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Pulp-Dentin Complex Regeneration Using Lyophilized Human Exfoliated Deciduous Teeth on a CultiSpher® and Fibrinogen-Thrombin Scaffold

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ABSTRACT

Background: Maintenance of dental pulp vitality is a primary goal of modern endodontic practice. A nonvital tooth exhibits compromised physiological function and diminished biomechanical resilience, thereby limiting its longevity within the oral cavity. Despite significant advances in vital pulp therapy and biomaterial development, uncertainties remain regarding the biological efficacy of these materials, their capacity to regenerate the pulp–dentin complex, and the predictability of long-term clinical outcomes.

Objectives: Given the clinical significance of maintaining pulp vitality, researchers and clinicians are increasingly adopting tissue engineering strategies to develop alternative biomaterials capable of functionally regenerating pulp–dentin complex while preserving its physiological integrity. These bioengineered approaches aim not only to sustain vitality but also to reconstruct the native biological architecture and restore the inherent regenerative capacity of dental tissues.

Methods: This study aimed to evaluate a newly developed bioengineered material for vital pulp therapy (VPT) in mechanically exposed pulp, using direct pulp capping and partial pulpotomy models. The in vivo experiment was performed on 24 sheep teeth (n=24) and was observed for 7, 14, and 28 days. The bioengineered material - Cultigel, consisted of mesenchymal stromal cells from human exfoliated deciduous teeth (SHED) cultured on gelatin microcarriers (CultiSpher®) within a fibrinogen-thrombin gel, while Biodentine™ served as the control. Histological evaluation assessed pulp vitality, inflammatory response, and reparative dentin formation.

Results: Histological analysis revealed favorable regenerative outcomes in the experimental teeth, characterized by angiogenesis, inflammation resolution, and the formation of a highly mineralized dentin bridge.

Conclusions: Histological evaluation confirmed the efficacy of the bioengineered material applied for vital pulp therapy, highlighting its potential to achieve functional regeneration of the pulp–dentin complex. These results provide a solid foundation for future large-scale studies to optimize the proposed bioengineering strategy and facilitate its translation into clinical practice.

Keywords: Direct pulp capping; partial pulpotomy; pulp-dentin complex; vital pulp therapy (VPT).

BACKGROUND

Following dental caries, traumatic dental injury represents the second most common oral pathology and the fifth most prevalent pathological condition globally, occurring predominantly in children and adolescents.[1] Loss of pulp vitality during the early stages of root development prevents further root maturation and apical closure,[2,3] thereby increasing the susceptibility to root fracture and, consequently, the likelihood of tooth extraction.[4,5] The preservation of pulp vitality (VPT) has long remained a major focus of endodontic research and clinical practice, both in cases of traumatic pulp exposure and in iatrogenic or caries-related mechanical exposure during cavity preparation. In such clinical scenarios, VPT involves either direct pulp capping with a biocompatible material or partial pulpotomy, the latter generally indicated when the extent of pulp exposure or inflammation is greater.

In contemporary dentistry, Mineral Trioxide Aggregate (MTA) and Biodentine are widely recognized as the gold standard materials for vital pulp therapy (VPT). Their mechanism of action involves creating a strongly alkaline microenvironment that promotes the differentiation of dental pulp progenitor cells into odontoblast-like cells.[6] Nevertheless, both materials present certain limitations, including delayed formation of the mineralized barrier and a predominantly reparative rather than regenerative tissue response.[7,8]

Given the clinical relevance of this issue, researchers and clinicians have increasingly sought to improve existing VPT techniques by integrating tissue-engineering strategies to restore the dentin-pulp complex with complete functionality and physiological characteristics. In this context, the present study aimed to develop an alternative bioengineered material for vital pulp therapy by combining lyophilized stem cell-loaded microcarriers with an injectable extracellular matrix component, a fibrinogen-thrombin gel, designed to provide high biocompatibility and strong regenerative potential for pulp tissue restoration.

METHODS

Isolation of mesenchymal stromal cells from human exfoliated deciduous teeth

As previously described in our study,[9] the permission of SHED isolation was approved by the Biomedical Research Ethics Committee of Tbilisi State Medical University (Approval No. N6-2022/99). Written informed consent was obtained from the parents or legal guardians of all donors. Exfoliated deciduous teeth were collected from healthy donors aged 7-

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12 years at Dental Clinic, Training and Research Center Unident and Tbilisi State Medical University Dental Center (Apolon Urushadze Dental Clinic). A total of six teeth (n=6) were obtained for cell isolation.

Immediately after extraction, the teeth were disinfected in 3% sodium hypochlorite solution for 2 minutes and rinsed once with phosphate-buffered saline (PBS). Each tooth was sectioned longitudinally using a sterile diamond fissure bur (Mani, Inc., USA) under continuous water irrigation with a high-speed turbine. The pulp tissue was carefully removed with a sterile curette and transferred into PBS.

For the derivation of mesenchymal stromal cells, the explant culture method was employed. The pulp explants were washed twice with DPBS containing gentamicin and then minced with a #20 surgical scalpel blade into 1-2 mm micro-fragments, which were transferred into a culture medium consisting of Dulbecco's Modified Eagle Medium (DMEM) supplemented with 15% MSC-qualified fetal bovine serum (FBS), 2 mM GlutaMAX, and an antibiotic–antimycotic solution (AA). Cultures were maintained in a humidified incubator at 37 °C with 5% CO_2. Cells were subcultured when they reached approximately 80% confluence. Cell viability was evaluated using the trypan blue exclusion assay, and the phenotypic profile of SHED was characterized using a Human Mesenchymal Stem Cell Marker Panel (R&D Systems, #FMC020).

Loading of Microcarriers (CultiSpher®) with SHED

Stem cells from human exfoliated deciduous teeth (SHED) were seeded onto CultiSpher® microcarriers following the protocol described previously.[10] Two aliquots of rehydrated CultiSpher® (0.15 g each) were mixed with SHED (15×10^6 cells) and placed in a 24-well Companion Plate (Falcon; Corning Life Sciences) and incubated at 37°C with 5% CO_2 and 90% humidity. Dulbecco's Modified Eagle Medium (DMEM; MilliporeSigma), supplemented with 10% fetal bovine serum, 50 U/mL penicillin, and 0.05 mg/mL streptomycin, was used as the growth medium. Co-culture was maintained for 7 days, with medium changes every 3 days. Following incubation, CultiSpher® loaded with mesenchymal stromal cells was freeze-dried for twelve hours using a Heto Power Dry PL6000 Freeze Dryer (Sjia Lab, Shenzhen, China).

The lyophilized mass was stored under sterile conditions until further use. Small representative samples were subjected to scanning electron microscopy (SEM) and fluorescence microscopy analyses. For fluorescence microscopy, the samples were stained with DAPI (4',6-diamidino-2-phenylindole; 10236276001, Roche, Sigma-Aldrich) and PKH26 Red Fluorescent Cell Linker (Sigma-Aldrich, USA) according to the manufacturer's protocol. This dual-staining approach enabled visualization of cell nuclei and assessment of SHED distribution and adhesion within the microcarrier structure.

Scanning electron microscopy (SEM) analysis

The lyophilized, two-component bioengineered material (SHED + CultiSpher®) was combined with a fibrinogen-thrombin gel, and after solidification, scanning electron microscopy (SEM) was performed. The bioengineered samples were coated with gold by vacuum sputtering, and imaging was performed using a Phenom ProX Scanning Electron Microscope (Thermo Fisher Scientific, USA). This analysis provided a detailed visualization of the surface morphology, porosity, and cell–matrix interactions of the composite bioengineered material.

Experimental design and animal model

The experimental study was conducted on three clinically healthy adult sheep of both sexes, with a mean age of 3.5 years. All experimental procedures were conducted in accordance with institutional and international guidelines for the care and use of animals and were approved by the Biomedical Research Ethics Committee of Tbilisi State Medical University (Session No. 63).

Premedication of animals was carried out using 2% xylazine at a dose of 0.1-0.5 mg/kg. All manipulations were performed under general anesthesia induced with thiopental sodium (7-15 mg/kg). According to the experimental procedures, all animals were observed under field conditions, with unrestricted access to water and food.

The total number of examined teeth was 24 (n=24). Observation periods were established at 7, 14, and 28 days to evaluate the pulp tissue response at different stages of repair. A schematic representation of the experimental design is shown in Figure 1.

FIGURE 1. Experimental design

Study tooth groups	Performed procedure	Number of teeth
I experimental teeth	Mechanical exposure of the dental pulp + Cultigel + Biodentine	6
II experimental teeth	Partial pulpotomy + Cultigel + Biodentine	6
III control teeth	Mechanical exposure of the dental pulp + Biodentine	6
IV control teeth	Partial pulpotomy + Biodentine	6

Under general anesthesia, the operative field was isolated with a rubber dam, and the teeth were disinfected using a 0.05% chlorhexidine solution. Access cavities were prepared with a high-speed turbine handpiece equipped with a round diamond bur 801L/012 (DIA.TESSIN SWISS) under continuous water cooling.

In the I and III teeth groups, mechanical exposure of the coronal pulp was performed, whereas in the II and IV groups, partial pulpotomy was carried out. Following model preparation, in Groups I and II (experimental), Cultigel was

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immediately injected into the canal. The microcarriers and SHED were first mixed with the fibrinogen fraction (0.03 g/0.2 mL) and injected into the canal under uniform pressure using a 25G needle, followed by the injection of thrombin to initiate gel formation.

In all teeth groups, the canal orifice was sealed with a 1.5-2 mm layer of Biodentine (Septodont, USA). After the material was completely set in the clinical setting (12 minutes), a tooth crown was restored with a light-cured composite bonding material (Asteria, Tokuyama Dental) according to the manufacturer's standard protocol.

Histological sample preparation and examination

Euthanasia was performed at 7-, 14-, and 28-day post-treatment by administering a lethal dose of thiopental sodium, followed by decapitation. Subsequently, the anterior segment of the sheep mandible containing the treated teeth was resected. The obtained specimens were fixed in 10% neutral buffered formalin for subsequent morphological and histological analyses.

The samples were decalcified for 5 weeks, embedded in paraffin, and sectioned at 3 µm using a rotary microtome. Sections were stained with hematoxylin and eosin (H&E) following standard histological protocols.

Statistical analysis

Histological assessment included pulp vitality, inflammation, necrosis, odontoblastic activity, dentin bridge formation, reparative tissue formation, and angiogenesis, each scored on a 0–3 scale. Differences between experimental and control groups were analyzed using the Mann-Whitney U test, and comparisons across observation periods (7-, 14-, and 28-day) within each subgroup were performed using the Kruskal-Wallis test.

RESULTS

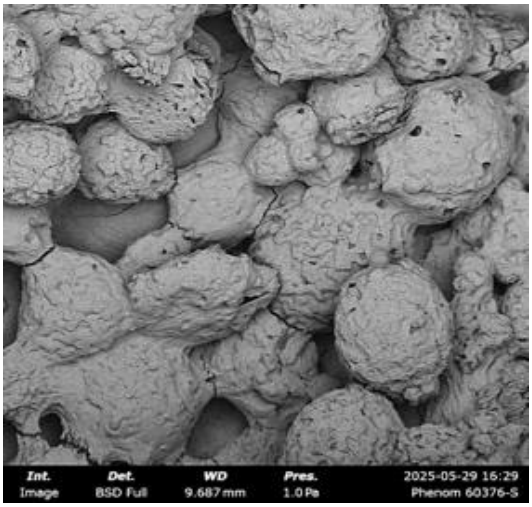
According to the findings of the present study, the mesenchymal phenotype of SHED was confirmed by positive expression of the surface markers CD73, CD90, and CD105, and negative expression of the hematopoietic markers CD34 and CD45.

Fluorescent analysis of Cultigel components—SHED and the microcarriers—was performed to evaluate the colocalization of mesenchymal cells on the porous surface of the microcarriers. The results demonstrated extensive distribution of SHED throughout the CultiSpher® surface, indicating efficient cellular attachment and colonization. These findings confirm that CultiSpher® provides a favorable microenvironment for SHED adhesion.

Scanning electron microscopy (SEM) analysis of Cultigel

SEM analysis revealed that Tisseel® is a fibrin-based, amorphous matrix that supports SHED-loaded microcarriers. Mesenchymal stromal cells were firmly attached to the porous surfaces, exhibiting flattened, elongated morphologies. The fibrin matrix contributed to the structural stability of Cultigel, underscoring Tisseel®'s role as an extracellular matrix analogue (Fig.2).

FIGURE 2. SHED-loaded CultiSpher® combined with a fibrinogen-thrombin gel. SEM. Magnification ×300



Histological evaluation of sheep teeth VPT

In the first week of observation, histological sections from both experimental and control groups of teeth revealed inflammatory changes within the pulp tissue, including interstitial edema, hemorrhagic areas of varying extent, and infiltration by inflammatory cells, predominantly macrophages. In the experimental teeth (Group I), odontoblast-like cells migrated and proliferated along the dentinal walls, with a continuously developing dentin bridge indicative of early reparative activity.

After 14 days of observation, histological sections from Group I teeth exhibited a marked reparative response of the dental pulp. At the site of bioengineered material application, active fibroblast proliferation and neocapillary formation were evident, while inflammatory infiltration remained minimal and localized. A continuous, well-mineralized dentin bridge was present, containing occasional areas of unmineralized matrix, and no evidence of pulpal necrosis was observed. In group II, histological evaluation revealed the formation of pulp-like tissue. Mild inflammatory infiltrate, organized newly differentiated odontoblast-like cells, active capillary proliferation, and deposition of reparative dentin were observed. Pulp vitality and normal tissue architecture were maintained along the entire length of the root canal.

At the same time point, control group III demonstrated preserved pulp vitality, with limited coagulative necrosis and focal inflammatory infiltrates at the site of injury. The coronal pulp showed migration of odontoblast-like cells and formation of an initial non-mineralized dentin matrix. Conversely, control group IV exhibited pronounced dystrophic changes with large intrapulpal vacuoles and the absence of regenerative features.

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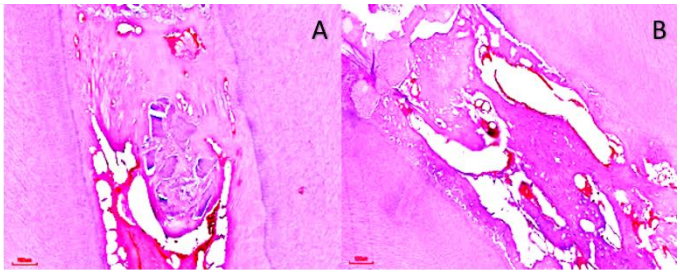
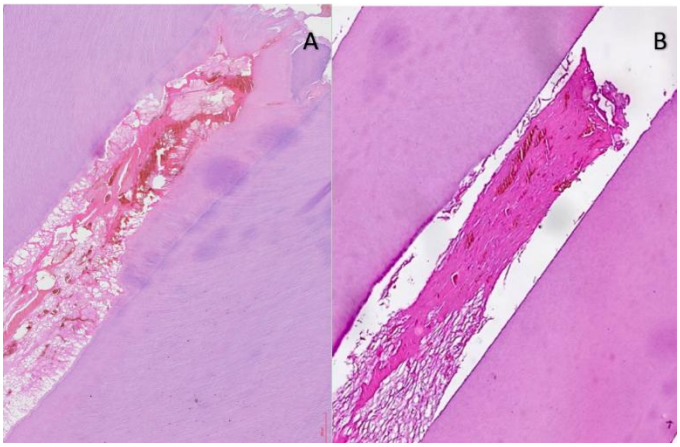
After 28 days, histological examination of both experimental groups (Group I, II) revealed a continuous, highly mineralized reparative dentin bridge bordered by a distinct layer of odontoblast-like cells. Within the pulp tissue, fibrin fibers and numerous newly formed blood vessels were identified, appearing as small, round or tubular structures containing erythrocytes. In the partial pulpotomy specimens (Group II), the pulp canal lumen was partially occupied by pulp-like connective tissue, which featured a well-organized vascular network and preserved cellular organization (Fig. 3).

FIGURE 3. (A) Mechanically exposed pulp VPT with CultiGel, showing a continuous, highly mineralized dentin bridge. (B) Partial pulpotomy VPT with CultiGel, demonstrating a predominantly mineralized continuous dentin bridge with small unmineralized regions. Observation period - 28 days. Staining: H&E. Magnification ×200.



At 28 days, control group III demonstrated residual inflammatory infiltrates, marked pulp proliferative activity, and a continuously formed reparative dentin bridge with tunnel-like inclusions. Although overall pulp vitality was maintained, focal coagulative necrosis was present in certain areas. Conversely, the control group IV showed no regenerative features and extensive coagulative necrosis of the pulp tissue (Fig.4).

FIGURE 4. (A) Mechanically exposed pulp VPT with Biodentin, showing a continuous mineralized dentin bridge with probable tunnel defects. (B) Partial pulpotomy VPT with Biodentin, demonstrating an extensive area of pulp coagulative necrosis. Observation period: 28 days. Staining: H&E. original magnification ×200



Across all evaluation periods (7, 14, and 28 days), the experimental group's teeth exhibited significantly higher total histological scores than the control group ($p = 0.029$), indicating superior pulp regenerative outcomes with Cultigel compared to Biodentine (Tab.1).

TABLE 1. Histological scoring outcomes of the experimental sheep teeth

Observation Period	Group I	Group I	Group II	Group II	Group III	Group III	Group IV	Group IV
7 days	11	12	7	7	5	4	3	3
14 days	17	16	11	10	8	9	4	3
28 days	17	16	17	16	15	15	5	3

DISCUSSION

Bioengineering-based vital pulp therapy (VPT) aims to regenerate living, functional tissue by coordinating stem cells, biocompatible scaffolds, and signaling molecules. By recreating the native microenvironment of the damaged pulp, this approach supports cellular proliferation, differentiation, and tissue remodeling, offering a realistic prospect for true pulp–dentin regeneration.[11-13] In this context, the present study sought to develop a bioengineered construct with superior regenerative efficacy and faster healing kinetics than the currently accepted "gold-standard" materials.

Quantitative assessments of dentin bridge formation following VPT remain limited in the current literature. Previous experimental studies have reported that, in rabbit models, the use of Biodentine resulted in the formation of a mineralized barrier measuring approximately 28.16 µm after one week and 33.66 µm after two weeks.[14] In canine models treated with MTA, no mineralized bridge was detected at 7 days, whereas mean thicknesses of 15.4 µm and 22.9 µm were observed at 21 and 60 days, respectively.[15] Similarly, a 2020 study reported an average calcified bridge thickness of approximately 250 µm after a 66-day observation period.[16] In contrast, the present investigation demonstrated mineralization that was significantly earlier and more extensive. Histological analysis revealed a mineralized bridge as early as 1-week post-treatment, and by day 28, a continuous, well-organized reparative dentin bridge was evident in both experimental subgroups. Quantitatively, in experimental group I, the mineralized bridge thickness ranged between 600-700 µm at one week, 400–500 µm at two weeks, and 700-800 µm at four weeks. In control group III, mineralized bridge formation was detected exclusively at 28 days, at a depth of 200-250 µm. Conversely, control group IV demonstrated coagulative necrosis of the pulp tissue.

These histomorphometric differences indicate that Cultigel possesses enhanced regenerative efficacy, accelerates mineral deposition, and bridge maturation compared with conventional materials.

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A ready-to-use dual-syringe fibrinogen–thrombin formulation, Tisseel (Baxter, USA), was used within Cultigel. The material contains aprotinin, an antifibrinolytic agent, and calcium chloride (500 IU/mL), which promote thrombin activation and stable fibrin matrix formation. Due to its plasma-derived nature, Tisseel exhibits intrinsic angiogenic properties, releasing PDGF, VEGF, and TGF-β, which support angiogenesis, cell proliferation, and matrix regeneration.[17-19]

In the developed bioengineered material, microcarriers and mesenchymal stromal cells underwent co-lyophilization to minimize cellular immunogenicity. The freeze-drying process induces structural modifications or masking of membrane surface antigens, particularly MHC class I and II molecules, thereby attenuating T-lymphocyte-mediated immune recognition. Moreover, lyophilization reduces the risk of pathogen transmission by dehydrating cells and enables long-term preservation of the bioengineered component in a stable, ready-to-use form.[20,21]

The use of a large-animal model in this study was a deliberate and scientifically grounded choice. Cultigel was initially tested on heterotopically transplanted tooth slices in rats,[10] followed by experiments on sheep due to the close anatomical and histological resemblance of their teeth to those of humans. Such large-animal models are considered clinically relevant and, in certain cases, serve as preclinical simulations.[22]

Overall, these results validate the developed bioengineered material as a promising strategy for functional regeneration of the pulp-dentin complex and provide a translational foundation for future preclinical and clinical applications.

CONCLUSIONS

The developed bioengineered material facilitated the rapid formation of a continuous, highly mineralized bridge that functioned as a hermetic biological barrier, protecting the dental pulp from chemical, mechanical, thermal, and microbial insults. The proposed bioengineering strategy demonstrated excellent biocompatibility and low immunogenicity, supporting its potential as an alternative material for vital pulp therapy. Nevertheless, further investigations, including human-based studies and infection-challenged models, are required to validate its regenerative efficacy, optimize the protocol, and support its future translation into clinical practice.

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REFERENCES

1. Petti S, Glendor U, Andersson L. World traumatic dental injury prevalence and incidence: a meta-analysis—one billion living people have had traumatic dental injuries. Dent Traumatol. 2018;34:71–86. doi:10.1111/edt.12389.
2. Andreasen JO, Farik B, Munksgaard EC. Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture. Dent Traumatol. 2020;18:134–137. doi:10.1034/j.1600-9657.2002.00097.x.
3. Elnaghy AM, Elsaka SE. Fracture resistance of simulated immature teeth filled with Biodentine and white mineral trioxide aggregate: an in vitro study. Dent Traumatol. 2016;32:116–120. doi:10.1111/edt.12224.
4. Jeeruphan T, Jantarat J, Yanpiset K, Suwannapan L, Khewsawai P, Hargreaves KM. Mahidol study 1: comparison of radiographic and survival outcomes of immature teeth treated with either regenerative endodontic or apexification methods: a retrospective study. J Endod. 2012;38:1330–1336. doi:10.1016/j.joen.2012.06.028.
5. Silujjai J, Linsuwanont P. Treatment outcomes of apexification or revascularization in nonvital immature permanent teeth: a retrospective study. J Endod. 2017;43:238–245. doi:10.1016/j.joen.2016.10.030.
6. Aksel H, Küçükkaya Eren S, Askerbeyli Õrs S, Karaismailoğlu E. Surface and vertical dimensional changes of mineral trioxide aggregate and Biodentine in different environmental conditions. J Appl Oral Sci. 2018;27:e20180093. doi:10.1590/1678-7757-2018-0093.
7. Accorinte Mde L, Holland R, Reis A, Bortoluzzi MC, Murata SS, Dezan E Jr, Souza V, Alessandro LD. Evaluation of mineral trioxide aggregate and calcium hydroxide cement as pulp-capping agents in human teeth. J Endod. 2008;34(1):1–6. doi:10.1016/j.joen.2007.09.012.
8. Bahammam LA, Alsharqawi W, Bahammam HA, Mounir M. Histological evaluation of pulpal response and dentin bridge formation after direct pulp capping using recombinant amelogenin and mineral trioxide aggregate (MTA). Cureus. 2024;16(2):e54560. doi:10.7759/cureus.54560.
9. Jikia T, Kakabadze M, Kharebava G, Batsatsashvili T, Bedineishvili N, Chipashvili N. Isolation of mesenchymal stromal cells from human exfoliated deciduous teeth. Georgian Biomed News. 2025;3(4):151–154. doi:10.52340/GBMN.2025.01.01.133.
10. Jikia T, Kakabadze M, Kharebava G, Chipashvili N. Semiorthotopic model for stem cell-based pulp regeneration: foundation for preclinical research. Georgian Biomed News. 2025;3(1):136. doi:10.52340/GBMN.2025.01.01.136.
11. Park MK, Kim S, Jeon M, Jung UW, Lee JH, Choi HJ, Choi JE, Song JS. Evaluation of the apical complex and the coronal pulp as a stem cell source for dentin-pulp regeneration. J Endod. 2020;46:224–231. doi:10.1016/j.joen.2019.10.025.
12. Iohara K, Imabayashi K, Ishizaka R, et al. Complete pulp regeneration after pulpectomy by transplantation of CD105+ stem cells with stromal cell-derived factor-1. Tissue Eng Part A. 2011;17:1911–1920. doi:10.1089/ten.tea.2010.0615.

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13. Khorsand A, Eslaminejad MB, Arabsolghar M, Paknejad M, Ghaedi B, Rokn AR, Moslemi N, Nazarian H, Jahangir S. Autologous dental pulp stem cells in regeneration of defect created in canine periodontal tissue. J Oral Implantol. 2013;39:433–443. doi:10.1563/AAID-JOI-D-12-00027.
14. Kayad M, Koura A, El-Nozahy A. A comparative histological study of the effect of TheraCal LC and Biodentine on direct pulp capping in rabbits: an experimental study. Clin Oral Investig. 2023;27(3):1013–1022. doi:10.1007/s00784-022-04658-9.
15. Emara RA, Abu-Seida AM, El Ashry SH. Histological evaluation of the synergistic effect of chitosan and mineral trioxide aggregate on mechanically exposed dental pulp following pulp capping in dogs' teeth. Saudi Endod J. 2022;12(1):25–30. doi:10.4103/sej.sej_294_20.
16. Accorinte ML, Loguercio AD, Reis A, Carneiro E, Grande RH, Murata SS, Holland R. Response of human dental pulp capped with MTA and calcium hydroxide powder. Oper Dent. 2008;33(5):488–495. doi:10.2341/07-143.
17. Dohan Ehrenfest DM, Rasmusson L, Albrektsson T. Classification of platelet concentrates: from pure platelet-rich plasma (P-PRP) to leucocyte- and platelet-rich fibrin (L-PRF). Trends Biotechnol. 2009;27(3):158–167. doi:10.1016/j.tibtech.2008.11.009.
18. Laurens N, Koolwijk P, de Maat MP. Fibrin structure and wound healing. J Thromb Haemost. 2006;4(5):932–939. doi:10.1111/j.1538-7836.2006.01861.x.
19. Jikia T, Chipashvili N. Tissue engineering scaffolds for dentin-pulp complex regeneration. Georgian Biomed News. 2024;2(2):106–113. doi:10.52340/GBMN.2024.01.01.73.
20. Pang SHM, D'Rozario J, Mendonca S, et al. Mesenchymal stromal cell apoptosis is required for their therapeutic function. Nat Commun. 2021;12:6495. doi:10.1038/s41467-021-26834-3.
21. Paresishvili T, Kakabadze Z. Freeze-dried mesenchymal stem cells: from bench to bedside. Adv Biol (Weinh). 2024;8(2):e2300155. doi:10.1002/adbi.202300155.
22. Nakashima M, Iohara K, Bottino MC, Fouad AF, Nör JE, Huang GT. Animal models for stem cell-based pulp regeneration: foundation for human clinical applications. Tissue Eng Part B Rev. 2019;25(2):100–113. doi:10.1089/ten.TEB.2018.0194.

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