REVIEW ARTICLE

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Bone graft material using teeth

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Autogenous tooth bone graft material contains organic and inorganic components for osteoinductive and osteoconductive healing. The clinical availability and safety of this material have been confirmed by various experimental and clinical studies. In the future, allogenic and xenogenic tooth bone graft materials, ideal scaffold using teeth for stem cells and bone growth factors, and endodontic and tooth restorative material will be developed.

Key words: Tooth, Bone graft material

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I. Introduction

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 minerals of teeth have biological calcium phosphate of 5 phases (hydroxyapatite, tricalcium phosphate, octacalcium phosphate, amorphous calcium phosphate [TCP], and brushite). These 5 phases in calcium phosphate interact with each other; it is assumed that good bony remodeling can be made when calcium phosphate is put into a living system. The apatite in osseous tissue takes the form of ceramic/high molecule's nanoscale composite. The apatite in humans' osseous tissue is low-crystalline, and its particle size is at the level of scores of nanometers. On the other hand, a hydroxyapatite created through sintering at high temperature is high-crystalline and dozens of times larger than apatite in osseous tissue due to grain growth occurring in the course of sintering. When its crystallinity is high, and its particle size is big, the biodegradation of apatite in the body is almost impossible, and its osteoconduction capacity is low. Moreover, it cannot be degraded by macrophage. Low-crystalline carbonic apatite has the most effective osteoconduction capacity[1,2].

The chemical compositions of teeth and bone are very similar. Enamel is 96% inorganic ingredients and 4% organic ingredients and water. Dentin has a 65% : 35% ratio, whereas cementum has the ratio of 45-50% : 50-55%. Finally, alveolar bone is made up of 65% inorganic ingredients and 35% organic ingredients. Tooth dentin and cementum contain a number of bone growth factors including type I collagen and bone morphogenic protein (BMP). Type I collagen accounts for 90%, with the rest consisting of noncollagenous proteins, biopolymer, lipid, citrate, lactate, etc. Noncollagenous proteins are phosphophoryn, sialoprotein, glycoprotein, proteoglycan, BMP, etc. They can perform the role of promoting bone resorption and bone formation. Therefore, bone graft materials using teeth are considered to be potentially useful in clinics[3-5].

II. Osteoinduction of Teeth

Dentin matrix has long been proven to be osteoinductive and rich in BMP[6-8]. Organic component accounts for about 20% of dentin weight and mostly consists of type I collagen. Moreover, it was proven to have BMP promoting cartilage and bone formation, differentiating undifferentiated mesenchymal stem cells into chondrocytes and osteogenic cells[9-12]. Noncollagenous proteins of dentin such as

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osteocalcin, osteonectin, phosphoprotein, and sialoprotein are known to be involved in bone calcification[13,14].

Bessho et al.[15] have extracted BMP from bone matrix, dentin matrix, and wound tissue after extracting teeth from rabbits. Each BMP was confirmed to have induced the formation of new bone when xenogenic implantation was performed. Bessho et al.[15] have extracted human dentin matrix containing 4 mol/L guanidine HC1 and refined it into liquid chromatography and found in SDS-PAGE and IEF that purified BMP is homogenous, inducing the formation of new bone within 3 weeks of implantation in muscle pouches in Wistar rats. Dentin matrix-derived BMP is not the same as bone matrix-derived BMP, but they are very similar. In other words, two types of BMP exhibit the same action in the body[16]. Matrix protein patterns in teeth must have osteoinductive potential even though it does not perfectly match the protein in alveolar bone. Moreover, the apatite in teeth has long been known to play the role of protecting proteins[17]. Boden et al.[18] suggested that LIM mineralization protein 1 (LMP-1) is an essential positive regulator of osteoblast differentiation and maturation and bone formation. Wang et al.[19] found that LIM-1 was expressed primarily in predentin, odontoblasts, and endothelial cells of the blood vessels of teeth.

Many researchers have observed that alveolar bone formation occur around bone graft materials as a result of experiments on animals[20-24]. Chung[25,26] registered the patent for the technology of extracting proteins from teeth in 2002 and 2004; this carries important meaning, showing evidence that teeth contain BMP. Ike and Urist[27] suggested that root dentin prepared from extracted teeth may be recycled for use as carrier of rhBMP-2 because it induces new bone formation in the periodontium. Murata et al.[28] suggested that demineralized dentin matrix (DDM) does not inhibit BMP-2 activity and shows better release profile of BMP-2. Human recycled DDM are unique, absorbable matrix with osteoinductivity, and DDM should be an effective graft material as carrier of BMP-2 and a scaffold for bone-forming cells for bone engineering.

III. Osteoconduction and Biocompatibility of Bone Graft Material Using Teeth

Since 1993, Kim et al.[29,30] have conducted basic studies such as component analysis, research through electron microscope, and production of block-type bone graft materials after incinerating human teeth at high temperature and then pulverizing to particle size of 0.149 mm. The main component of toothash powder has been identified to be HA and β-TCP, which are osteoconductive bone graft materials with biocompatibility and which can be absorbed over time[29,30]. Since then, the results of related experiments have been reported such as guided bone regeneration using lyodura, comparative experimental study with other bone substitutes on the market, tissue response using transmitted microscopy after implantation, cytotoxicity, and hypersensitivity test[31-34]. A clinical research has done retrospective observation on 10 patients into whom particulate dentin-plaster of Paris (mix in 2 : 1 proportion) was implanted after cyst enucleation. The cystic defects were all bigger than 20 mm, and the follow-up period was 50-57 months (average of 52.2 months). Although wound dehiscence and complications of infection have developed in 3 patients after cyst enucleation, they were cured through resuturing using the buccal mucosa flap and incision & drainage. It has clinically proven to be a convenient bone graft material with excellent biocompatibility after long-time observation[35]. A variety of research has been performed for the comparison with xenogenous bone graft material (Bio-Oss; Geistlich Pharma AG, Wolhusen, Switzerland), the evaluation of healing process after placing into defects around the implant, multiple application of platelet-rich plasma, healing process after inducing osteoporosis, multiple application of tissue adhesive, multiple application of chitosan, and healing process after guided bone regeneration. Toothash has proven to be an osteoconductive bone graft material with excellent biocompatibility. It has been introduced as toothash or particulate dentin in overseas academic journals[36-40].

IV. Development and Clinical Application of Autogenous Tooth Bone Graft Material

Teeth extracted from humans are considered dental waste. Therefore, they should be disposed of by waste removal services. Because of this legal restriction, the commercialization of teeth is impossible in Korea.

Long ago, to reduce the risk of nerve injury while extracting mandibular impacted third molar, intentional partial odontectomy was introduced in the literature on oral and maxillofacial surgery; its safety has also been proven[41]. Similarly, the author has reported a related surgery and confirmed that the remaining root and osseous tissue were united without unusual complications based on long observation[42]. Operations for leaving the root of a tooth intact intentionally to prevent alveolar bone atrophy among completely edentulous patients have been introduced and applied clinically for a long time in the field of dental medicine[43-45]. Some scholars have reported evidences that an implant did not affect osseointegration even though the implant penetrated an impacted tooth in the course of placement[46]. Autogenous tooth bone graft material has been developed after the autogenous tooth root was reconfirmed to have excellent compatibility with alveolar bone via these papers.

When the DDM of the extracted teeth from a person is used as bone graft material for him/her, it is safe because there is little immune rejection response. Kim and colleagues[47,48] have developed the technology of making bone graft materials with autogenous tooth after partial demineralization and freezing-drying and commercialized it domestically and internationally for the first time.

Kim et al.[49] analyzed the inorganic component of extracted fresh tooth and specimen treated with autogenous tooth bone graft material and found that the crown mainly consists of high-crystalline calcium phosphate, and that the root is mainly made up of low-crystalline calcium phosphate. If dentin and cementum which make up most of the teeth are used as bone graft materials, good bony remodeling by osteoconduction can be expected because the main minerals of bone tissue are low-crystalline apatite. The analyses of mandibular cortical bone taken from patients, crown of autogenous tooth bone graft material, root of autogenous tooth bone graft material, irradiated mineralized allogeneic cancellous bone (ICB; Rocky Mountain Tissue Bank, Denver, CO, USA), xenograft bone (Bio-Oss), and synthetic bone MBCP (Biomatlante, Vigneux de Bretagne, France) showed that the x-ray diffraction (XRD) pattern of dentin of autogenous tooth bone graft material and allograft bone was most similar to autogenous bone, and this finding has been announced[50]. Many authors have published case reports as well as the results of clinical studies on sinus bone graft, ridge augmentation, guided bone regeneration, socket preservation or graft, and they have proven to be useful materials for hard tissue defect restoration[51-59].

Lee[60] performed quantitative analysis of the proliferation and differentiation of the MG-63 cell line on the bone grafting material using human tooth. This study demonstrated that the cellular adhesion and proliferation activity of MG-63 cells on partially demineralized dentin matrix (PDDM) were comparable and could be controlled with enhanced osteogenic differentiation. Jeong et al.[61] conducted experimental research on bone formation after the autogenous tooth bone graft of a miniature pig, recorded average bone formation of 43.74% after 4 weeks, and concluded that it was a good substitute for autogenous bone graft. Kim et al.[62] and Lee et al.[63] have performed sinus bone graft and guided bone regeneration using autogenous tooth bone from humans and took the tissue specimen 2 months and 4 months later for histomorphometric analysis. They found favorable new bone formation as a result and suggested that autogenous tooth bone graft materials can be used in various bone grafts.

Nilsson et al.[64] said that a lot of BMP was needed to realize proper osteoinduction when used alone. Therefore, an appropriate carrier is needed. For the autogenous tooth bone graft material, BMP and bone growth factors in dentin can be used as they are. There have been reports that DDM by itself can play the role of carrier of exogenous BMP and growth factors as well as have an osteoinductive effect[27,65].

Meanwhile, teeth can have a huge amount of organic component even though they have been left for a long time after being extracted because the solid apatite of external teeth can preserve the internal organic component for long[17]. Therefore, excellent bone healing effect can be expected if the organic component of internal teeth is released slowly through an appropriate demineralization process and stem cells, growth factors, and BMP are seeded inside the teeth.

V. Conclusion

The safety of autogenous tooth bone graft material has been established. Moreover, it is a useful material that can substitute free autogenous bone graft, showing bone healing via excellent osteoinduction and osteoconduction because it contains both organic and inorganic components. When the amount of bone graft material is insufficient, other bone graft material can be combined. Nowadays, research on osteoinductive and osteoconductive bone graft material using homogenous and xenogeneous tooth, development of ideal scaffold to convey stem cells and growth factors, endodontic treatment and tooth restorative material are being conducted actively. The author expects tangible achievements to be made soon.

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