Review Article

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Chairside autogenous tooth bone graft for alveolar ridge preservation: A review

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Alveolar ridge resorption after tooth extraction is an inevitable process, and may result in major implant placement problems. Alveolar ridge preservation procedure can be used to minimize the biological consequences of alveolar ridge resorption. In the past decade, autogenous teeth have been proposed as a bone graft material in post-extraction sockets with very encouraging outcomes. Some studies demonstrated the feasibility of preparing autogenous tooth-derived bone graft materials chairside during the regenerative procedure visit, as well as alveolar ridge preservation. This review discusses the available evidence on autogenous teeth as a biomaterial in alveolar ridge preservation, its clinical evaluation and the process of manufacturing tooth graft materials chairside.

Keywords: alveolar ridge preservation, autogenous tooth-derived bone graft, bone substitute materials, chair side, extracted tooth

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Introduction

The biological mechanisms for bone grafting materials comprise osteogenesis, osteoinduction, and osteoconduction. Autogenous bone grafts are the gold standard materials because these materials have all three desired biological mechanisms, and are biocompatible and non-toxic. However, limited donor site issues, rapid resorption, limited access, and surgical site creation are complications associated with this technique [1]. Due to these factors, numerous studies on bone replacement materials, such as mineralized and freeze-dried bone allografts and synthetic alloplastic grafts, have been conducted. The use of allografts and xenografts in bone defects has resulted in good outcomes. However, patient acceptance for commercially processed xenograft and allograft materials differ based on personal and religious beliefs [2]. Furthermore, synthetic materials have the lowest osteoinductivity and are not as widely accepted as allograft materials due to the lack of documented clinical studies supporting their effectiveness [3]. Autologous alternatives may be able to resolve this issue.

The contractile activity of myofibroblasts affecting the alveolar bone tends to decrease following tooth extraction [4]. After the remodeling process in the tooth socket, the average amount of bone resorption is 1.67 mm vertically and 3.87 mm horizontally [5] that can cause major implant placement problems. At the time of tooth extraction, there are two different options available for implant placement to avoid dimensional ridge alteration. The first option is immediate implant placement with or without bone regeneration. The second option is delayed implant placement combined with socket preservation or alveolar ridge preservation [6]. In the last decade, several studies demonstrated the possibility of using autogenous extracted tooth as bone substitute materials for bone regeneration and alveolar ridge preservation chairside. This changes the extracted tooth from waste material into a bone substitute during the surgical visit.

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Therefore, the aim of this review was to describe the application of autogenous tooth-derived bone graft or autogenous tooth bone graft (ATBG) material prepared chairside for alveolar ridge preservation based on the most recent literature, lightening its clinical evaluation and the process of manufacturing tooth graft material.

Similarity between tooth and bone

The organic and inorganic composition of dentin are very similar to bone [7]. Dentin contains 70–75% inorganic content, 20% organic content, and 10% water, whereas the contents in alveolar bone are 65%, 25%, and 10%, respectively [8]. The main mineral components of dentin comprise four types of calcium phosphate [hydroxyapatite (HA), tricalcium phosphate (TCP), octacalcium phosphate (OCP), and amorphous calcium phosphate (ACP)]. The organic content in dentin is 90% Type I collagen and 10% non-collagenous proteins that can induce bone formation, such as bone morphogenetic protein (BMP), insulin-like growth factor-II, and transforming growth factor-beta. Although a limited amount of BMPs and growth factors can be extracted from teeth compared with those from human bone [9], dentin has been shown to be involved in the bone remodeling process with its osteoconductive and osteoinductive properties [10].

Kim *et al*. [8] used an autogenous tooth material and a series of steps, such as dehydration, degreasing, and ethylene oxide disinfection, to manufacture a new type of autogenous tooth granular bone substitute called autogenous tooth bone graft material (AutoBT®, Korea Tooth Bank, Korea). X-ray diffraction analysis demonstrated the presence of HA, TCP, ACP, and OCP after tooth preparation. Scanning electron microscopy (SEM) revealed that the structural pattern of AutoBT was similar to that of autogenous cortical bone [8]. However, the composition ratio varies in different parts of the tooth. The crown is mainly composed of enamel, thus, crown-derived AutoBT is mainly composed of highly crystalline calcium phosphate. However, materials with high crystal content are not easily broken down by osteoclasts, resulting in poor osteoconduction. In contrast, root-derived AutoBT has a low crystalline structure, enabling osteoinduction and osteoconduction. Moreover, the density, roughness, and homogeneity of AutoBT are relatively similar to autogenous cortical bones [11].

ATBG preparation method for chairside operation

There are various methods presented in many studies for preparing ATBG chairside. These methods differ in their details. However, in brief, extracted teeth are cleaned of the periodontal ligament, soft tissue debris, caries, calculus, crown restorations, and root filling restorations using a dental bur. Subsequently, the teeth are ground, using a hand bone mill or a grinding chamber. Next, disinfection and/or demineralization are performed. The following methods are presented as some examples of using a chamber and techniques to produce ATBG chairside.

Binderman *et al*. [12] used a grinding sterile chamber, 'Smart Dentin Grinder'™ (KometaBio, Fort Lee, NJ, USA) in 2014. This chamber ground the roots in 3 seconds, vibrated for 20 seconds, and the particles fell through sieves with different mesh sizes. Dentin particles between 300-1200 μm were collected and immersed in basic alcohol cleanser consisting of 0.5M NaOH and 30% alcohol (v/v) for 10 minutes for disinfection. Finally, the particulate was washed twice in sterile phosphate-buffered saline, leaving wet undemineralized particulate dentin ready to graft. The process from tooth extraction until grafting took approximately 15-20 minutes. The volume of the particulate dentin was more than twice that of the original volume. Alternatively, the wet particulate can be dried on a hot plate (140°C) for 5 minutes and used for immediate or future grafting procedures. Minamizato *et al*. [13] used a specific machine with a high-speed rotation ceramic blade (Takigen, Japan; international patent application No. PCT/JP2007/053321, international published No. WO2007/099861 A1). The resulting 400-800 μm particles were washed in 1.0 M sodium chloride and partially demineralized in 2% HNO3 (pH 1.0) for 10 min. The particles were extensively rinsed twice in 0.1 M Tris–HCl (pH 7.4) for 10 min. This process took approximately 40 minutes.

After the tooth grinding step, the devices mentioned above need to be chemically treated by the clinician to obtain tooth decontamination and demineralization. Some of the commercial devices that perform the grinding and demineralizing processes are automated without any possibility of human error. Minetti *et al*. [14,15] described a medical device (Tooth Transformer® SRL, Via Washington, 59 – Milan, Italy). The extracted tooth was cleaned by a dental bur, cut into small pieces, and placed inside the mill. After milling, a small box containing disposable liquids was inserted into the device per the manufacturer's instructions. A demineralized dentin graft (400–800 μm) was ready in 30-45 minutes. When using another machine, the Bonmaker® tooth grinder (Korea Dental Solutions Co. Ltd., South Korea), after tooth grinding, the particulate tooth material underwent a 3-step disinfection and preparation process via proprietary A, B, and C solutions in the Bonmaker® device, resulting in ready-to-use undemineralized 425 μm–1500 μm ATBG particles. The preparation and disinfection procedure usually requires 30–35 min (10–15 min preparation, 20 min disinfection) [16]. The methods mentioned above are just some techniques to produce ATBG (Table 1). Several protocols for the preparation of ATBG granules have been reported in the literature.

ATBG demineralization level

To obtain more tooth-derived substances, demineralization is required to free the various growth factors and proteins that are essential for tissue regeneration and repair. Demineralization induces an abundant release of transforming growth factor-β; an intermediate abundance of BMP-2, fibroblast growth factor-2, vascular endothelial growth factor, platelet-derived growth factor, and insulin-like growth factor-1 with a lower abundance of BMP-4 and BMP-7 [17]. Demineralization is the process of removing some of the highly crystalline inorganic substances from the dental hard tissues, however, aggressive demineralization can result in the loss of its structural integrity with the collapse and degradation of the supporting collagen matrix, leading to the collapse of the 3D structure [18,19]. Crystallinity is related to the dissolution rate and solubility; apatite with high crystallinity is more difficult to dissolve than apatite with low crystallinity [20].

Table 1 Some example of using machine and technique to produce chairside ATBG

	Grinding machine	Disinfection process	Demineralization process	Type of preparation	Particle size (μm)	Time consuming (minutes)
Binderman *et al*. [12]	'Smart Dentin Grinder'™	Manual	None	Undemineraized	300-1,200	15-20
Minamizato *et al*. [13]	high-speed rotation ceramic blade machine	Manual	Manual	Partially demineralized	400-800	40
Minetti *et al*. [14,15]	Tooth Transformer®	Tooth Transformer®	Tooth Transformer®	Demineralized	400-800	30-45
Radoczy-Drajko Z *et al*. [16]	Bonmaker® tooth grinder	Bonmaker® device	None	Undemineraized	425-1,500	30-35

Three main categories concerning the degree of demineralization have been reported in the literature; undemineralized dentin (UDD), partially demineralized dentin matrix (PDDM), and completely demineralized dentin matrix (CDDM). In many previous studies, CDDM preparation required processing outside of the dental clinic, usually at another institution, requiring a second operation for grafting at a later stage and an overall longer treatment time [21]. More recently, research has shown the feasibility of preparing ATBG material chairside with successful and predictable results when using CDDM, PDDM, or UDD [13, 21, 22, 16, 23].

ATBG particle size

In terms of particle size, the particle sizes of most commercially available bone grafting range from 300-1500 μm. Although several previous studies have focused on the influence of the ATBG material particle size on bone regeneration, there is currently no consensus on the optimal particle size of graft materials for bone regeneration. However, many authors suggested that fine particles < 300 μm was a non-efficient particle size for bone grafting [24]. The smaller-sized particles were more resorbable in the defect site before new bone formation initiated [17]. Koga *et al*. [19] concluded that PDDM with a large particle size of ~1000 μm induced robust bone regeneration in bony defects because PDDM possessed a suitable surface for cell attachment.

The clinical effectiveness of ATBG on alveolar ridge preservation

Joshi CP *et al*. [23] reported a randomized, controlled, clinical pilot study comparing ridge preservation with conventional β-TCP alloplast and ATBG. After a 4-month follow-up period, the ATBG sites demonstrated the best results with a minimal reduction in alveolar crest height and width. Histological analysis also showed the same trend with more new bone formation at the ATBG sites compared with the β-TCP-grafted sites. Santos A *et al.* [25] performed a randomized controlled clinical trial in fifty-two patients comparing ATBG versus xenograft granules for implant placement after ridge preservation. They concluded that implants placed in sites preserved with ATBG had similar primary stability compared with xenograft granules. ATBG generated a significantly higher quantity of newly formed bone and a lower amount of residual graft in histomorphometry results and similar clinical and patient-related outcomes.

A systematic review found that using ATBG prepared chairside led to ridge dimension changes ranging from -0.64 mm to +2.26 mm in height and from -1.21 mm to +0.41 mm in width. These results are comparable to those reported for other materials used for ridge preservation as well as when the tooth was not prepared chairside [21]. Moreover, a recent meta-analysis revealed a positive ridge preservation effect from ATBG with a pooled mean difference ridge width change of -0.72 mm. The pooled mean residual graft proportion was 11.61%, and the newly formed bone proportion was 40.23%. The pooled mean of the newly formed bone proportion was higher in the group where ATBG originated from the root and crown of the tooth [26]. Therefore, ATBG can be an alternative biomaterial for alveolar ridge preservation and results in acceptable clinical outcomes as suggested by the currently available evidence [21,26].

Degree of demineralization VS clinical effectiveness of ATBG

To determine which demineralization levels are the most effective, Elfana *et al*. [22] conducted a randomized controlled clinical trial to evaluate autogenous undemineralized whole-tooth graft (AWTG) versus autogenous demineralized dentin graft (ADDG) for alveolar ridge preservation. They concluded that AWTG or ADDG employed in alveolar ridge preservation is equally effective at reducing dimensional losses after 6 months, with no adverse effects. Histologically, both grafts were biocompatible and osteoconductive, with ADDG exerting a higher osteoinductive effect [22]. However, a recent meta-analysis reported that a conclusion regarding the efficacy of the processing methods resulting in different levels of ATBG mineralization (UDD, PDDM, CDDM) cannot be drawn, due to few studies, however, a slight difference between the outcomes can be observed [26]. The newly formed bone proportion was highest in the PDDM group (51%) and lowest in the CDDM group (31%), a statistically and clinically significant difference. In contrast, the connective tissue proportion was the lowest in the PDDM group (39%) and highest in the CDDM group (51%), however, this difference was not significant. These data suggest that partial demineralization may positively affect the rate of new bone formation. Although no significant difference was observed between the subgroups in residual graft remnants, the difference in the residual graft proportion between the CDDM (9.5%), PDDM (9.8%) vs. UDD groups (14.5%) may be clinically relevant [26].

A study comparing the BonMaker, Tooth Transformer, and Smart Dentin Grinder devices concluded that these systems, which generated different structural and chemical differences in the dentin granules, had a comparable clinical efficacy and potential for obtaining regenerative material [27]. Furthermore, the histological examination revealed no inflammation and a good connection between the bone and dentin matrix, and clinically all patients were qualified for implant placement, that supported the conclusion that these systems have the potential for obtaining regenerative material from the patient's teeth [28].

Discussion

Alveolar ridge resorption is an inevitable process following tooth extraction. Alveolar ridge preservation strategies are indicated to minimize this loss of ridge volume [29]. Although there are many choices for bone substitutes, the concept of recycling compromised teeth that require extraction, rather than discarding them, to avoid the use of expensive heterologous or synthetic bone substitutes, is anticipated to be well-received by patients [15]. ATBG is considered an autologous, cost-effective, sustainable alternative because it is easily retrievable, safe, and has minimal risk of rejection or infection, thus, it should be considered as a natural resource to be used to full advantage for other applications [22]. Moreover, due to the need for a faster way of transforming an extracted tooth into a ready-to-use bone grafting material, the recent articles are more focused on chairside tooth preparation that can be used in a clinical setting [24].

ATBGs can result in acceptable clinical outcomes as suggested by the currently available evidence. A lack of uniformity and standardization in the literature has made it difficult to determine which graft form is advantageous for which clinical indication with certainty. However, when employed in alveolar ridge preservation procedures, several authors have reported success using CDDM, PDDM, and UDD, indicating that each form can be a viable option [30].

There are several advantages to using chairside ATBG as mentioned above, however, some disadvantages and limitations need to be considered. The chairside preparation process of ATBG includes cleaning, grinding, and disinfection, requiring considerable time and effort. As an autogenous graft, it is available in limited quantity, requires the extraction of a hopeless tooth for graft preparation, and hence cannot be used in individuals who do not have teeth indicated for extraction. Moreover, the available equipment, liquid solutions, and the graft material processing skill of the operator are also important factors.

Based on the above findings, appropriate case selection, suitable equipment, and skill of the operator can lead to successful treatment.

Conclusion

Autogenous tooth bone grafts prepared chairside may be a feasible alternative to other biomaterials used for bone alveolar ridge preservation. These grafts generate an acceptable clinical outcome, including with different structural and chemical differences of the dentin granules from each device and degree of mineralization. However, when selecting cases for this graft, some disadvantages and limitations need to considered.

However, further research, using standardized protocols in patient selection, dentin processing, surgery procedure and comparison with other grafts are essential to reach a definitive conclusion about this graft's efficacy.

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