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Molecular and regenerative responses in traumatized immature permanent teeth: A mini review

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Abstract:

Traumatic dental injuries frequently affect immature permanent teeth, whose open apices and apical papilla stem cells confer distinctive healing potential. Therefore, it is of interest to examine the post-traumatic pulp survival, the balance of inflammatory and reparative signaling and regenerative endodontics. Persistent cytokine and NF- κ B activity, matrix metalloproteinases and osteoclastic signaling drive necrosis and root resorption, whereas Wnt/ β -catenin and mineralization pathways favor reparative dentinogenesis and continued root maturation. Thus, data show that regenerative endodontic procedures and emerging cell-free, biomarker-guided strategies point toward personalized care, although outcomes remain largely reparative and demand standardization.

Keywords: Traumatic dental injuries (TDIs), immature permanent teeth, pulp regeneration, inflammatory biomarkers, regenerative endodontics

Background:

Traumatic dental injuries (TDIs) are common in children and the fate of the pulp largely determines their outcome [1]. After injury, pulp cells signal through cytokines and reactive species that regulate inflammation and repair [2]. In immature teeth, the apical papilla harbors stem cells (SCAP) that sustain continued root development [3]. External inflammatory root resorption after trauma can be monitored through gingival crevicular fluid biomarkers [4]. When inflammation persists, RANKL/OPG signaling and matrix metalloproteinases drive external root resorption [5]. Reparative Wnt/ β -catenin signaling instead drives odontoblast-like differentiation and dentin bridge formation [6]. Regenerative endodontic procedures recruit endogenous SCAP to continue root maturation in necrotic immature teeth [7, 8]. Therefore, it is of interest to describe the current molecular trends in pulp survival, inflammatory signaling and regeneration after trauma in immature teeth.

Regenerative outcomes and cell-free strategies:

Outcome syntheses show improved root development but heterogeneous, often reparative results across scaffold options [9]. Emerging cell-free, exosome-based strategies aim to standardize regeneration, though predictable outcomes remain a challenge [10].

Scaffolds, stem cells and growth factors:

More broadly, regeneration rests on a tissue-engineering triad of polymer scaffolds, stem cells and growth factors; biodegradable matrices such as collagen and gelatin methacryloyl, increasingly delivered through injectable hydrogels and three-dimensional bioprinting, support cell attachment and localized release of

bioactive factors to promote root development, apical closure and fracture resistance [11].

Regenerative procedures versus apexification:

Clinically, this biology gives regenerative procedures an advantage over apexification, which only forms an apical barrier without further root growth; meta-analysis reports comparable survival but favors regeneration when root development is severely deficient, supporting continued root maturation [12]. Consistent with prior reviews, regenerative endodontic procedures are increasingly considered the preferred treatment for immature permanent teeth following trauma, restoring pulp vitality and supporting continued root development [13, 14].

Conclusion:

Post-traumatic healing of immature permanent teeth is governed by the balance between inflammatory and reparative molecular signaling. Regenerative endodontics and emerging cell-free strategies are shifting care toward biologically guided, personalized management. Predictable regeneration will still require standardized protocols and validated biomarkers.

References:

- [1] Krastl G *et al. Int Endod J.* 2021 **54**:1221. [PMID: 33683731]
- [2] Pohl S *et al. Front Immunol.* 2024 **15**:1474466 [PMID: 39534600]
- [3] Liu Q *et al. Biomedicine.* 2023 **11**:2047 [PMID: 37509686]
- [4] Johnson RM *et al. Dent Traumatol.* 2023 **39**:264 [PMID: 36458683]
- [5] Galler KM *et al. BMC Oral Health.* 2021 **21**:163 [PMID: 33771147]
- [6] Amir M *et al. Cells.* 2024 **13**:1153. [PMID: 38995004]

- [7] Kahler B *et al.* *Dent Traumatol.* 2024 **40**:618 [PMID: 38989999]
 - [8] Wang Y *et al.* *Transl Pediatr.* 2025 **14**:1637. [PMID: 40800182]
 - [9] Sabeti M *et al.* *Int Endod J.* 2024 **57**:238 [PMID: 37966465]
 - [10] Beco M *et al.* *Medicina (Kaunas).* 2026 **62**:375. [PMID: 41752774]
 - [11] Farjaminejad R *et al.* *Polymers (Basel).* 2025 **17**:1475 [PMID: 40508718]
 - [12] Panda P *et al.* *J Clin Med.* 2022 **11**:3909 [PMID: 35807193]
 - [13] Zhou C *et al.* *Front Dent Med.* 2022 **2**:767226 [DOI: 10.3389/fdmed.2021.767226]
 - [14] Zbańska J *et al.* *Appl Sci.* 2021 **11**:6211 [DOI: 10.3390/app11136211]
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