

Tertiary Dentin Barrier Formation: A Comparison Between the Effects of Two Calcium Silicate Based Materials

ANTOANELA MAGDALENA COVACI^{1,2}, MIHAI ANDREI¹, IOANA DINCA³,
LUCIAN TOMA CIOCAN⁴, MADALINA NICOLETA MATEI²,
ANDREEA CRISTIANA DIDILESCU¹

¹Department of Embryology and Microbiology, Faculty of Dentistry, "Carol Davila"
University of Medicine and Pharmacy, 050474 Bucharest, Romania

²Department of Dental Medicine, Faculty of Medicine and Pharmacy,
Dunarea de Jos University of Galati, 800010 Galati, Romania

³National Institute of Laser Plasma and Radiation Physics,
P.O. Box MG-36, 76900 Bucharest-Magurele, Romania

⁴Department of Prosthetics Technology and Dental Materials, Faculty of Dentistry, "Carol Davila"
University of Medicine and Pharmacy, 010221 Bucharest, Romania

ABSTRACT: Pulp capping is a vital pulp therapy that aims to prolong the life of a tooth by protecting it after pulp exposure occurred. Pulp capping biomaterials are intended to induce odontoblasts to deposit a natural tertiary dentin barrier to protect the pulp-dentin complex. Two pulp capping agents with calcium silicates in their composition, but with different mechanisms of the setting reaction were tested *in vivo* with the main objective of comparing their effect on the pulp-dentin complex. The specific aim was to evaluate the preservation of pulp vitality following *in vivo* direct and indirect pulp capping on eight human third molars. TheraCal LC, a light-cured calcium silicate-based material, was tested both by direct and indirect pulp capping, while the mineral trioxide aggregate (MTA) cement was tested by direct pulp capping. The molars were assessed by micro-computed tomography (micro-CT) and by light microscopy and stereo-microscopy following histological processing of the teeth. Dental pulp vitality testing was performed before tooth extraction. Inflammatory pulp status was performed on light microscopy images and it was investigated the presence of inflammatory infiltrate, edema, vascular congestion and pulp necrosis. Following pulp capping, the MTA cement showed more favorable results, generating the formation of complete or incomplete dentin bridges in all treated teeth, while TheraCal LC induced the formation of dentin bridges in only two teeth. Tooth vitality was preserved in all tested teeth. In conclusion, both materials stimulated neodentinogenesis, with the MTA cement being more effective and presenting a much more favorable biological pulpal response.

KEYWORDS: Pulp capping, MTA, dentin bridge, micro-CT, neodentinogenesis.

Introduction

Vital pulp therapies such as pulp capping are designed to preserve the pulp vitality of teeth affected by deep caries, tooth wear and trauma, aiming to prolong the survival of the tooth. This procedure involves the placement of protective biomaterials, pulp capping agents, which can be applied in direct contact with the dental pulp (direct pulp capping) or indirectly, when a layer of dentin remains interposed between the material and the dental pulp (indirect pulp capping) [1,2].

Since Pfaff's first described attempt at pulp capping in 1756 by applying a gold foil to an exposed dental pulp [3] and up to date, pulp-capping biomaterials have been constantly improved and modified to provide the most biologically effective pulp response. For more than half a century, calcium hydroxide has been the gold standard in the class of pulp capping biomaterials [4].

However, this material had several drawbacks and in the early 1990s mineral trioxide aggregate (MTA), a new material developed for the endodontic system, was commercially introduced [5,6].

New Ca-silicate-based materials such as MTA or its derivatives, are currently being used to preserve pulpal vitality. Modifications of these materials have improved their chemophysical, mechanical and biological properties to ensure optimal clinical efficacy, resulting hybrid materials such as TheraCal LC, a light-curable MTA-like material with a dual mechanism of the setting reaction-photopolymerization and hydration reaction [7,8].

This study was conducted *in vivo* and *ex vivo* with the main objective of comparing two different pulp-capping materials, in terms of their effect on the pulp-dentin complex. The specific aim was to evaluate the preservation of pulp vitality after pulp capping.

Material and Methods

The *in vivo* study was carried out at the dental office of Dr. Antoanela Covaci, where the pulp capping therapies were performed between January 2023 and May 2024.

The *ex vivo* research was carried out in the Embryology Laboratory, Faculty of Dentistry, "Carol Davila" University of Medicine and Pharmacy, for dental ground sections processing and for stereomicroscopy and light microscopy analysis.

Demineralized teeth were processed at the Department of Anatomical Pathology, Faculty of Dentistry, "Carol Davila" University of Medicine and Pharmacy and at Histovet Laboratory.

Micro-CT assessment was carried out within the National Institute of Laser Plasma and Radiation Physics for micro-CT assessment.

The study was carried out with the informed consent of the patients and the approval of the University Ethics Commission, University "Dunărea de Jos" of Galati (no. 4842/20/02/2020)

The biomaterials used in the pulp capping procedures on human patients were: TheraCal LC (Bisco, USA) a hybrid pulp-capping agent and BioMTA+(Cerkamed, Poland), a MTA cement. The pulp capping agents were prepared according to the manufacturers' instructions.

Following pulp capping, the teeth cavities were filled with a glass ionomer cement, Fuji IX (GC, Japan) or glass ionomer cement and a light-curing resin Reveal HD Bulk (BISCO Inc., USA).

In vivo testing of pulp capping with the aim of inducing neodentinogenesis was performed on eight human patients. The treated teeth were third molars, affected by deep carious lesions with extraction recommended.

Following pulp capping, patients were monitored and clinically evaluated for a period of approximately 28 days.

A total of eight third molars (referred to as D1-D8) were used in the *in vivo* neodentinogenesis research. These teeth were divided and noted as it follows (Table 1):

- Teeth D1-D4 were pulp capped with TheraCal LC. Teeth D1-D3 were processed by demineralization and investigated by light microscopy, except for tooth D4 which was analyzed by micro-CT and ground sections were obtained which were further analyzed by stereo-microscopy. Pulp capping was performed as it follows: D1 and D4 were directly pulp

capped, while D2 and D4 were indirectly pulp capped.

- Teeth D5-D8 were directly pulp capped with BioMTA+. These teeth were investigated by micro-CT analysis. Subsequently, they were processed histologically and evaluated by light microscopy, except tooth D8 which was processed by ground sections and assessed by light microscopy and stereo-microscopy.

Table 1. Teeth involved in the study and the type of pulp capping therapy.

Nr.	Tooth	Pulp capping biomaterial	Pulp capping	FDI tooth notation
1	D1	TheraCal LC	Direct	2.8
2	D2	TheraCal LC	Indirect	4.8
3	D3	TheraCal LC	Indirect	3.8
4	D4	TheraCal LC	Direct	3.8
5	D5	BioMTA+	Direct	3.8
6	D6	BioMTA+	Direct	4.8
7	D7	BioMTA+	Direct	4.8
8	D8	BioMTA+	Direct	2.8

Dental pulp vitality was assessed by thermal testing with Frisco spray (Arztbedarf GmbH-Germany) before teeth extraction (D1-D8).

Scores of "1", which signifies the preservation of the pulp vitality, and "0", which signifies its loss, were assigned.

The inflammatory pulp response was determined by light microscopy evaluation of teeth that were histologically processed by demineralization (D1-D3 and D5-D7). The slides were stained with Hematoxylin Eosin (H&E) and Giemsa.

The pulp tissue of these teeth, in the proximity of the pulp capping agent, was investigated for the presence of: inflammatory cell infiltrate, vascular edema, vascular congestion and necrosis.

The following scores were assigned for the presence or absence of pulpal inflammation: '-' signifying absence, '+' signifying minimal presence, '++' signifying moderate presence and '+++ signifying abundant presence.

Ex vivo assessment of teeth by micro-CT: samples were CT scanned with a custom-built micro-tomograph with a transmission X-ray microfocus from YXLON International GmbH (maximum voltage 225 kV) and a Perkin Elmer flat-panel detector with 4K x 4K square pixels of 200µm size and 16-bit digital output.

Results

Following dental pulp vitality testing, all teeth (D1-D8) maintained their pulp vitality, receiving scores of 1.

In teeth pulp capped with TheraCal LC (D1-D3) (Figure 1), minimal inflammatory cell infiltrate was observed in D1 and no inflammatory cell infiltrate in D2.

In contrast, D3 showed abundant inflammatory cell infiltrate. The inflammatory infiltrate was absent in teeth D5-D7 (Figure 1).

In terms of the presence of edema and vascular congestion, these were abundantly present in the pulp tissue of all teeth. The dental pulp of tooth D1 showed rare fibroblasts, the presence of an inflammatory edema and congestive capillary vessels (Figure 1, D1).

Tooth D2 showed a pulp tissue with rare fibroblasts, with the presence of inflammatory edema and congestive capillary vessels (Figure1, D2).

Tooth D3 presented a pulp with dilated blood vessels and an inflammatory edema (Figure 1, D3).

Tooth D5 exhibited a hypocellular dental pulp with dilated blood vessels, vascular congestion and inflammatory edema (Figure 1, D5).

A discrete presence of lymphocytes and vascular congestion was observed in the pulp of tooth D6 (Figure 1, D6).

Tooth D7 showed a dense eosinophilic hyalinized pulp tissue (Figure 1, D7).

No tooth showed pulp necrosis (Table 2).

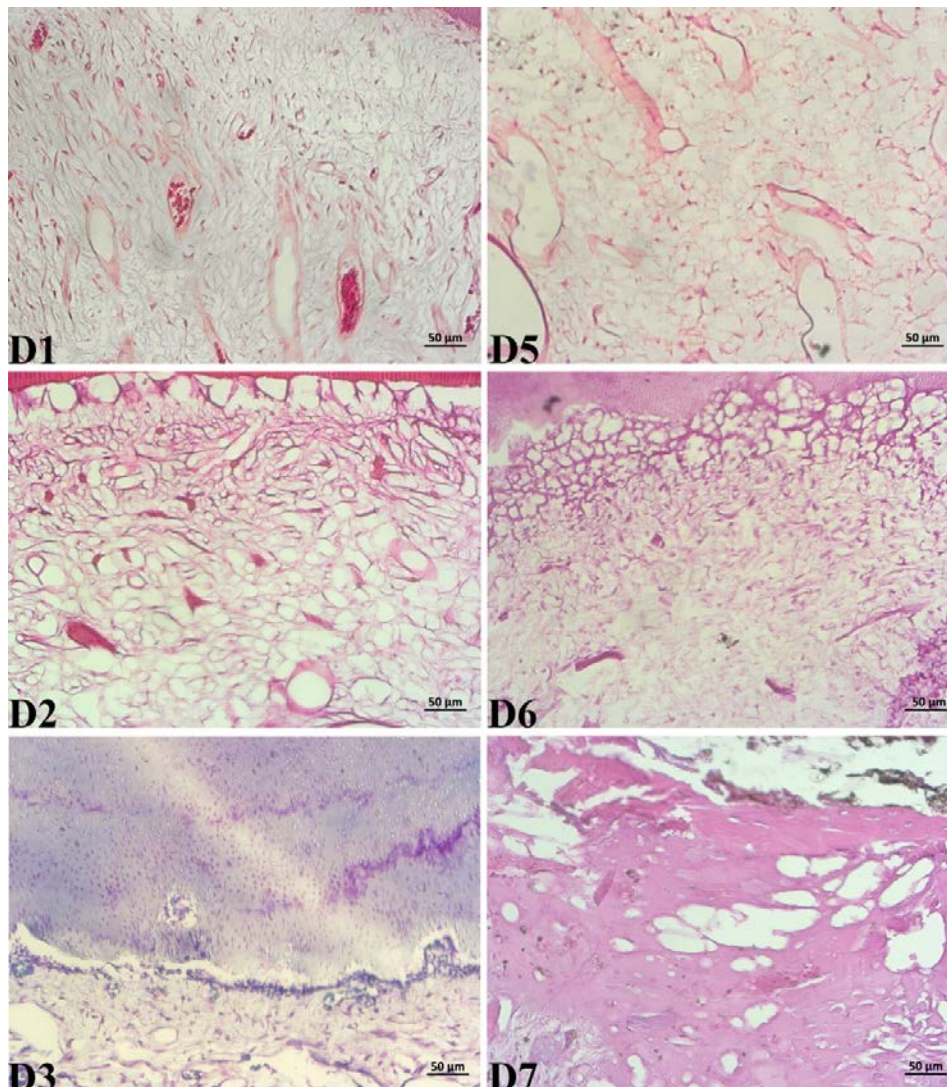


Figure 1. The histology images on which the inflammatory pulp response has been assessed for teeth D1-D3 (pulp capped with TheraCal LC) and D5-D7 (pulp capped with BioMTA+). D3-Giemsa staining, all the other figures-Hematoxylin Eosin staining.

Table 2. Inflammatory pulp response for teeth D1-D3 and D5-D7.

Tooth	Inflammatory cell infiltrate	Vascular edema	Vascular congestion	Necrosis
D1	+	+++	+++	-
D2	-	+++	+++	-
D3	+++	+++	+++	-
D5	-	+++	+++	-
D6	-	+++	+++	-
D7	-	+++	+++	-

Investigation of neodentinogenesis

Teeth pulp capped with Theracal LC

The exposure site of D1’s pulp chamber can be seen over a distance of 0.4mm [Figure 2, D1(1)].

The pulp capping material is detached from the exposure site and penetrated over a relatively small area of the pulp.

The dental pulp showed discrete macrophages and lymphocytes and the presence of a pale-eosinophilic material, which represent islands of tertiary dentin (marked by an arrow) deposited as a result of direct pulp capping.

The presence of tertiary dentin is detectable in Figure 2, D1(2) as islands, including a tubular appearance, in the form of an incomplete dentin bridge.

At the top of the image of D2 from Figure 2, D2(1) is the cavity in which the pulp capping material was placed.

At the bottom of the image is the pulp chamber.

The dental pulp has been torn away from the pulp chamber during the histologic processing steps of the tooth and is no longer present in the image.

A dentin layer, characterized by the presence of dentinal tubules with a uniform pattern of organization can be seen between the two cavities.

Tertiary dentine is not present at this level, not having been deposited following indirect pulp capping.

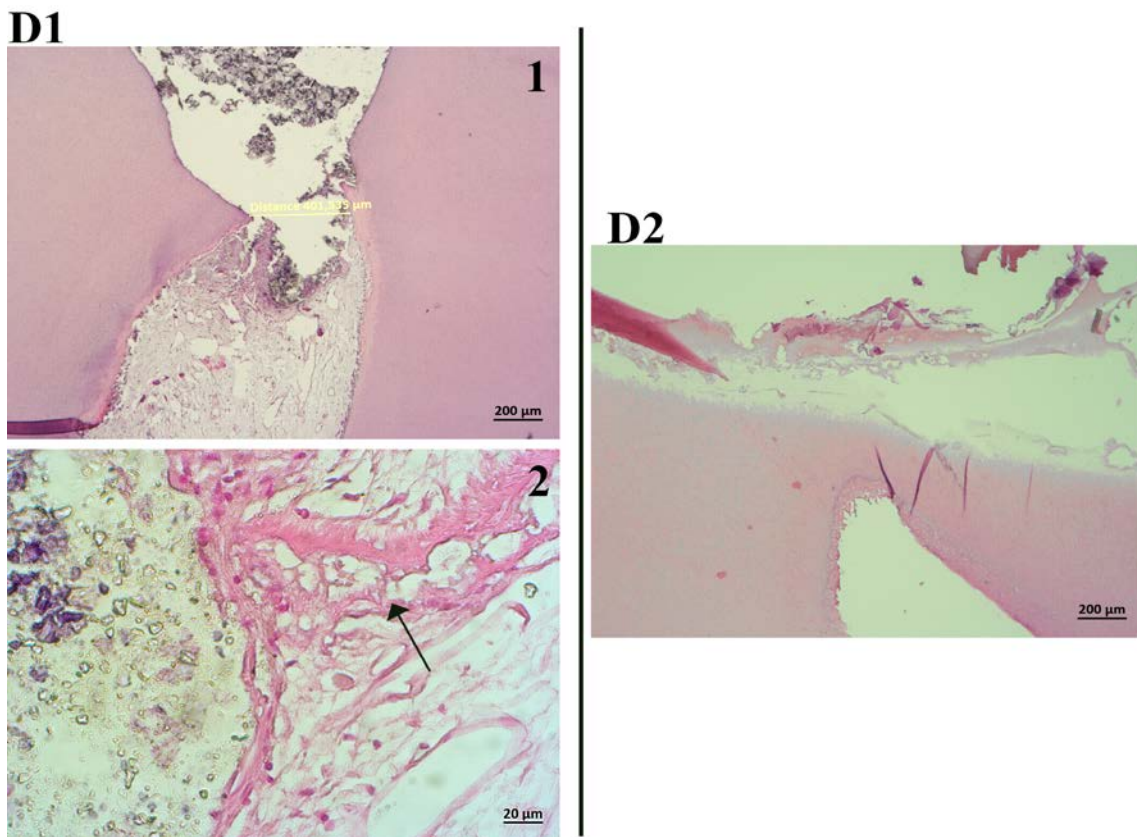


Figure 2. Histological images of teeth D1 and D2. D1(1) represents the area of pulp exposure and the penetration of the pulp-capping agent over a relatively small area of the pulp. D1(2) represents the incomplete dentin bridge in the form of tertiary dentin islands (arrow). D2(1) represents the lack of dentin bridge formation following indirect pulp capping in tooth D2. The upper cavity is the cavity in which the pulp capping material has been placed and the lower cavity is the pulp chamber. Hematoxylin-Eosin staining.

Tooth D3 was indirectly pulp capped.

The upper part of Figure 3, D3(1) shows the cavity in which the pulp capping material was placed and the lower part shows the pulp chamber.

Between the two cavities there is a layer of dentin and tertiary dentin respectively (indicated in image by an arrow), deposited as a complete, compact and uniform dentin bridge.

The dentin is characterized by the presence of dentinal tubules and has variable thicknesses (259.81µm-321.24µm) [Figure 3, D3(2)].

From the micro-CT section of tooth D4 from Figure 3, D4(1), it can be seen the glass ionomer cement filling and the pulp capping agent, TheraCal LC.

The figure shows the area of pulp exposure and the contact between the material and the dental pulp, without the presence of tertiary dentin.

The same aspect can be seen from the ground section [Figure3, D4(2)] where on the TheraCal LC surface adjacent to the pulp exposure site there is no deposition of tertiary dentin.

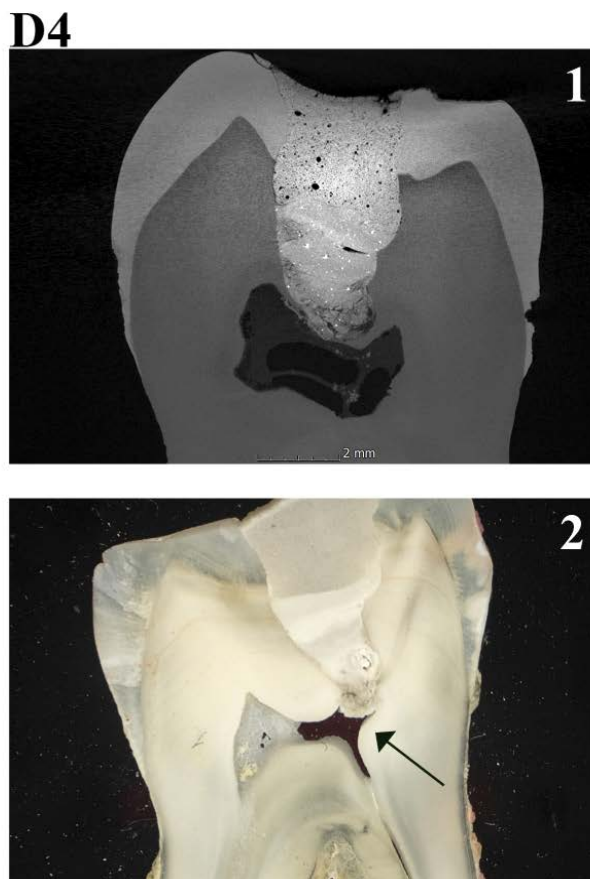
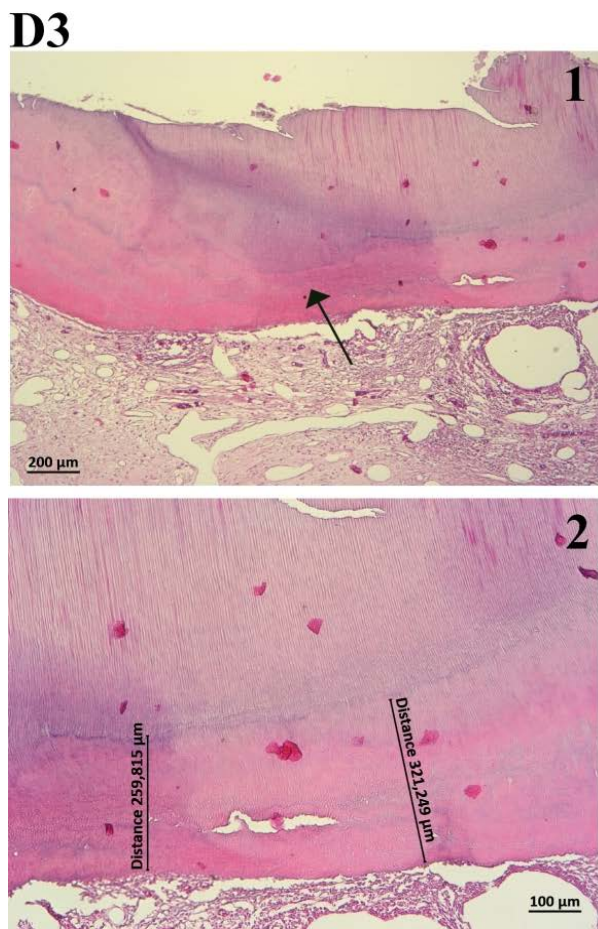


Figure 3. Histological and micro-CT images of teeth D3 and D4. Image D3(1) represents the dentin bridge formation after indirect pulp capping with TheraCal LC; tertiary dentine is indicated by the arrow. D3(2) represents the newly formed dentin bridge. In the micro-CT section D4(1) of tooth D4 the presence of the dentin bridge is not noticeable. The same result is seen in D4(2) at the ground section. Hematoxylin-Eosin staining for D3(1) and D3 (2) images.

Teeth pulp capped with BioMTA+

From the two micro-CT sections of tooth D5 (Figure 4, D5(1,2)) it can be observed the presence of a dentin bridge deposited under the pulp capping material that penetrates the pulp chamber over a relatively small portion.

The dentin bridge is complete and shows an intensity identical to that of dentin and has a uniform appearance.

Tooth D6 presents a complete dentin bridge detectable on the micro-CT section of Figure 4, D6(1).

The dentin bridge completely closes the pulp exposure site.

Figure 4, D6(2) shows a histologic image in the close proximity to the exposure site.

A complete homogeneous dentine bridge with a tubular structure with a non-uniform pattern can be identified.

The micro-CT section of teeth D7 [Figure 5, D7(1)] shows the presence of newly formed tissue interposed between the BioMTA+ cement surface and the dental pulp adjacent to the exposure area.

The dentin bridge is present, but it is incomplete.

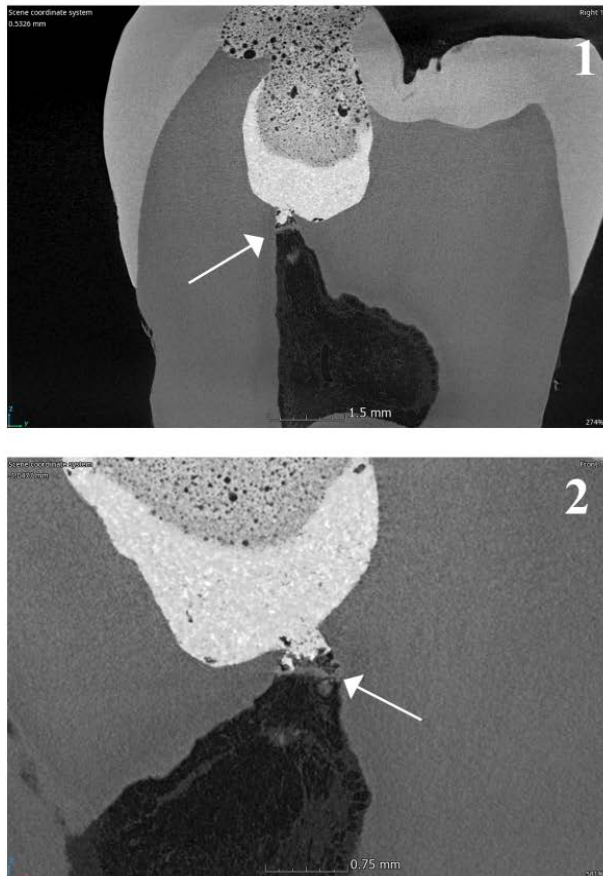
The morphology of the newly formed dentin bridge can be seen in Figure 5, D.7(2).

The presence of non-uniform, tubular structures can be observed.

These structures are dentinal tubules within the tertiary dentin.

The tertiary dentin deposits have a relatively compact structure.

D5



D6

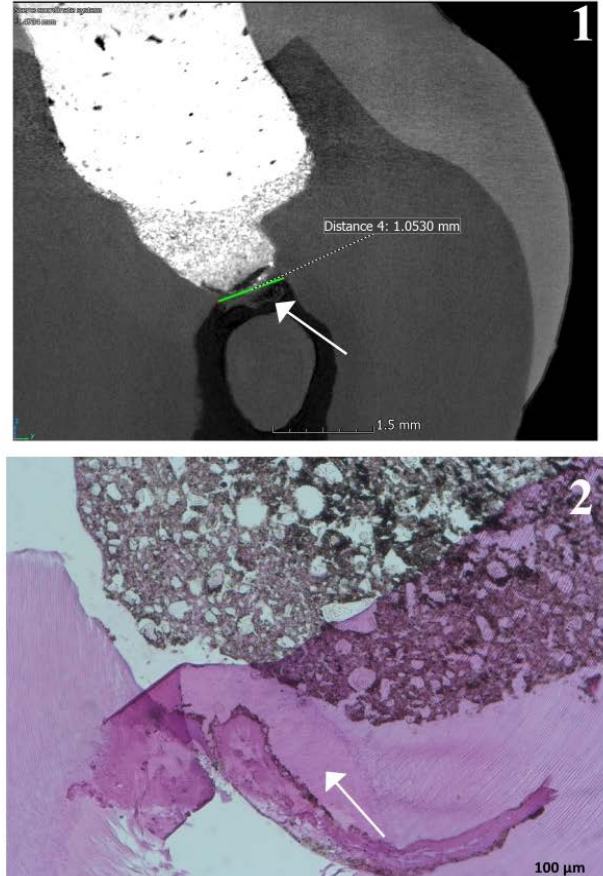


Figure 4. Histological and micro-CT images of teeth D5 and D6. In the images D5(1 and 2) it can be noticed on the micro-CT sections the deposition of a complete dentin bridge that closes the pulp exposure site (arrows). The formation of a complete dentin bridge can also be seen in tooth D6 in the micro-CT section D6(1) (arrow) and on the histologic image of D6(2) (arrow). Hematoxylin Eosin staining for D6(2) image.

The micro-CT section of tooth D8 [Figure 5, D8(1)] shows a relatively narrow exposure site with the presence of a 0.5mm structure, with a radiopacity identical to that of dentin (indicated by arrow).

This structure is a complete dentin bridge which encloses the pulp exposure site, in the proximity of BioMTA+.

Figure 5, D8(2) shows a stereo-microscopy image of the tooth ground section in which the

complete dentin bridge that remained attached to the BioMTA+ cement can be seen (indicated by arrow).

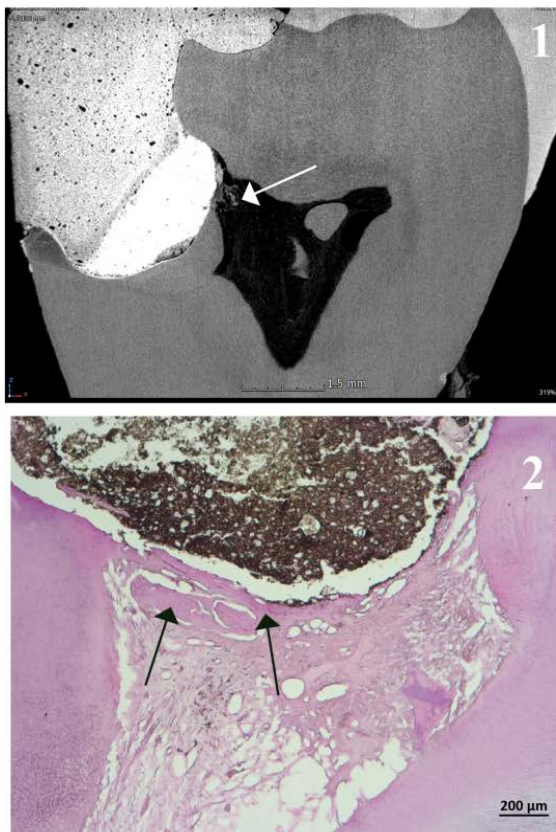
In Figure 5, D8(3) the complete dentin bridge shows variable thickness (79.98μm-161.54μm) in the dark field microscopy image.

Dentin bridge formation in teeth D1-D8 is summarized in Table 3.

Table 3. Dentin bridge formation following pulp capping.

Teeth	Pulp capping biomaterial	Pulp capping	Dentin bridge formation		
			Complete	Incomplete	No formation
D1	TheraCal LC	direct		Yes	
D2	TheraCal LC	indirect			No
D3	TheraCal LC	indirect	Yes		
D4	TheraCal LC	direct			No
D5	BioMTA+	direct	Yes		
D6	BioMTA+	direct	Yes		
D7	BioMTA+	direct		Yes	
D8	BioMTA+	direct	Yes		

D7



D8

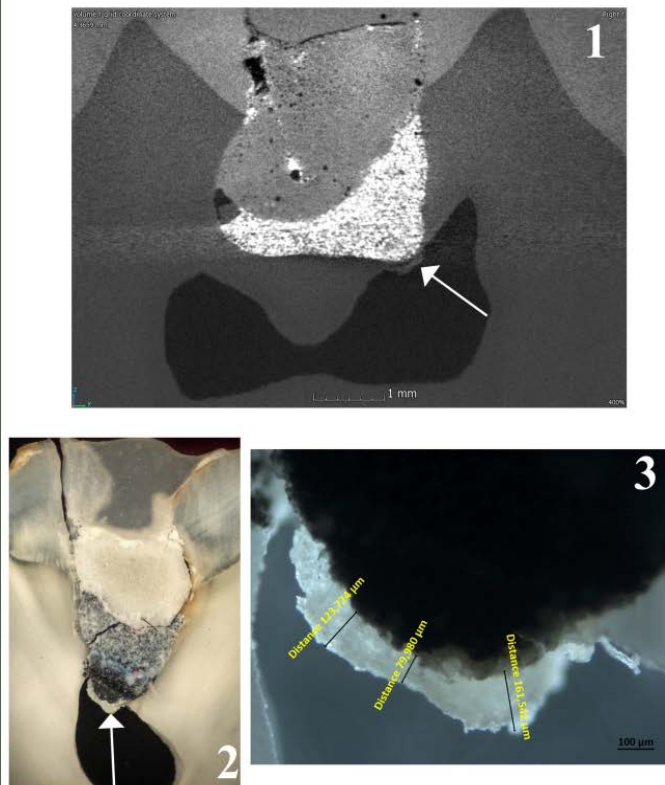


Figure 5. Histological and micro-CT images of teeth D7 and D8. In image D7(1) the micro-CT section shows the presence of an incomplete dentin bridge in the pulp exposure site (arrow). The incomplete bridge can also be seen on the histologic section of image D7(2) in the form of tertiary dentin islands. Micro-CT image D8(1) shows the formation of a complete dentin bridge (arrow) in teeth D8. The complete dentin bridge that has remained attached to the BioMTA+ cement can be seen in the stereo-microscopy image, D8(2) (arrow) and in the dark-field microscopy image, D8(3). Hematoxylin Eosin staining for D7(2) image.

Discussion

The aim of pulp capping is to preserve the vitality and regeneration of the dental pulp exposed to pathogenic stimuli [9].

Pulp capping is considered a conservative and effective pulp treatment option.

According to previous studies, the dental pulp has a much better potential for tissue repair and regeneration when exposed due to

mechanical or traumatic processes (in the first instance the pulp is not exposed to microbial factors) than when exposed due to deep carious processes (involving the presence of bacterial populations) [10].

Depending on the type of exposure, pulp responses may vary significantly in the short and long term, and may be low or high in intensity [11].

Following pulp exposure, a series of inflammatory steps will be initiated at the pulp-dentin complex, which may induce cell death or pulp necrosis if uncontrolled and unfavorable.

Under these conditions it is necessary and beneficial that the regenerative potential of the dental pulp is stimulated and activated to avoid a situation in which the pulp injury becomes irreversible [12].

An important factor in the pulp-dentin complex regeneration following direct pulp capping is attributed to the undifferentiated mesenchymal cells of the dental pulp which play an essential role in tissue repair processes.

These cells intervene when odontoblasts adjacent to the pulp exposure site are injured and have the ability to form a new cell population of odontoblast-like cells that will secrete reparative dentin [8,12].

Pulp capping success is attributed both to the experience and skill of the practitioner performing the procedure and to his decision in selecting the pulp capping agent.

Biocompatibility is essential in dental materials, involving interactions between the material and the host tissue [13].

Both materials tested *in vivo* in the present study showed good biocompatibility, with pulp vitality being preserved in all teeth, irrespective of the material tested and the type of pulp capping performed, direct or indirect.

A study investigating the cytotoxicity effects of calcium silicate-based materials on human fibroblasts concluded that Biodentine, MTA Angelus and iRoot BP Plus showed good biocompatibility, while TheraCal LC should be used with caution due to the cytotoxic effects it induces [14].

Another study comparing the local and systemic effects of resin-containing pulp capping materials versus traditional, conventional ones, showed that ProRoot MTA cement showed the best biocompatibility and that the polymer-containing materials showed significantly more inflammation after subcutaneous insertion in laboratory rats [15].

In our study, the inflammatory infiltrate was present in only two teeth treated with TheraCal LC and was absent in the BioMTA+ treated teeth.

Calcium silicate-based cements, such as MTA, seem to have a more favorable result after pulp capping than resin-based materials [16].

Regarding neodentinogenesis activation, dentin bridges were present in all teeth pulp

capped with BioMTA+ and only 2 teeth treated with TheraCal LC showed dentin bridges.

In other MTA-type cements studies, dentin bridge deposition is also clinically successful following direct pulp capping.

Thus, ProRoot MTA cement was tested and compared with a calcium hydroxide-based cement in an experiment on 20 human third molars following direct pulp capping.

MTA cement showed clinical success as quantified by the deposition of dentin bridges in 100% of cases compared to 60% with calcium hydroxide.

The dentin bridges generated by MTA were also thicker and more complete [17].

The tertiary dentin deposited in teeth D1 and D3 was in the form of complete (in tooth D3) or incomplete (in tooth D1) bridges, which had tubular dentinal tubules structures.

These tubules showed a non-uniform pattern, a characteristic feature of tertiary dentin.

No formation of dentin bridges was observed in teeth D2 and D4. One study reported a better deposition of tertiary dentin in the form of complete dentin bridges by TheraCal LC compared to Biodentine, a calcium silicate-based cement [18].

At the same time, another study indicated a better mineralization of demineralized dentin by Biodentine; however, TheraCal LC shows a good ability to induce mineralization of demineralized dentin tissue [19].

BioMTA+ pulp capped teeth showed complete homogeneous dentin bridges, except for tooth D7 which showed an incomplete dentin bridge.

In a study performed on 90 temporary molars, three direct pulp capping materials were clinically tested: MTA Angelus, TheraCal LC and Dycal (a calcium hydroxide cement), and the clinical follow-up period was at 3, 6 and 9 months by radiographs.

In terms of clinical success, quantified radiologically and by clinical examination, MTA had the highest success rate, followed by TheraCal LC and Dycal [20].

A major limitation of the study was represented by the difficulty of teeth histological processing, especially demineralization, as this step is not standardized for each individual tooth and may vary as time range.

In conclusion, both materials stimulated neodentinogenesis, with the MTA cement being more effective and presenting a much more favorable biological pulpal response.

Acknowledgments

We would like to thank Prof. Dr. Sabina Zurac, Department of Anatomical Pathology, Faculty of Dentistry, Carol Davila University of Medicine and Pharmacy, and Histovet laboratory, for histological processing of the samples.

Conflict of interest

None to declare.

References

1. Cohenca N, Paranjpe A, Berg J. Vital pulp therapy. *Dent Clin North Am*, 2013, 57(1):59-73.
2. Ballikaya E, Celebi Saltik B. Approaches to vital pulp therapies. *Australian endodontic journal : the journal of the Australian Society of Endodontology Inc*, 2023, 49(3):735-749.
3. Dammaschke T. The history of direct pulp capping. *J Hist Dent*, 2008, 56(1):9-23.
4. Ghatole K, Gowdra RH, Azher S, Sabharwal S, Singh VT, Sundararajan BV. Enhancing the antibacterial activity of the gold standard intracanal medicament with incorporation of silver zeolite: An in vitro study. *J Int Soc Prev Community Dent*, 2016, 6(1):75-79.
5. Tawil PZ, Duggan DJ, Galicia JC. Mineral trioxide aggregate (MTA): its history, composition, and clinical applications. *Compend Contin Educ Dent*, 2015, 36(4):247-252.
6. Didilescu AC, Cristache CM, Andrei M, Voicu G, Perlea P. The effect of dental pulp-capping materials on hard-tissue barrier formation: A systematic review and meta-analysis. *J Am Dent Assoc*, 2018, 149(10):903-917.e4.
7. Voicu G, Didilescu AC, Stoian AB, Dumitriu C, Greabu M, Andrei M. Mineralogical and Microstructural Characteristics of Two Dental Pulp Capping Materials. *Materials (Basel)*, 2019, 12(11).
8. Gandolfi MG, Siboni F, Prati C. Chemical-physical properties of TheraCal, a novel light-curable MTA-like material for pulp capping. *International Endodontic Journal*, 2012, 45(6):571-579.
9. Fouad AF. The microbial challenge to pulp regeneration. *Adv Dent Res*, 2011, 23(3):285-289.
10. Islam R, Islam MRR, Tanaka T, Alam MK, Ahmed HMA, Sano H. Direct pulp capping procedures-Evidence and practice. *Jpn Dent Sci Rev*, 2023, 59:48-61.
11. Islam R, Islam MR, Tanaka T, Alam M, Ahmed H, Sano H. Direct pulp capping procedures-Evidence and practice. *Japanese Dental Science Review*. 2023, 59:48-61.
12. Sanz JL, Soler-Doria A, López-García S, García-Bernal D, Rodríguez-Lozano FJ, Lozano A, Llena C, Forner L, Guerrero-Girones J, Melo M. Comparative Biological Properties and Mineralization Potential of 3 Endodontic Materials for Vital Pulp Therapy: Theracal PT, Theracal LC, and Biodentine on Human Dental Pulp Stem Cells. *J Endod*, 2021, 47(12):1896-1906.
13. Paqué PN, Özcan M. A Review on Biocompatibility of Dental Restorative and Reconstruction Materials. *Current Oral Health Reports*, 2024, 11(1):68-77.
14. Adigüzel M, Ahmetoğlu F, Eldeniz A, Tekin MG, Gögebakan B. Comparison of cytotoxic effects of calcium silicate-based materials on human pulp fibroblasts Mehmet. *J Dent Res Dent Clin Dent Prospects*, 2019, 13(4):241-246.
15. Bakir EP, Yıldırım ZS, Bakir Ş, Ketani A. Are resin-containing pulp capping materials as reliable as traditional ones in terms of local and systemic biological effects? *Dent Mater J*, 2022, 41(1):78-86.
16. Andrei M, Vacaru RP, Coricovac A, Ilinca R, Didilescu AC, Demetrescu I. The Effect of Calcium-Silicate Cements on Reparative Dentinogenesis Following Direct Pulp Capping on Animal Models. *Molecules*, 2021, 26(9):2725.
17. Min KS, Park HJ, Lee SK, Park SH, Hong CU, Kim HW, Lee HH, Kim EC. Effect of mineral trioxide aggregate on dentin bridge formation and expression of dentin sialoprotein and heme oxygenase-1 in human dental pulp. *J Endod*, 2008, 34(6):666-670.
18. Singh S, Joshi P, Rajasekhar R, Saoji SV, Richhawal A, Punia JK. Efficacy of TheraCal LC and Biodentine as Direct Pulp Capping Agents-An Clinico-Histological Study. *J Pharm Bioallied Sci*, 2024, 16(Suppl 2):S1420-s1422.
19. Fathy SM. Remineralization ability of two hydraulic calcium-silicate based dental pulp capping materials: Cell-independent model, *J Clin Exp Dent*, 2019, 11(4):e360-e366.
20. Rani R, Namdev R, Singhal R, Singhal P, Goel N, Jha S. Comparative Evaluation of Effectiveness of TheraCal LC, MTA, and Calcium Hydroxide in Direct Pulp Capping in Primary Molars: Randomized Clinical Study. *International Journal of Clinical Pediatric Dentistry*, 2023, 16:S213-S219.

Corresponding Author: Mihai Andrei, Department of Embryology and Microbiology, Faculty of Dentistry, "Carol Davila" University of Medicine and Pharmacy, 050474 Bucharest, Romania, e-mail address: mihai.andrei@umfcd.ro