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Regenerative Endodontic Procedures in Immature Permanent Teeth

With their wide-open apices and thin root dentin walls making them susceptible to fractures, immature permanent teeth with necrotic pulp and apical periodontitis present a challenge to the practitioner. Results of clinical studies have failed to identify prognostic factors for regenerative endodontic procedures, along with other suspected prognostic factors. Because their previous study had a small sample size and could not identify outcome factors, Theekakul et al from Mahidol University, Thailand, conducted a larger phase 2 study to evaluate treatment outcomes and identify prognostic factors for regenerative endodontic procedures in immature permanent teeth.

The study included 108 patients, approximately two-thirds were <12 years of age, with 120 necrotic immature permanent teeth that had either negative electronic pulp test or cold test results, along with teeth with irreversible pulpitis, in which bleeding could not be stopped and vital pulp therapy could not be performed. All teeth were treated with regenerative endodontic procedures and followed for ≥ 12 months.

Preoperative data included age, sex, systemic disease, tooth type, clinical signs and symptoms, etiology of pulpal disease, response to sensibility testing and pulpal/periapical diagnoses. Seven stages of root development were defined (Table 1). Intraoperative data included irrigant, supplemental irrigation, intracanal medicament, duration of canal medication, bonding application, collagen placement on the blood clot, type and level of capping material, and type of coronal restoration. Postoperative data included recall period, tooth function, cause (if any) of failure, clinical signs and symptoms, response to sensibility test, status of coronal restoration, radiographic periapical healing, and root development.

The primary outcome measures for regenerative endodontic procedures were functional retention—the treated tooth retained in the dental arch at recall without clinical signs and symptoms—and success rate, for which results were divided into 3 outcomes:

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■ **healed:** no clinical signs or symptoms and no periapical radiolucencies

■ **healing:** periapical radiolucency reduced in size with no clinical signs or symptoms

■ **disease:** having clinical signs/symptoms and/or a newly emerged or persisting increased size periapical radiolucency

Radiographic evidence of continued root development was the secondary outcome measure, and responsiveness to sensibility testing was the tertiary outcome measure.

The success rate was 80% (96 teeth), 97.5% of all teeth were functional. A multivariate analysis showed that 2 significant factors for disease were stage III root formation and patients aged ≥ 12 years. However, healing in patients aged ≥ 12 years with stage IV or V root formation was not significantly different from that of patients aged < 12 years. Continued root development correlated with patient age and etiology of pulpal disease from caries or dental anomalies. The 2 significant factors for response to pulpal sensibility testing were the use of ethylenediaminetetraacetic acid (EDTA) before creating a blood clot and the level of capping material at or above the cemento-enamel junction.

Conclusion

Regenerative endodontic procedures on immature permanent teeth were effective in patients < 12 years of age whose disease was not caused by caries or dental anomalies. The overall success rate of 80% and the functional retention rate of 97.5% suggest that regenerative endodontic procedures

are an effective treatment in the great majority of immature permanent teeth.

Theekakul C, Banomyong D, Osiri S, et al. Mahidol study 2: treatment outcomes and prognostic factors of regenerative endodontic procedures in immature permanent teeth. J Endod 2024;50:1569-1578.

Nosocomial Endodontic Infections and Bacteremia

Studies have suggested that a significant proportion of patients undergoing invasive dental procedures, such as tooth extraction, periapical curettage, raising surgical flap and root canal treatment, will test positive for bacteremia, which can be associated with septic conditions in immunocompromised patients and may affect the clinical outcome in patients undergoing endodontic procedures. To further investigate bacteremia associated with apical periodontitis and endodontic retreatment, Bakhsh et al from Umm Al-Qura University, Saudi Arabia, used next-generation sequencing to identify the pathogens found in the saliva, blood and root canals of patients, along with those found on practitioners' gloves.

The study included 65 medically fit patients undergoing either root canal retreatment or periapical surgery at a postgraduate endodontic clinic. Researchers obtained 5 samples from each patient:

- preoperative saliva
- pre- and postoperative blood
- intracanal samples from the retreatment group after access preparation and again before root canal obturation

Two samples were obtained from the operating clinicians' gloves: immediately after putting them on and at the end of the procedure before removing them. Bacterial DNA was extracted from all samples, and each microbiome was profiled.

Seven different bacterial taxa were found in both saliva and postaccess intracanal samples—*Streptococcus*, *Prevotella*, *Neisseria*, *Actinomyces*, *Rothia*, *Fusobacterium* and *Porphyromonas*. *Streptococcus* was the most prevalent taxon found in saliva, while *Enterococcus* was the most prevalent in intracanal samples (Table 2). Samples from preoperative gloves showed 17 genera and 18 from postoperative glove samples; in both cases, *Cutibacterium* was most prevalent. A significant decrease in *Cutibacterium* on gloves was seen postoperatively, while significant increases were seen for *Streptococcus*, *Actinomyces* and *Rothia*, suggesting that the gloves may have become contaminated from the patients' oral cavities.

In both root canal retreatment and periapical surgery groups, bacteremia was present in pre- and postoperative blood samples; 24 different genera were identified in the preoperative samples and 21 in the postoperative

Table 1. Stages of root development.

Stage I root formation:	in early stage
Stage II root formation:	one-quarter of root length
Stage III root formation:	one-half of root length
Stage IV root formation:	three-quarters of root length
Stage V root formation:	full-length root formation with a wide-open apical foramen
Stage VI root formation:	full-length root formation with a half-closed apical foramen
Stage VII root formation:	full-length root formation with complete apical closure

Table 2. Relative abundance of common taxa between saliva and postaccess intracanal samples.

Genus	Saliva Relative abundance	Intracanal Relative abundance
<i>Actinomyces</i>	7.0%	3.6%
<i>Fusobacterium</i>	2.2%	2.2%
<i>Neisseria</i>	8.6%	1.1%
<i>Porphyromonas</i>	2.0%	1.5%
<i>Prevotella</i>	17.6%	4.1%
<i>Rothia</i>	3.0%	1.5%
<i>Streptococcus</i>	25.4%	6.6%

samples. The most prevalent genera found in the blood samples were the nosocomial pathogens *Cutibacterium acnes* and *Staphylococcus*, which suggested a possible link between gloves and the blood microbiome. The presence of bacteremia in preoperative blood samples suggested an endodontic source for infection; several intracanal genera present in preoperative blood samples increased in postoperative blood samples, confirming the endodontic source of bacteremia. *Actinomyces*, *Afipia*, *Prevotella*, *Pseudomonas*, *Rothia*, *Sphingomonas* and *Streptococcus* were found in glove, intracanal and blood samples.

Conclusion

Root canal infections increase the risk of bacteremia, and pathogens released during treatment further elevate the risk. *Streptococcus* is the primary microbe associated with infective endocarditis. Bacteremia also may trigger a chronic inflammatory response that can lead to atherosclerosis, suggesting the need for pretreatment antibiotics for high-risk cardiac patients. Frequent changing of gloves by the practitioner is a practical step that can mitigate exposure to pathogens.

Bakhsh A, Moyes D, Mannocci F, et al. Links between nosocomial endodontic infections and

bacteremia associated with apical periodontitis and endodontic treatment. J Endod 2024;doi:10.1016/j.joen/2024.11.009.

Esthetic Restorations of Fractured Young Incisors

Dental esthetics has long been recognized as a factor in patient treatment. Traumatic dental injuries in young persons often result in fractured teeth requiring immediate treatment to restore the tooth's function and esthetics. The gold standard for an esthetically pleasing result in these situations has been composite resin restorations, employing a multi-shade layering approach that utilizes layers of composite with different optical parameters to mimic the look of natural teeth. Yet the practitioner's ability to create such restorations involves proficiency in complex, time-consuming clinical procedures requiring many hours in the chair, a lengthy time horizon that is often not practical for treating young patients.

The use of recently introduced monoshade composites eliminates the need for various shades while delivering superior esthetic outcomes, reducing the amount of chair time required for the restoration, making it an excellent approach, especially for younger patients. Çehreli from Hacettepe University, Türkiye, recently published a clinical review examining the use of monoshade composites with the composite cutback technique and how this procedure translates into restoring fractured teeth in young patients.

The composite cutback technique calls for the placement of an initial monoshade composite restoration followed by a selective reduction and subsequent addition of more translucent and/or enamel-like composite layers, allowing for better control over translucence and fluorescence, optical properties critical to achieving a proper esthetic appearance. They also adapt to surrounding tooth color. Using a permanent tooth strip crown form, a monoshade composite is placed, creating a natural-looking foundation. This eliminates the need for complex layering techniques involving a palatal index followed by the placement of composite resin layers with varying opacities and shades.

After completion of the monoshade restoration, the outermost composite layer is removed, creating space for the final enamel layer, incisal halo and inner dentinal anatomy, all critical for achieving desired translucency and optical characteristics. Following the application, shaping and curing of the final layers of transparent and translucent composites, the restoration is contoured and polished so it replicates the tooth's natural surface texture.

Conclusion

Although long-term evidence is not currently available for the clinical effectiveness of direct resin-based composite restorations in the anterior teeth, studies have shown a similar high survival rate for monochromatic and layered polychromatic resin build-ups after 4 years. This procedure eliminates technical complexity and chairside time required for composite build-up, along with the need for a separate visit for impressions and laboratory procedures for making a palatal index. Thus, the composite cutback technique with monoshade composites and permanent tooth strip crown forms offers an efficient and cost-effective single-visit solution to restore fractured anterior teeth in young patients.

Çehreli ZC. *Simplified composite restorations for fractured young incisors: a clinical review.* Dent Traumatol 2025;41(Suppl 1):38-42.

Use of Newer Bioceramics In Retrograde Apicoectomy

When persistent periapical lesions remain unresponsive to nonsurgical treatment, apicoectomy becomes the final treatment option. For many years, the retrograde filling material of choice has been mineral trioxide aggregate (MTA), because of its biocompatibility, excellent sealing capacity and ability to promote hard tissue formation. However, MTA has a long setting time and challenging handling properties; it can also cause discoloration of the tooth.

Newer bioceramics retain the advantages of MTA but with improved usability. Primarily calcium silicate-based cements, the newer bioceramics set in moist environments, release calcium ions, exhibit antimicrobial properties and form hydroxyapatite at the dentin interface. They can be used not only for root-end fillings but also for perforation repairs, pulp capping and regenerative endodontic procedures.

Barnaba et al from the University of Rome Tor Vergata, Italy, conducted a systematic review and meta-analysis, of available literature to evaluate the clinical evidence on the use of bioceramic materials in retrograde apicoectomy, and to evaluate their performance compared with conventional filling materials. Nineteen studies met the criteria of human clinical trials (including randomized controlled trials, prospective or retrospective cohort studies and comparative studies) employing bioceramic-based materials in root-end surgery with a follow-up of ≥ 6 months.

Bioceramic materials exhibited excellent sealing properties due to their hydrophilic nature and expansion upon setting, results confirmed by scanning electron microscopy and micro-computed tomography analyses. Calcium silicate-based cements generated minimal inflammatory response and encouraged tissue regeneration, periapical healing, new cementum formation and reattachment of the periodontal ligament; their high pH led to antimicrobial activity and promoted cellular differentiation. Clinical success rates ranged from 85% to 95%. Biodentine and premixed formulations had comparable or improved clinical outcomes compared with MTA.

A meta-analysis of 18 eligible studies showed a mean healing rate of 90.8%.

Most studies reported success rates of $>90\%$, with no studies reporting a success rate of $<83\%$, demonstrating a robust, consistent clinical performance of bioceramic materials among various patient populations and treatment protocols.

Conclusion

MTA demonstrates superior performance. Bioceramic materials release calcium and silicon ions that stimulate the deposition of hydroxyapatite-like crystals, enhancing long-term sealing and biological integration at the root-end interface. The alkaline environment created suppresses microbial growth and enhances mineralized tissue formation at the periapical site. Newer bioceramic materials perform equally as well as MTA while offering improved handling and clinical versatility.

Barnaba P, Rosa A, Gargari M, Martelli M. *The use of bioceramics in retrograde apicoectomy: a systematic review of clinical applications and outcomes.* Aust Endod J 2025;doi:10.1111/aej.12960.

In the next issue:

- Permanent tooth intrusion outcomes
- Dentinal surface roughness after apicoectomy
- Temporomandibular disorders and endodontic pain

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