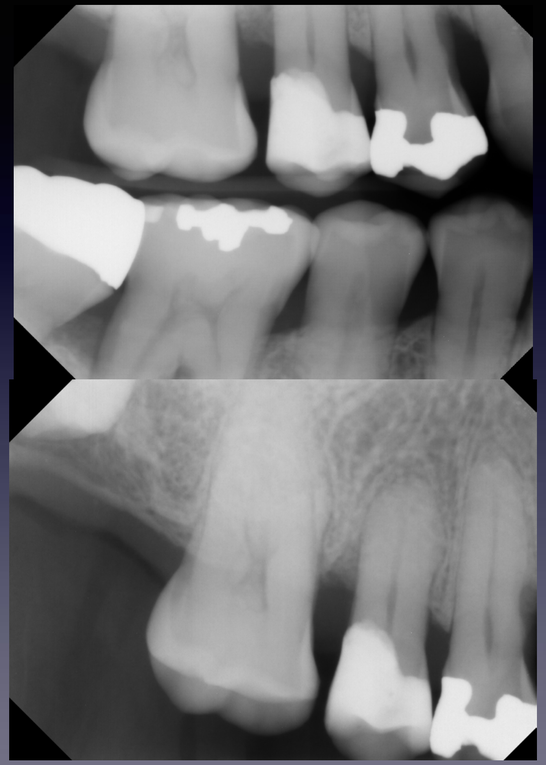


1 year later

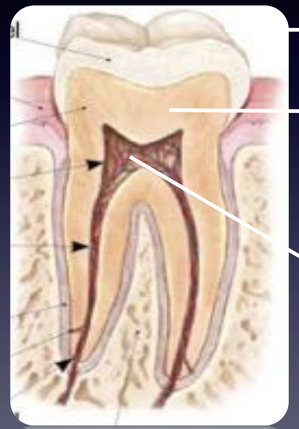
3 years later







A new paradigm of caries control and pulpal management in restorative dentistry



Enamel → Sealants, PRR

Dentin → Shallow – simple fillings

Deep – **indirect pulp-capping**

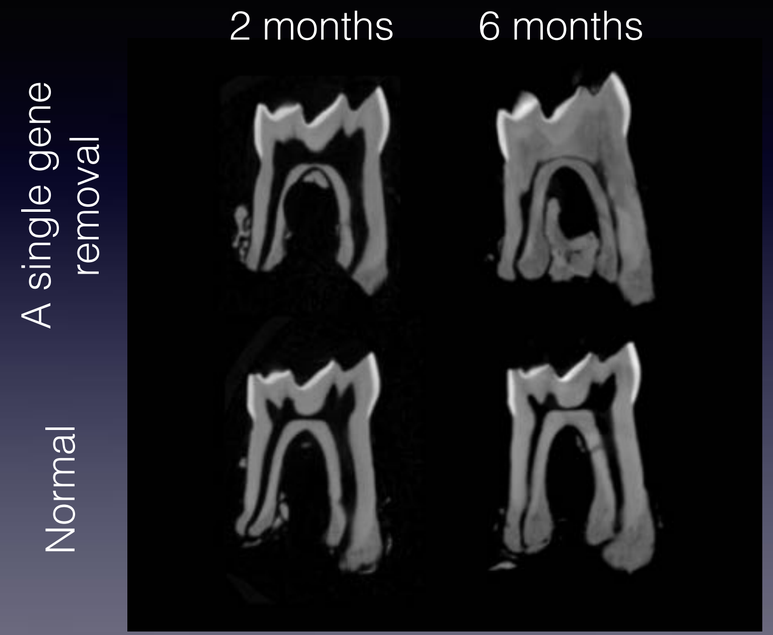
Pulp → Small exposure (< 1mm) – **direct pulp-capping**

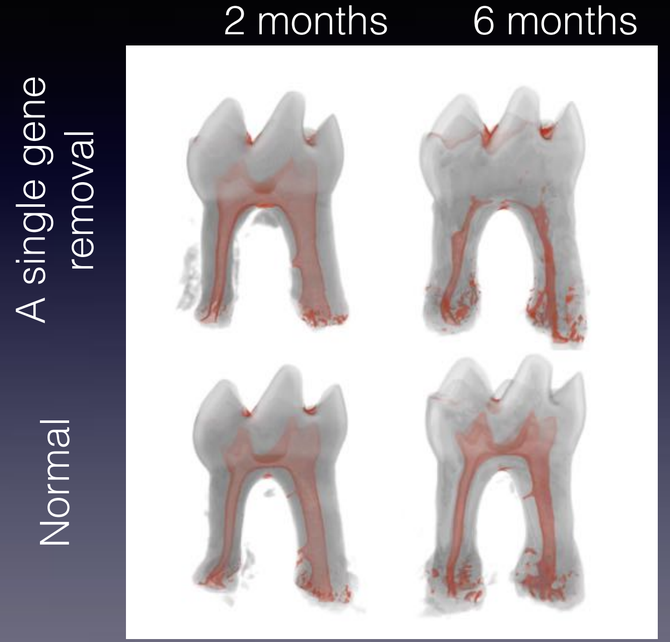
? Large exposure (iatrogenic) ~~prophylactic RCT~~ → *Partial pulp removal in the pulp chamber followed by HCSCs*

? Large exposure (infection) ~~RCT~~ → *Partial pulp removal to the orifices followed by HCSCs*

What's next?

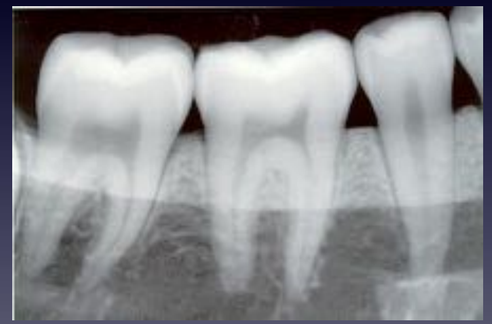
- By removing a single gene, one can significantly induce tertiary dentin formation in mice





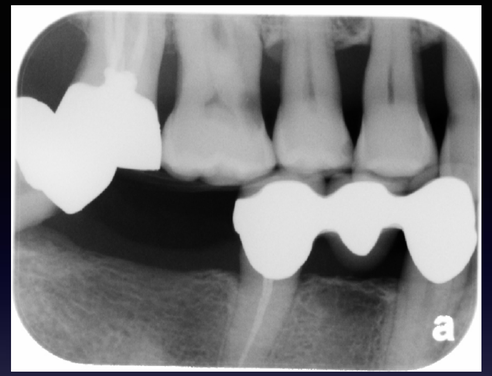
Hypersensitivity?

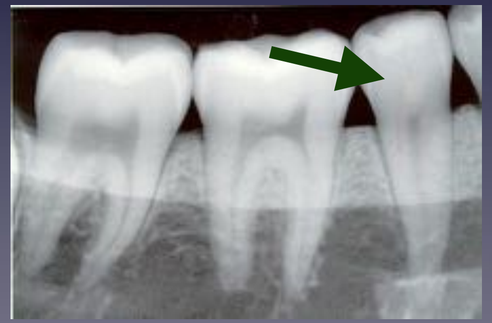
Younger patient



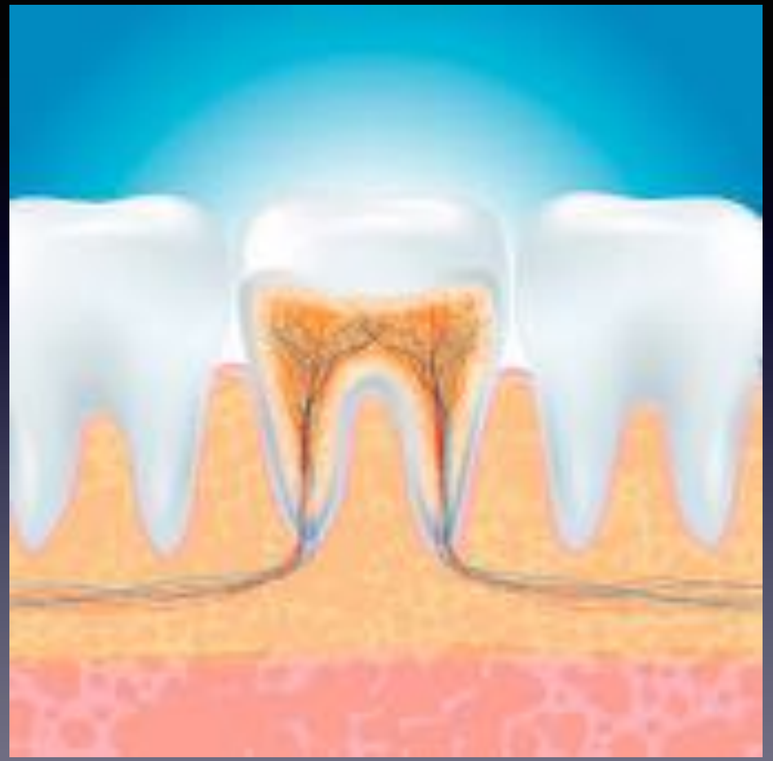
Natural aging

Induced pulp calcification





Reduced sensitivity



Keep the pulp tissues alive!

Thank you!!!

- rkim@dentistry.ucla.edu