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Review Article

# Review on regenerative endodontics: Past concepts, current protocols and future strategies

**M Robert Justin[1], Pranjali Naresh Patil*, Aditi Subhashchandra Sarda[1], Lalit Dattu Darade[1], Supriya Ramchandra Zanjad[1], Rupesh Bowlekar[1]**

[1]*Dept. of Conservative Dentistry and Endodontics, Aditya Dental College, Beed, Maharashtra, India*

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ABSTRACT

Till last few decades, a necrosed tooth with immature apex was an indication for apexogenesis. With advances in dentistry such as improved irrigation protocols, better visibility to the operating site and increased skills of endodontists, regenerative endodontic procedures have come into the limelight. The alongside research in tissue engineering also have been beneficial for researchers and endodontists to open new horizons in regenerative endodontics. This review paper involves the triad of tissue engineering, concepts of regenerative endodontics applied in past, current protocols according to American Association of Endodontists and future concepts of tooth tissue regenerations which are being researched.



## 1. Introduction

Traditionally immature necrosed teeth were being treated by apexification using calcium hydroxide and recently by using MTA. Drawbacks of this traditional approach were no continued root development and thin roots prone to fracture in future. Regenerative endodontics uses concept of tissue engineering to restore the root canals to a healthy state, allowing for continued root development and surrounding tissue. With the advances in tissue engineering and molecular sciences, the higher success rates can be achieved.

### *1.1. Definitions*

Tissue engineering is an interdisciplinary field that applies the principles of engineering and life sciences toward the development of biological substitute that restores, maintain or improve the tissue function or whole organ.[1] (Langar and Vacanti)

Tissue engineering is 'understanding the principles of tissue growth and applying this to produce functional replacement tissue for clinical use.[2] (McArthur and Oreffo)

Regenerative endodontic procedures (REP) defined as biologically based procedures designed to replace damaged structures as dentin, root structure and cells of pulp dentin complex.[3] (Murray)

### *1.2. History*[4]

Dr B. W Hermann (early 1960): Application of Calcium Hydroxide [$Ca(OH)_2$] for vital pulp therapy

Nygaard-Ostby, 1961: Established a blood clot to use as a scaffold to re-vascularize tissue within the root canals of teeth

Rule DC, 1966: Use of double antibiotic paste

Hoshino, 1993: Use of triple antibiotic paste

Iwaya, 2001: Evoked intracanal bleeding step

* *Corresponding author.*
*E-mail address*: pranjalipatil19@gmail.com (P. N. Patil).

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### 1.3. Triad of tissue engineering[5]

#### 1.3.1. Stem cells

Stem cells are undifferentiated cells that divide and response to specialised cells on response to morphogens. Stem cells are defined as "Distinct subpopulation of undifferentiated cells with self-renewal and differentiation potential."

### 1.4. Characteristics of stem cells

1. Exist as undifferentiated cells and maintain this phenotype by the environment and/or the adjacent cell populations and they are exposed to and respond to appropriate signals.
2. Ability to self-replicate for prolonged period.
3. Maintain their multiple differentiation potential throughout the life of the organism.

### 1.5. Categories of stem cells

#### 1.5.1. According to their source

Autologous cells: Obtained from same individual to whom it will be replanted.

Allogeneic cells: Obtained from body of the donor of same species.

Xenogeneic cells: Isolated from individuals of another species. Eg: Animal cells in construction of cardiovascular implants.

Syngeneic/ Isogenic cells: Isolated from genetically identical organisms. Eg. Twins, Clones.

### 1.6. According to their potency

Totipotent: Cells that can differentiate into new organisms. Eg. cells from early embryos.

Pluripotent: Cells that can differentiate into nearly all cells but not entire organism. Eg. Blastocyst

Multipotent: Cells that can differentiate into limited range of cells. Eg. Fetal tissues, Cord blood, Dental pulp stem cells (DPSCs)

### 1.7. Different populations of adult stem cells in the oral region

| | |
|---|---|
| **SCAP** | Stem cells of apical papilla |
| **iPACs** | Inflammatory periapical progenitor cells |
| **DFSCs** | Dental follicle stem cells |
| **DPSCs** | Dental pulp stem cells |
| **PDLSCs** | Periodontal ligament stem cells |
| **BMSCs** | Bone marrow stem cells |
| **TGPCs** | Tooth germ progenitor cells |
| **SGSCs** | Salivary gland stem cells |
| **SHED** | Stem cells from human exfoliated deciduous teeth |
| **OESCs** | Oral epithelium derived stem cells |
| **GMSCs** | Gingival derived mesenchymal stem cells |
| **PSCs** | Periosteal derived stem cells |

### 1.8. Stem cells markers

Cells coated with surface receptors such as proteins have capability of selectively binding to other signalling molecules. Stem cells markers have ability to fluoresce or emit light energy when activated by UV light or Laser beam. They help in identification and isolation of stem cells.

### 1.9. Isolation of stem cells

1. By staining the cells with specific antibody markers and using flow cytometer. This process is called as "Fluorescent antibody cell sorting (FACS)".
2. Physiological/ Histological criteria of isolation of stem cells are by phenotype, chemotaxis, proliferation, differentiation and mineralization.
3. Immunomagnetic bead selection.
4. Immunohistochemical staining.

#### 1.9.1. Growth factors / Morphogens / Signaling Molecules

These factors trigger the differentiation of selected mesenchymal stem cells into odontoblast like cells. Their functions are:

1. To stimulate division of neighbouring cells.
2. To stimulate differentiation of certain cells along a specified pathway.
3. To stimulate angiogenesis.
4. Dentin is considered as a reservoir of growth factor and cytokines. These growth factors /cytokines secreted by odontoblast during primary dentinogenesis become sequestrated and fossilized into the dentin after biomineralization.[6]

### 1.10. Different growth factors

1. Growth hormone (Paracrine/ Autocrine role)
2. Insulin like growth factor (IGF-1, IGF-2)
3. Transforming growth factor β (TGF β-1, TGF β-2, TGF β-3)
4. Bone morphogenic proteins (BMP-2, BMP-4, BMP-6)
5. Fibroblast growth factors (FGFs)
6. Tumour necrotic factors (TNFs)
7. Colony stimulating factors
8. Interlukins
9. Platelet derived growth factors (PDGF)
10. Nerve growth factors (NGF)

### 1.11. Morphogens

1. Second level of regulation by transcription factor MSX-1 and MSX-2.
2. Toll like receptors (TLR-4 activated by lipopolysaccharides).

Patients taking long term corticosteroids present with dramatic reduction in radiographic size of pulp chamber and upto fivefold increase in thickness of predentin layer.[7]

#### *1.11.1. Scaffold / Matrix*

Scaffold provides a physiochemical and a biological three dimensional micro-environment for cell growth and differentiation, promoting cell adhesion and migration. Scaffold is used to guide, organize and provide physical or chemical signals and help in growth and differentiation of cells.

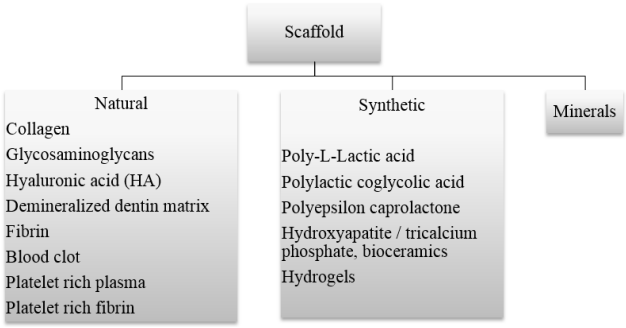
Scaffold is necessary to,

1. Provide a spatially correct position of cell location.
2. Regulate differentiation, proliferation or metabolism while promoting nutrient / gaseous exchange.

### *1.12. Properties of ideal scaffold*[8]

1. Should be porous to allow placement of cells and growth factors.
2. Should allow effective transport of nutrients, oxygen and waste.
3. Should be biodegradable, leaving no toxic by-products.
4. Should be replaced by regenerative tissue while retaining the shape and form of the final tissue structure.
5. Should be biocompatible.
6. Should have adequate physical and mechanical strength.

**Classification of scaffold**




### *1.13. Overview of regenerative endodontics*

Traditionally immature roots were treated by apexification using calcium hydroxide or apical plug of MTA. This procedure resolved the signs and symptoms but no continued root development or pulpal nociception was seen.

Regenerative endodontic procedures (REPs) are biologically based procedures designed to replace damaged structures as dentin, root structures and cells of pulp dentin complex. It aims to,

1. Heal apical periodontitis.
2. Promotes normal pulpal physiological functions.
3. Continued root development.
4. Immune competency.
5. Normal nociception.

Blood clot could be the first step in healing of damaged dental pulp, similar to role of blood clot in healing of other areas. (Eg. Alveolar socket after extraction)[9]

### *1.14. According to clinical studies on regenerative endodontics mentioned in Cohen's pathways of pulp 12th edition,*[5]

Initially, there was strong focus on disinfection and intentional bleeding into the root canal. But there is paradigm shift from "disinfect canals at all cost" to "disinfect while creating a micro-environment conducive for tissue engineering." Other terms for regenerative endodontics are: Revascularization, Revitalization, Maturogenesis.

According to the American association of Endodontists (AAE), clinical consideration for a regenerative procedure, primary goal of regenerative procedure is elimination of clinical symptoms and resolution of apical periodontitis. Secondary goal is thickening of canal walls and continued root maturation. Tertiary goal is to have a positive response from pulp vitality.[10]

### *1.15. Different techniques of tissue engineering*[3]

1. Root canal vascularization via blood clotting
2. Post natal stem cell therapy
3. Pulp implantation
4. Scaffold implantation
5. Injectable scaffold delivery
6. 3-D cell printing
7. Gene delivery

### *1.16. Root canal vascularization via blood clotting*

Incompletely formed roots (often blunderbuss) present difficulty in cleaning and shaping of the apical portion of the root canal. Presence of thin fragile dental walls may prone to fracture during instrumentation or obturation of root canal which possess risk of extruding materials into periradicular tissues. To treat this, traditionally apexification was choice of treatment which means creating apical barrier to prevent extrusion. But major disadvantages of apexification procedure are:

1. Reduced root strength
2. No further root development

So, American Association of Endodontists recommends clinical considerations for Regenerative Endodontic procedures as follows:[10]

Ideal case selection would be young patients with immature infected teeth where cessation of root maturation has occurred. Three measures advocated by American Association of Endodontists clinical considerations for Regenrative Endodontic procedures are.

*1.16.1. Minimal or no instrumentation of dentinal walls*

Regenerative endodontic procedures advocate minimal or no filing of the canal. Although some studies suggest formation of biofilms and penetration into dentinal tubules in histologic studies.[5] Some degree of mechanical debridement may also be required to disrupt biofilms on canal walls for continued root maturation.[11]

*1.16.2. Disinfection of the root canal system*

Copious irrigation with 20ml sodium hypochlorite with close ended needle / side vented needle / Endovac / Max I probe is recommended. Lower concentration of sodium hypochlorite (1.5%) (20ml / canal for 5 mins) is advised followed by irrigation with saline / EDTA (20ml / canal for 5 mins) with irrigating needle positioned about 1 mm from root end to minimize cytotoxicity to stem cells in apical tissues. Higher concentrations of NaOCl decreases survival of SCAP.

Use of 1.5% NaOCl has minimal destructive effect on SCAP whereas use of 17% EDTA increases SCAP survival.[12] According to Galler 2015, EDTA demineralizes dentin which exposes dentin matrix which in turn releases growth factors.[13] Irrigation with Chlorhexidine should be avoided due to its cytotoxicity to stem cells.[14]

*1.16.3. Placement of an intracanal medicament*

AAE Protocol is to use Triple Antibiotic Paste (TAP) at concentration no greater than 0.5mg/ml (Conducive to stem cell survival). TAP contains Metronidazole, Ciprofloxacine and Minocycline in the ratio 1:1:1.

Creation of blood clot / protein scaffold in canal after resolution of symptoms. REP involves lacerating periapical tissues to initiate bleeding or use of PRF / PRP.

Effective coronal seal is of importance after formation of blood clot. Premeasured piece of Collaplug on the top of blood clot to serve as internal matrix for placement of approximately 3 mm of MTA followed by 3-4 mm layer of GIC bonded by Reinforced composite over it.

*1.16.4. Clinical procedure involving regenerative endodontic procedure.*[10,15]

*1.16.5. Outcome assessment*

The goal of REP is to have continued root development and reestablishment of pulp vitality. REP resulted in 31.6% increase in radiographic root area. (RRA)[16]

According to Jeeruphan 2012, Survival rate of revascularization is 100% versus 95% for MTA apexification and 71.2%for calcium hydroxide apexification.[17]

Chen et al. 2012 described 5 types of responses for teeth treated with REPs

1. Increased thickness of root canal walls and continued root maturation.
2. No significant continuation of root development with root apex becoming blunt and close.
3. Continued root development with apical foramen remaining open.
4. Severe calcification of canal space.
5. Hard tissue barrier formed in the canal between coronal MTA plus and root apex.

*1.16.6. Possible mechanisms for continued root development followed by REPs*[18]

1. Few vital pulp cells remain at the apical end: They have ability to proliferate and differentiate into odontoblasts guided by the intact HERs.
2. Periodontal ligament stem cells: This possibility is valid in case of destruction of HERs and apical papillary tissues.
3. SCAP: instrumentation beyond apical limit of canal leads to transplantation of SCAP into tissue lumen
4. Blood Clot itself: Blood clot is reservoir of growth factors such as PDGF, TGF etc. It stimulates differentiation, growth, maturation of fibroblast, odontoblast and cementoblast from their undifferentiated precursors.

*1.16.7. Complications associated with REPs*

1.16.7.1. Discolouration . Discolouration is more associated with TAP due to minocycline. It is also associated with calcium hydroxide / MTA. To treat discolouration, walking bleach using sodium perborate can be performed.

1.16.7.2. Collapse of MTA material into the canal. This can be managed by keeping Collaplug above the blood clot and waiting for atleast 15 minutes after inducing bleeding.

Teeth requiring retention in canal space by using posts are contraindications for REPs.

*1.17. Post natal stem cell therapy*

Stem cell categories are

1. Embryonic (Pluripotent): Isolated from blastocyst. They can give rise to all derivatives of 3 germ layers.
2. Post natal cells: Collected from bone marrow / umbilical cord blood. They are less plastic, have limited potential of differentiation.

Stem cells of dental origin are:

DPSCs: Responsible for dental repair.

Can regenerate pulp-dentin like complex.

**Table 1:** American association of endodontists clinical consideration for a regenerative procedure

| | |
|---|---|
| **Case Selection** | |
| **1.** | Tooth with necrotic pulp and an immature apex. |
| **2.** | Pulp space not needed for post/core, final restoration. |
| **3.** | Compliant patient/parent. |
| **4.** | Patients not allergic to medicaments and antibiotics necessary to complete procedure (ASA 1 or 2). |
| **Informed Consent** | |
| **1.** | Two (or more) appointments. |
| **2.** | Use of antimicrobial(s). |
| **3.** | Possible adverse effects: staining of crown/root, lack of response to treatment, pain/infection. |
| **4.** | Alternatives: MTA apexification, no treatment, extraction (when deemed non salvageable). |
| **5.** | Permission to enter information into AAE database (optional). |
| **First Appointment** | |
| **1.** | Local anesthesia, dental dam isolation and access. |
| **2.** | Copious gentle irrigation with 1.5% NaOCI (20 ml/canal, 5 min) followed by irrigation with saline (20 ml/canal, 5 min), with irrigation needle positioned about 1 mm from root end |
| **3.** | Dry canals with paper points. |
| **4.** | Place calcium hydroxide or low concentration of triple antibiotic paste. If the triple antibiotic paste is used: 1) consider sealing pulp chamber with a dentin bonding agent (to minimize risk of staining) and 2) mix 1:1:1 ciprofloxacin: metronidazole: minocycline to a final concentration of 0.1 mg/ml. |
| **5.** | Deliver into canal system via syringe. |
| **6.** | If triple antibiotic is used, ensure that it remains below CEJ (minimize crown staining). |
| **7.** | Seal with 3-4 mm of a temporary material such as Cavit, IRM, glass-ionomer or another temporary material. Dismiss patient for 1-4 weeks. |
| **Second Appointment (1-4 weeks after $1^{st}$ visit)** | |
| **1.** | Assess response to initial treatment. If there are signs/symptoms of persistent infection, consider additional treatment with antimicrobial, or alternative antimicrobial. |
| **2.** | Anesthesia with 3% mepivacaine without vasoconstrictor, dental dam isolation. |
| **3.** | Copious, gentle irrigation with 20 ml of 17% EDTA. |
| **4.** | Dry with paper points. |
| **5.** | Create bleeding into canal system by over-instrumenting (endo file, endo explore) (induce by rotating a pre-curved K-file at 2 mm past the apical foramen with the goal of having the entire canal with blood to the level of cement-enamel junction). Stop bleeding at a level that allows for 3-4 mm of restorative material. |
| **6.** | Place a resorbable matrix such as CollaPlug. Collacote. CollaTape or other material over the blood clot if necessary and white MTAiCa011 as capping material. A 3-4mm layer of glass ionomer (e.g.. Fuji IILCFM. GC America. Alsip. IL) is Bowed gently over the capping material and light-cured for 40s. Alternatives to MTA (such as bioceramics or tricalcium silicate cements [e.g.. Biodentinelk Septodont. Lancasted. PA, USA. EndoSequence10 BC RRM-Fast Set Putty, Brassekr. USA)) should be considered in teeth where there is an esthetic concern. |
| **7.** | Anterior and premolar teeth - Consider use of Collatape/Collaplug and restoring with 3mm of RMGI followed by bonding a filled composite to the beveled enamel margin. |
| **8.** | Molar teeth or teeth with PFM crown - Consider use of Collatape/Collaplug and restoring with 3mm of MTA. Followed by RMGI or alloy. |
| **Follow-up (6-, 12-, 24-months)** | |
| **1.** | Clinical and Radiographic exam |
| **2.** | No pain. soft tissue swelling or sinus tract (often observed between first and second appointments). |
| **3.** | Resolution of apical radiolucency (often observed 6-12 months after treatment) |
| **4.** | Increased width of root walls (this is generally observed before apparent increase in mot length and often occurs 12-24 months after treatment). |
| **5.** | Increased root length. |
| **6.** | Positive Pulp vitality test response |
| **7.** | Recommended yearly follow-up after the first 2 years |
| **8.** | CBCT is highly recommended for initial evaluation and follow-up visits |

SHED: Can differentiate into odontonblast-like cells that form dentin like structures.

PDLSCs: Present in enzymatically digested PDL.

Can form cementum / PDL like structures.

SCAP: Found at apices of developing teeth at junction of apical papilla and dental pulp. They can undergo odontoblastic, osteogenic, neurogenic differentiation.

In post natal stem cell therapy, cells are injected in infected root canal.

### *1.18. Pulp implantation*

1. Pulp tissue grown in library is transplanted to disinfected root canal.
2. Pulp tissue is grown in sheets of biodegradable polymer nanofibers. (in vitro)
3. Sheets are rolled together to form 3-D pulp tissue.
4. Drawback is this procedure does not ensure whether cells are properly adhered to the wall.

### *1.19. Scaffold implantation*

During dental pulp regeneration, an ideal scaffold should also ensure good neurovascular supply to new pulp tissue. Eg. DPSCs are seeded on 3-D polyglycolic acid matrix, grown in vitro and surgically implanted.

### *1.20. Injectable scaffold delivery*

1. Polymerizable hydrogel alone / containing cell suspensions are delivered by injections. It may provide regeneration by providing substitute for extracellular matrix. (ECM)
2. Drawbacks are low cell survivals and limited control over tissue formation.

### *1.21. 3-D cell printing*

1. It is used to precisely position the cells and thus constructed tissue mimics the natural dental pulp tissue structure.
2. Inkjet device is used to disperse the layers of cells suspended in hydrogel to recreate dental pulp tissue.
3. Precise 3-D models for individual pulp cavity and effective delivery system are required.

### *1.22. Gene delivery*

It is the means of delivering genes for growth factors, morphogens and ECM molecules to somatic cells of individual resulting in therapeutic effect.

#### *1.22.1. Recent studies done in the field of Regenerative endodontics*

1. Shah N. et al. 2012[19] introduced a recent novel technique named as "**sealbio**" which is regeneration based non obturation technique for management of pulp and periapical tissues involved matured permanent teeth.

   This technique incorporates the apical clearing meaning preparation larger than 3 sizes of master apical file. (MAF) also known as apical foramen widening followed by intentional over-instrumentation. (Scaffold of blood clot)

   It is hypothesized that endogeneous, locally residing stem cells will populate the scaffold, differentiate into forming cells and lay down fibrous / cemental tissue to achieve a biologic seal over the apical foramen, hence the term sealbio.
2. Roots et al. 2009 suggested endodontic grafting. It involves filling of root canal with ceramic sealer which acts as osteoconductive. It promotes the physiological closure of the root canal by cementoid hard tissue. (Eg. Bioaggregate and iRoot SP)
3. Nakahara et al. 2007[20] suggested whole tooth generation by tooth/ periodontal organ engineering.

## 2. Conclusion

Regenerative endodontics present a new era in biological and clinical endodontics. Further research in the area of stem cell based pulp engineering will allow for true regeneration.

## 3. Conflict of Interest

The author declares no potential conflicts of interest with respect to research, authorship, and/or publication of this article.

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## References

1. Langer R, Vacanti JP. Tissue engineering. *Science*. 1993;260(5110):920–6.
2. Macarthur BD, Oreffo ROC. Bridging the gap. *Nature*. 2005;(6):19–19.
3. Murray PE, Garcia-Godoy F, Hargreaves KM. Regenerative endodontics: a review of current status and a call for action. *J Endod*. 2007;33(4):377–90.
4. Chandra B, Gopikrishna V. Gopikrishna. Grossman's endodontic practice, 13th Edn. Wolters Kluwer Health; 2014.
5. Berman LH, Hargreaves KM. Cohen's Pathways of the Pulp, 12th Edition. St. Louis, Mo: Mosby Elsevier; 2011.
6. Smith AJ. Vitality of the dentin-pulp complex in health and disease: growth factors as key mediators. *J Dent Educ*. 2003;67(6):678–89.
7. Nasstrom K. Dentin formation after corticosteroid treatment. A clinical study and an experimental study on rats. *Swed Dent J*. 1996;115:1–45.
8. Saber SE. Tissue engineering in endodontics. *J Oral Sci*. 2009;51(4):495–7.
9. Nygaard-Ostby B. Tissue formation in the root canal following pulp removal. *Scand J Dent Res*. 1971;79(5):333–49. doi:10.1111/j.1600-0722.1971.tb02019.x.

10. American Association of Endodontists (AAE) (2016) ClinicalConsiderations for a Regenerative Procedure; 2016.
11. Lin LM, Shimizu E, Gibbs JL, Loghin S, Ricucci D. Histologic and histobacteriologic observations of failed revascularization/revitalization therapy: a case report. *J Endod*. 2014;40(2):291–5. doi:10.1016/j.joen.2013.08.024.
12. Martin DE, Almeida JD, Henry MA, Khaing ZZ, Schmidt CE, Teixeira FB, et al. Concentration-dependent effect of sodium hypochlorite on stem cells of apical papilla survival and differentiation. *J Endod*. 2014;40(1):51–5.
13. Galler KM, Buchalla W, Hiller KD. Influence ofroot canal disinfectants on growth factor release from dentin. *J Endod*. 2015;41(3):363–8. doi:10.1016/j.joen.2014.11.021.
14. Trevino EG, Patwardhan AN, Henry MA. Effectof irrigants on the survival of human stem cells of the api-cal papilla in a platelet-rich plasma scaffold in human roottips. *J Endod*. 2011;37(8):1109–15. doi:10.1016/j.joen.2011.05.013.
15. Pulyodan MK, Mohan SP, Valsan D, Divakar N, Moyin S, Thayyil S, et al. Regenerative endodontics: A paradigm shift in clinical endodontics. *J Pharm Bioall Sci*. 2020;12(5):20–6.
16. Flake NM, Gibbs JL, Diogenes A, Hargreaves KM, Khan AA. A standardized novel method to measure radiographic root changes after endodontic therapy in immature teeth. *J Endod*. 2014;40(1):46–50.
17. Jeeruphan T, Jantarat J, Yanpiset K, Suwannapan L, Khewsawai P, Hargreaves KM, et al. 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(10):1330–6.
18. Nagy MM, Tawfik HE, Hashem AA, Abu-Seida AM. Regenerative potential of immature permanent teeth with necrotic pulps after different regenerative protocols. *J Endod*. 2014;40(2):192–8.
19. Shah N, Logani A. SealBio: A novel, non-obturation endodontic treatment based on concept of regeneration. *J Conserv Dent*. 2012;15(4):328–32.
20. Nakahara T. Tooth/periodontal organ engineering: the ultimate goal of tooth regeneration. In: Tissue Engineering Research Trends. 1st Edn. Nova Science Publishers; 2008. p. 7–13.

## Author biography

**M Robert Justin,** Professor and HOD

**Pranjali Naresh Patil,** Final Year Post Graduate Student

**Aditi Subhashchandra Sarda,** Senior Lecturer

**Lalit Dattu Darade,** Final Year Post Graduate Student

**Supriya Ramchandra Zanjad,** 2nd Year Post Graduate Student

**Rupesh Bowlekar,** 2nd Year Post Graduate Student

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