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From Waste to Wonder: The Story of Dentin Grafts In Periodontal Regeneration

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Abstract

Periodontal regeneration is defined as the regeneration of the tooth's supporting tissues, including alveolar bone, periodontal ligament, and cementum over a previously diseased root surface.(1)One of the major challenges in dentistry is achieving consistent and predictable regeneration of alveolar bone lost as a result of periodontitis. Bone grafting is a surgical procedure performed to restore or replace deficient bone using material derived from the patient or from artificial, synthetic, or naturally sourced substitutes. Owing to the close chemical resemblance between dentin and bone, extracted teeth can also serve as an alternative source of graft material.

Tooth-derived grafts are useful in periodontal treatment for filling intraosseous defects, preserving extraction sockets, ridge augmentation, and guided bone regeneration. Rather than being discarded, extracted teeth can be processed into a biocompatible graft material that promotes bone regeneration and may offer advantages over many conventional graft options.

This review summarizes the biological basis, processing techniques, and clinical applications of tooth-derived grafts, emphasizing their promise in advancing regenerative periodontal therapy.

Introduction

The periodontium is a dynamic supporting apparatus of the tooth, consisting of four main components: the gingiva, cementum, periodontal ligament (PDL), and alveolar bone.

Periodontitis is defined as "an inflammatory disease of the supporting tissues of the teeth caused by specific microorganisms, resulting in progressive destruction of the periodontal ligament and alveolar bone with pocket formation, recession, or both".(1)

The ultimate goal of periodontal therapy is to preserve teeth in functional health and comfort while fulfilling esthetic demands. Treatment is traditionally organized into three phases. The cause-related (Phase I) therapy aims to control microbial and behavioral risk factors, thereby halting disease progression. The surgical (Phase II) phase focuses on managing the sequelae of periodontitis, such as periodontal pockets and mucogingival defects.

Its objective is ideally the regeneration of lost periodontal support through new attachment techniques. Finally, the maintenance or supportive (Phase III) phase seeks to prevent recurrence of disease and ensure long-term stability.

Conventional pocket reduction methods such as surgical debridement and resective procedures improve clinical parameters—such as bleeding on probing, probing depth, and clinical attachment level—but their ability to regenerate lost structures remains limited and unpredictable. Contemporary surgical approaches therefore emphasize true regeneration, defined as the restoration of alveolar bone, periodontal ligament, and cementum in their original architecture and function.

PERIODONTAL REGENERATION:

Regeneration is the process which involves the restoration, reconstitution and reconstruction of the tissue lost due to trauma or disease. Periodontal regeneration is defined histologically as regeneration of the tooth's supporting tissues, including alveolar bone, periodontal ligament, and cementum over a previously diseased root surface.(2)

Periodontal regeneration refers to the complete restoration of periodontal tissues in both structure and function, including the formation of new alveolar bone and a functional connective tissue attachment, with collagen fibers inserted into newly formed cementum.(3) Ideally, management of intrabony and furcation defects should achieve not only reductions in probing depth, gains in clinical attachment, and radiographic evidence of bone fill, but also true defect resolution through regeneration.(4)

A major ongoing challenge in dentistry is the regeneration of alveolar bone lost due to periodontitis. This process is complex and multifactorial, requiring a well-coordinated sequence of biological events such as cell adhesion,

migration, proliferation, and differentiation, along with the recruitment of local progenitor osteoblastic cells to the affected site. Regeneration of the tooth-supporting structures can be facilitated using a variety of natural and synthetic materials. Among the most well-established approaches are bone grafting and Guided Tissue Regeneration (GTR). (3)

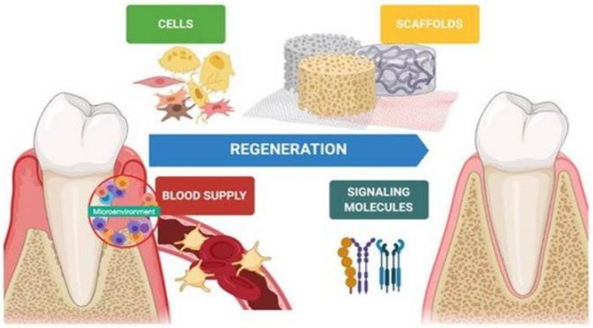

Fig 1:Requirements for ideal periodontal regeneration

1.GUIDED TISSUE REGENERATION (GTR):

Guided tissue regeneration (GTR) refers to procedures aimed at restoring lost periodontal structures by promoting selective cellular repopulation, primarily focusing on regeneration of the periodontal attachment.(2)

This technique involves placing a mechanical barrier to prevent the rapid migration of epithelial and gingival connective tissue cells into the wound site. By creating a protected space, it allows periodontal ligament and bone cells to repopulate the area and re-establish the tooth's attachment apparatus. Various barrier materials—such as expanded polytetrafluoroethylene (ePTFE), polyglactin, polylactic acid, calcium sulfate, and collagen—are used with the intention of excluding epithelium and gingival connective tissue, as these are thought to hinder true regenerative healing.(3)

2.BONE GRAFTING:

Bone grafting is a surgical procedure used to restore deficient bone by placing graft material obtained from the patient (autogenous) or from artificial, synthetic, or natural substitutes.(5) These materials may originate from vital or non-vital bone sources and can be composed of organic or inorganic components. Bone grafts function as a scaffold, supporting new bone formation and enhancing wound healing. They are generally bioresorbable and do not elicit antigen–antibody reactions, while also acting as a mineral reservoir that promotes osteogenesis.

The primary rationale for using bone grafts or biomaterials in periodontal regenerative therapy is to provide a matrix for the delivery of biologically active agents (such as growth factors or enamel matrix derivatives) and to maintain space by preventing collapse of the mucoperiosteal flap, thereby facilitating optimal conditions for regeneration.

Graft:

A graft is a material that, once harvested from a donor site, is transplanted into a defect area to restore, repair, or regenerate the lost tissue.

Osteoconduction:

A process in which the graft matrix serves as a scaffold, allowing osteoblasts from the surrounding bone to migrate into it and form new bone by using it as a structural framework.

Osteoinduction:

Osteoinduction refers to the process by which progenitor cells are recruited to the grafted site and stimulated to differentiate into preosteoblasts. BMPs are osteoinductive cell mediators that are present in autografts, allografts and xenografts.

Osteopromotion:

Osteopromotion refers to the augmentation of osteoinduction without having intrinsic osteoinductive capacity. For instance, enamel matrix derivative can enhance the osteoinductive potential of demineralized freeze-dried bone allograft (DFDBA), but it does not independently induce bone formation.

Osteogenesis:

It refers to the intrinsic ability of osteoblasts present within the graft to independently generate new bone, a property most commonly associated with autogenous bone grafts.(1, 2, 5)

Ideal requirements for bone grafts or bone graft substitutes include:

1. High biocompatibility
2. Reliable and predictable outcomes
3. Ease of clinical application
4. Low risk during the surgical procedure
5. Minimal post-operative complications
6. Good patient acceptance(5)

CLASSIFICATION OF BONE GRAFTS USED IN PERIODONTICS:

	Autograft	Allograft	Xenograft	Alloplast
Description	Bone obtained from the same individual	Bone obtained from a different individual of the same species from commercial tissue banks	Bone obtained from a different species from which all cellular and protein material has been removed	Synthetic, biocompatible, and sometimes bioactive bone substitute
Examples	• **Intraoral source:** Osseous coagulum bone blend • **Extraoral source:** Cancellous bone marrow from iliac crest	• Demineralized freeze-dried bone allograft (DFDBA) • Freeze-dried bone allograft(FDBA)	• Bovine derived hydroxyapatite • Porcine derived • Equine derived	• **Organic:** Dentin, cementum, collagen, corals • **Inorganic:** Plaster of Paris, bioceramics (hydroxyapatite, tricalcium phosphate), bioactive glass, polymers (PMMA/ HEMA)
Role in bone regeneration	Osteogenic Osteoinductive Osteoconductive	Osteoconductive (DFDBA–possibly osteoinductive)	Osteoconductive	Osteoconductive

Fig 2: Types of bone grafts used in Periodontics

AUTOGRAFTS:

Autogenous bone grafts, obtained from the same individual, are regarded as the ideal grafting material due to their osteoconductive and osteoinductive properties. They also provide viable osteoprogenitor cells, which is why they are considered the gold standard among bone graft materials.There are

several sites in the human body from which autogenous bone grafts can be harvested.
Intraoral autogenous grafts can be obtained from sites such as the maxillary tuberosity, edentulous ridges, healing bony defects, extraction sockets, and the mental and retromolar regions. Extraoral sources, particularly cancellous bone and marrow from the iliac crest, exhibit strong osteogenic potential. However, a major limitation of autogenous grafts is donor site morbidity, as their procurement necessitates an additional surgical procedure.(6, 7)

ALLOGRAFTS:
Allografts are bone grafts obtained from one individual and transplanted into another individual of the same species. They are commonly sourced from cadavers and preserved in bone banks. The main types of bone allografts include:
1. Fresh or fresh-frozen bone
2. Freeze-dried bone allograft (FDBA)
3. Demineralized freeze-dried bone allograft (DFDBA)

Before being used in bone defects, allografts must undergo processing to ensure sterilization and to inactivate proteins that may elicit antigenic reactions. During preparation, the inorganic component of the bone is reduced or removed, thereby exposing the organic matrix—particularly the osteoinductive elements of the demineralized bone matrix (DBM)—which play a key role in promoting bone regeneration.(6, 7)

XENOGRAFTS:
Xenografts refer to bone graft materials obtained from species other than humans, commonly of bovine or porcine origin. One widely used example is an anorganic bovine-derived bone marketed as Bio-Oss, which has demonstrated effectiveness in both periodontal defect management and implant procedures. This material consists of a porous, osteoconductive bone mineral matrix derived from bovine cancellous or cortical bone.(6, 7)

ALLOPLASTIC GRAFTS:
Alloplastic grafts are synthetic bone substitutes that primarily function as passive fillers. They contribute very little to connective tissue regeneration and lack the osteogenic capacity seen in autografts. Absorbable alloplastic materials include ceramics such as beta-tricalcium phosphate, hydroxyapatite (HA), calcium sulfate, and calcium carbonate. In contrast, non-absorbable options comprise porous and dense forms of hydroxyapatite, bioglass, and calcium-coated polymers made from hydroxyethyl methacrylate and polymethyl methacrylate (PMMA).(6)

TOOTH DERIVED GRAFTS:
Autogenous bone is widely regarded as the gold standard in bone grafting, although it does have certain drawbacks. To address these limitations, there has been growing interest in alternative graft materials, prompting extensive research into various regenerative techniques over time. The biochemical similarity between dentin and bone has further supported the concept of utilizing dentin as a potential material for bone regeneration.(8)

INORGANIC AND ORGANIC COMPONENTS OF DENTIN:
Teeth are composite biological structures made up of both mineral and organic components. The inorganic portion is largely derived from calcium phosphate compounds, including hydroxyapatite, tricalcium phosphate (TCP), octacalcium phosphate (OCP), amorphous calcium phosphate (ACP), and dicalcium phosphate dihydrate. These mineral phases have the ability to support and participate in bone remodeling when used as graft materials. In both bone and dentin, the mineral phase predominantly exists as low-crystalline apatite within a nano-composite matrix, a feature that facilitates continuous remodelling.(9)

Beyond their mineral composition, teeth and bone exhibit notable developmental and biochemical similarities. Structures such as teeth, cartilage, nerves, and maxillofacial bones arise from neural crest cells, indicating a shared embryological origin. The organic matrix of dentin and cementum is rich in type I collagen and contains several bioactive molecules, including bone morphogenetic proteins (BMPs). Approximately 90% of the organic matrix is composed of type I collagen, while the remaining fraction includes non-collagenous components such as phosphophoryn, sialoproteins, glycoproteins, proteoglycans, osteopontin, osteocalcin, dentin matrix protein-1, osterix, and Runx2, all of which play roles in regulating bone turnover and formation.(10)

Dentin closely resembles bone in composition, containing roughly 80% mineral (primarily hydroxyapatite) and 20% organic matrix, predominantly type I collagen. It also harbors growth factors similar to those found in bone, such as insulin-like growth factor-II (IGF-II), transforming growth factor-beta (TGF-β), and BMPs. Given these shared characteristics—along with the abilities to support osteoconduction, osteoinduction, and, indirectly, osteogenesis—extracted teeth present a promising source for developing novel bone graft materials utilizing both their organic and inorganic components.

DEVELOPMENT OF TOOTH DERIVED GRAFTS:
The concept of using bone grafts for treating periodontal intraosseous defects dates back to early work by Hegedus in 1923. Later, Ike and Marshall R. Urist proposed the use of processed root dentin

obtained from extracted teeth as a carrier for recombinant human BMP-2 (rh-BMP-2), given its ability to stimulate new bone formation within the periodontium.(11)

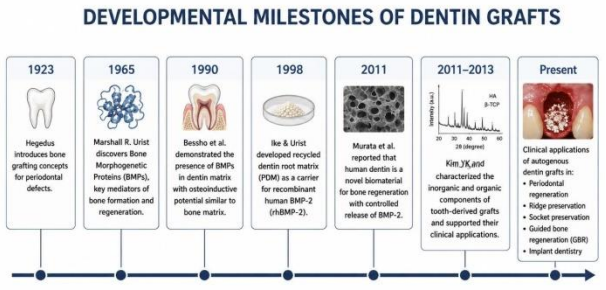

Fig 3: Developmental milestones of Dentin grafts

Subsequent investigations, particularly those led by Kim YK, provided significant evidence supporting the clinical viability of tooth-derived graft materials, demonstrating that properly processed teeth can serve as effective bone substitutes. In addition, studies by Murata and colleagues evaluated the release kinetics of BMP-2 from demineralized dentin matrix (DDM), further reinforcing its potential role in regenerative therapies.(12)

STUDIES ON THE PROPERTIES OF TOOTH DERIVED GRAFTS:

The role of bone morphogenetic proteins (BMPs) in tissue regeneration was first identified by Marshall R. Urist in 1965. Since then, multiple studies have demonstrated the presence of BMPs in dental tissues, including dentin, enamel, and cementum, across various animal models such as bovine, rat, guinea pig, and rabbit teeth.(13)

Research by Finkelman and colleagues showed that human dentin contains growth factors like TGF-β, IGF-I, and IGF-II, although their concentrations are comparatively lower than those found in human bone.(14)

Further compositional analysis by Kim YK using electron microscopy revealed that tooth-derived graft materials are primarily composed of hydroxyapatite (HA) and beta-tricalcium phosphate (β-TCP), both known for their osteoconductive properties.(10)

Additionally, Bessho K suggested that BMPs derived from dentin matrix exhibit biological activity comparable to those obtained from bone matrix, indicating similar osteoinductive potential.(15)

Clinical investigations have also explored the effectiveness of autogenous tooth-derived grafts as scaffolds combined with growth factors in patients with alveolar bone deficiencies undergoing implant placement, demonstrating favorable bone healing outcomes.(16)

In another analytical study, Kim YK evaluated freshly extracted teeth and reported that the X-ray diffraction (XRD) pattern of dentin closely resembles that of autogenous bone, supporting its suitability as a grafting material.(17)

DEMINERALIZATION OF TOOTH DERIVED GRAFTS:

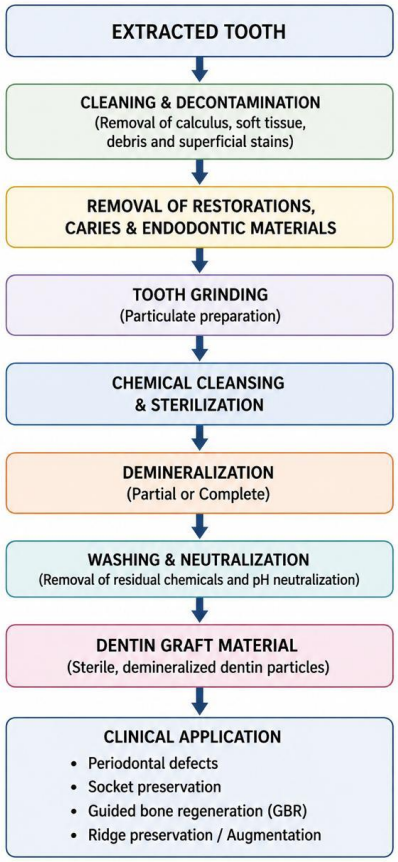

Fig 4: Preparation of particulate Dentin graft

Demineralization plays a key role in exposing bioactive molecules within dentin, as hydroxyapatite crystals can hinder the release of embedded growth factors and proteins. By removing the mineral component, these factors—particularly bone morphogenetic proteins (BMPs)—become more available, thereby enhancing osteoinductive potential.

Various chemical methods have been explored to achieve this effect. For instance, treatment of dentin or bone with 0.6N hydrochloric acid (HCl) has been shown to stimulate connective tissue cell activity and promote endochondral bone formation when implanted in muscle or subcutaneous tissues. In earlier work, Ike and Marshall R. Urist utilized 0.6N HCl to partially demineralize tooth roots over a 24-hour period, subsequently preparing them into approximately 0.5 g segments to create a partially demineralized matrix (PDM).(11)

Other protocols have also been reported, including the use of 2% nitric acid (HNO_3) for preparing demineralized dentin matrix (DDM). Overall, a range

of acid-based treatments has been investigated, reflecting variations in methodology aimed at optimizing growth factor release and regenerative outcomes. (16).

CLINICAL APPLICATION OF AUTOGENOUS TOOTH BONE GRAFT MATERIAL:

PERIODONTAL REGENERATION:

Autogenous grafts prepared from a patient's own teeth are largely composed of type I collagen (around 95%), along with matrix-associated proteins, including bone morphogenetic proteins and transforming growth factor-beta (TGF-β). Human dentin has also been shown to contain insulin-like growth factors such as IGF-I and IGF-II, which play important roles in regulating both bone resorption and new bone formation. Owing to these biological properties, tooth-derived graft materials have significant potential in periodontal regeneration, particularly for treating intraosseous defects. Additionally, their non-antigenic nature supports favorable bone remodeling and healing outcomes.(18,19)

RIDGE PRESERVATION:

In alveolar ridge preservation procedures Autogenous teeth bone grafting was found to be safe with good bone forming capacity, and has shown good outcome on implant stability after ridge augmentation.(20, 21)

GUIDED BONE REGENERATION (GBR):

In clinical investigations, Hee-Yung C and colleagues evaluated the outcomes of guided bone regeneration (GBR) for both vertical and horizontal ridge augmentation using autogenous tooth-derived grafts, applied with and without a resorbable membrane. Their findings demonstrated effective bone formation, and histological examination revealed a well-developed trabecular bone pattern surrounding the grafted material. These results suggest that tooth-derived autogenous grafts can serve as a viable alternative to conventional bone graft materials in GBR procedures. (22)

SOCKET PRESERVATION:

According to findings by Jadhav and colleagues, the use of autogenous tooth-derived grafts in extraction sockets resulted in favorable healing and effective ridge preservation. This approach supports adequate bone volume maintenance, making the site more suitable for subsequent implant placement. (23)

OTHER APPLICATIONS:

In conditions predisposing pathological fractures like resected tumors, enucleated cysts, autogenous dentin graft may serve as a potential bone grafting material.(10)

CONCLUSION:

Tooth-derived bone grafts represent an innovative and biologically favorable option for periodontal regeneration. Their compositional similarity to bone, autogenous origin, and ability to utilize extracted teeth that would otherwise be discarded make them unique among grafting materials. Current evidence supports their role in intraosseous defect management, socket and ridge preservation, and guided bone regeneration, with outcomes comparable to established grafts. Future research should focus on standardized processing protocols, long-term clinical trials, and expanded applications in implantology and peri-implantitis defects. Tooth-derived grafts thus hold great promise as a biomimetic and sustainable alternative in regenerative dentistry.

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