



Autogenous Tooth Bone Graft - A Biomimetic Promise for Regenerative Dentistry

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Abstract

Regeneration is defined as reconstitution of a lost or injured part, with form and function of lost structures restored. Graft associated regeneration still remains the mainstay and newer graft materials of diverse origin are added to the already existing lot, with claims of superior clinical outcomes. Thus, the search for newer, near ideal biomaterials and procedures continue to be a challenge in the field of regenerative dentistry. Based on the regenerative properties of osteoconduction, osteoinduction, creeping substitution and osteogenesis mediated via the expression of growth factors derived from the patient's own tooth and the histo-morphological similarities between tooth and bone, a novel bone graft material has been developed utilizing the structural components of an extracted tooth. This review elaborately describes a novel regenerative technology of the autogenous tooth derived bone graft material, a biomimetic system that treats patients by fabricating a bone graft material from their own extracted teeth.

Keywords: Autogenous Tooth Bone Graft; Bone Regeneration, Bone Substitutes; Endogenous Regenerative Technology; Tooth

Introduction

Regeneration is defined as reconstitution of a lost or injured part, with form and function of lost structures restored [1]. Periodontal Regeneration comprises de novo osteogenesis, cementogenesis and generation of functionally oriented periodontal fibers into both newly formed alveolar bone and cementum. Periodontal Regeneration constitute a complex multifactorial process influenced by interaction among various progenitor cells, hormones, growth factors, and the components of the extra cellular matrix [2]. Several different approaches are currently under research and exploration

to achieve complete, reliable, and reproducible results in regeneration of periodontal tissues. The therapeutic management of the interosseous periodontal defects is the formation of new bone for successful periodontal regeneration.

Over the past five decades, attempts at periodontal regeneration are harnessed with an array of biomaterials which include Bone graft materials of various types, Guided tissue regeneration (GTR) membranes, biologics like Enamel matrix derivatives (EMD), Growth factors (GF), Bone morphogenic proteins (BMP) and Platelet concentrate analogues. The emergence of tissue

engineering concepts has further opened a new exciting arena in periodontal regeneration.

Graft associated regeneration still remains a mainstay and newer graft materials of diverse origin are added to the already existing lot, with claims of superior clinical outcomes. Autogenous bone grafts have been regarded as gold standard for the reconstruction of hard tissue defects with promising osteogenic, osteoconductive, osteoinductive, and osseointegrative capabilities without triggering any foreign body reaction in the host. However, due to difficulties faced in procuring them in an adequate amount along with the plausible risk of donor site morbidity pose as challenges [3]. This result in a surge for research on the development, application, and effectiveness of non-autologous origin grafting materials namely allografts, xenografts and synthetic grafts. But these too are associated with problems of antigenicity, immune rejection response by heterologous proteins, contagion possibility and high cost. It is therefore, difficult to obtain bone graft material with the advantages of autogenous bone but not its disadvantages [4]. Thus, the search for newer, near ideal biomaterials and procedures continue to be a challenge in the field of regenerative periodontics.

Tooth and bone

Teeth are known as a composite of organic and inorganic components consisting of minerals of the calcium phosphate range, collagen and other organic elements. The compositions of teeth and bone are very chemically similar. The tooth which is composed of inorganic and organic ingredients within the dentin has a 65%: 35% ratio, cementum of 45-50%: 50-55% and the alveolar bone of 65%:35%, respectively [5]. Thereby, sharing similar bone remodeling potential and histo-morphological resemblance to the host bone. Based on the regenerative forte of a tooth by the processes of osteoconduction, osteoinduction, creeping substitution and osteogenesis via recruitment of growth factors, a novel bone graft material has been developed utilizing the structural components of an extracted tooth [6].

Herewith, this review elaborately describes the autologous bone grafting technology of the autogenous tooth derived bone graft material, a biomimetic regenerative system that treats patients by manufacturing a bone graft material from their own extracted teeth.

Development of autogenous tooth bone graft material

The use of bone grafts in the management of periodontal intraosseous defects was proposed in studies by Hegedus in 1923. A major revolution has resulted from then to the current practice in the evolution of these bone grafts. Ike and Urist suggested recycled root dentin prepared from extracted teeth for use as a carrier of Recombinant human BMP-2 (rh-BMP2) because it induces new bone formation in the periodontium [7].

It was, however, the breakthrough research done by Kim YK et al. which proved the successful use of artificially processed tooth as a bone grafting material [5]. Murata, et al. further supported that demineralized dentin matrix (DDM) does not inhibit BMP2 activity rather shows a better release profile of BMP-2 [8]. Chung PH extracted proteins from teeth in their papers published in 2002 and 2004, provided evidence that teeth contain BMP, further strengthening the role [9,10].

Patient's extracted tooth is classified as environmental waste. However, the use of tooth may be permitted if the patient consents to process and use his/her own teeth. Reports even suggest that the remainder of a root can be left intentionally to preserve the alveolar bone [11,12]. Literature also reported that 90% of the tooth's organic components are type I collagen and has growth factors such as Insulin-like growth factor (IGF)-II, BMP2, and transforming growth factor (TGF)-beta like bone, all of these playing a crucial role in the calcification of bone [13]. Studies also suggest that the tooth enamel expressed BMP2 which possess osteoinductive potential [14,15]. Even the tooth cement and its progenitor cell contain TGF-beta, IGF-I and platelet derived growth factor, which are also essential for bone formation [16]. To summarize, the tooth borne enamel and cement have many growth factors and proteins that are vital for bone formation.

Biocompatibility of bone graft material using teeth

Studies have been conducted since 1993, Kim YK, et al. have conducted basic studies such as component analysis, research through electron microscope and identified the main component of the toothash powder to be Hydroxyapatite (HA) and beta-Tricalcium phosphate (β -TCP), which was osteoconductive as well as biocompatible and absorbed over time [17,18]. Since then, the results of many related experimental studies have suggested

the indications and comparisons for guided bone regeneration using lyodura and with other bone substitutes, tissue reaction after implantation, cytotoxicity, hypersensitivity test and biocompatibility have been evaluated [19-23].

Osteoinductivity and osteo conductivity of teeth

A variety of research has been performed for the comparison with other bone grafts like xenograft, the evaluation of their healing process around implants, along with platelet analogues like platelet rich plasma, the healing process after inducing osteoporosis, multiple application of tissue adhesive, chitosan, and the healing process after guided bone regeneration. Tooth ash has proven to be an osteoconductive bone graft material with excellent biocompatibility in evidenced literature [24-28].

Bessho K., *et al.* extracted human dentin matrix and found in Sodium dodecyl sulphate polyacralamide gel electrophoresis (SDS-PAGE) and Isoelectric focusing (IEF) that purified BMP is homogenous, inducing the formation of new bone within 3 weeks of implantation in muscle pouches in Wistar rats [29]. Also influence of dentin matrix derived BMP is very similar to bone matrix derived BMP, both exhibiting the same action in the body [30].

Boden SD., *et al.* suggested that LIM mineralization protein 1 (LMP-1) is pivotal for regulation of osteoblastic differentiation and their maturation leading to bone formation [31]. Their presence was confirmed by Wang X., *et al.* wherein LIM expression was evident in the predentin layer of the odontoblastic and endothelial cells of the teeth [32].

Further in an *ex vivo* study performed on artificially created alveolar bone defects in Wistar rats were filled with either tooth or iliac bone graft material or left as controls. The study concluded that tooth graft material produced a similar amount of new bone compared to iliac bone graft material at the end of 8 weeks. Dentin sialoprotein was found to be expressed in the new bone formed by the tooth graft material at 6 weeks. The authors also suggested as early as 6–8 weeks for new bone formation as compared to the conventional bone graft [33].

Similar results were found in a histomorphometric study by Jeong HR on miniature pigs for bone regeneration in an artificial bony defect. They examined the effect of autogenous tooth bone as a graft material which showed higher amount of bone formation and

remodeling in experimental groups and concluded the usefulness of this graft with possible clinical feasibility in the reconstruction of bony defects [34].

A prospective study was conducted to evaluate the bone healing effect and clinical capabilities like bone healing ability of autogenous tooth bone materials as a scaffold when used together with growth factor in patients with alveolar deficient sites for implant placement [35].

An analytical study of extracted fresh tooth, X-ray diffraction (XRD) pattern of dentin of autogenous tooth bone graft material was found to be most similar to autogenous bone [36].

In a study performed quantitative analysis of the proliferation and differentiation of the MG63 cell line on the bone grafting material using human tooth demonstrated that the cellular adhesion and proliferation activity of MG63 cells on partially demineralized dentin matrix (PDDM) were comparable and could be controlled with enhanced osteogenic differentiation [37].

Clinical application of autogenous tooth bone graft material

Endogenous regenerative technology and autogenous tooth bone graft in periodontal regeneration

Based on the principles of endogenous regenerative technology (ERT), stimulation of latent self-repair mechanisms in patients and harnessing the host's innate capacity using the patient's own "Regenerative Tools", i.e. Patient-derived growth factors and fibrin scaffolds to create a material niche in an injured site where the progenitor/stem cells from neighboring tissues can be recruited for *in situ* periodontal regeneration [38]. Fulfilling this criteria, the patient's tooth derived autogenous bone grafts, like the Demineralized dentin matrix (DDM) and Demineralized bone matrix (DBM) composed of predominantly type I collagen (95%) and matrix binding proteins such as BMPs namely transforming growth factor-beta (TGF- β), insulin growth factor-I (IGF-I) and IGF-II were detected in human dentin [39-42]. Thus, contributing in the role of promoting bone resorption and bone formation [43-45]. Therefore, these tooth derived bone graft materials are considered to be potentially useful in periodontal regenerative sciences in management of interosseous defects.

Alveolar cleft repair

A report published on the application of a combination of maxillary bone transport and auto tooth bone grafting for alveolar

cleft repair using autogenous extracted teeth, concluded to be an effective approach for alveolar cleft repair. It was seen that Autotooth bone allowed for repair of the bone defects of the nasal floor and alveolar cleft and resulted in a superior bone connection [46].

Maxillary sinus and ridge augmentation

In an another in-vivo study performed on 250 patients, Implant placement was combined with maxillary sinus augmentation using block type, powder type, and block with powder type autobone graft material. In their histological assessment, formation of new bone, densified lamellated bone, trabecular bones, osteoblast and planting fixtures were investigated [4].

Similar results were confirmed by Jeong KI study wherein it was found appropriate for the use in maxillary sinus augmentation [47].

A prospective study was performed to evaluate the effectiveness of two bone graft materials in the application for sinus bone graft procedure, using Bio-Oss in control and autogenous tooth bone graft (AutoBT) powder in experimental group respectively. There was significant difference in osteoid thickness (8.35 μm in Bio-Oss group Vs. 13.12 μm in AutoBT group) ($P=0.025$). Thus concluding that AutoBT could be considered a viable alternative to the autogenous bone or other bone graft materials in sinus bone graft procedure [48].

Current consensus suggests autogenous teeth bone grafting for alveolar ridge augmentation to be a clinically safe with good bone forming capacity, and shows good outcome on implant stability [49].

Guided bone regeneration (GBR)

A number of clinical studies comparatively analyzed the clinical results for vertical and horizontal ridge augmentation (GBR) using the autogenous tooth bone graft material, with and without the resorbable membrane. The results showed clinically acceptable bone regeneration without any eventful complications [50] with excellent clinical results were evaluated [51].

In a clinical experimental study which conducted a Feasibility Analysis in humans concluded that the autogenous tooth-based bone graft (ATBBG) material was not only viable for GBR but also yielded a stable marginal bone level (MBL) even after functional loading of implants [52].

A clinical study evaluated the efficacy of the autogenous tooth bone graft material, clinically and radiologically, as related to implant installation with various surgical procedures like guided bone regeneration (GBR), sinus graft and defect filling using autogenous tooth bone. The histological assessment revealed, formation of the new bone and continuous trabecular bone pattern identified around autogenous tooth bone. Thus suggesting that this material as a potential substitute for the autogenous bone [53].

Socket preservation

In a human study conducted by Gomes, *et al.* the experimental sockets were filled with autogenous DDM and covered with polytetrafluoroethylene (PTFE) membrane. These sockets showed bone formation of the same radiopacity as the surrounding bone, at a faster rate and superior bony architecture as compared to the other groups [54]. Similarly supporting studies published by Kim, *et al.* and Park SM, *et al.* also reported good healing of the extraction socket after 3 to 3.5 months for future implant placement after autogenous tooth bone graft placement [55].

Endodontic applications

Work by Jiang Y, *et al* reported the use of autogenous DDM as a prospective material of choice as an apexification material as well as a permanent root canal filling material in the branch of endodontics [56].

Other applications

The tooth derived Autogenous bone graft may serve as a potential bone grafting material for oral pathological conditions like resected tumors, enucleated cyst, traumatic injuries resulting in pathological fracture predisposition. Autogenous DDM has further been reported to be an ideal scaffold for stem cells and bone growth factors and found emerging acceptance in endodontic and restorative dentistry [5].

Conclusion

Extracted tooth are categorized as a hazardous biomedical waste and disposed appropriately. However, if the same extracted teeth can be processed into a potential regenerative biomaterial and used in the same patient for his/her oral health benefit, it may serve as an exciting and novel approach in regenerative sciences. The emergence of autogenous tooth bone graft based on the principles of Endogenous Regenerative Technology (ERT) promotes not only the natural healing process but also reconstruction of

lost tissues by body's inherent capabilities. Thus, Randomized clinical trials comparing this biomimetic material with other commercially available bone graft materials are the need of the hour to substantiate its purposefulness.

Conflict of Interest

The authors have none to declare.

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