Introduction

At present, the bone defect caused by trauma, tumor, inflammation and so on, as well as the increase of bone mass during implantation and maxillary sinus elevation are common in the field of oral and maxillofacial surgery. The treatment is usually to repair bone defect with bone grafts. Ideal material of bone grafts need to have good biocompatibility, osteoinductive, osteoconductive, rapid osteogenic and vascularization properties. It was difficult to find the ideal bone graft material. For a long time, bone graft materials mainly include autogenous bone, allogeneic bone and synthetic bone, but each of them has its own limitations. The volume of autogenous bone is often limited, such as the iliac crest and rib; allogeneic bone has strong immune rejection, which leads to osteonecrosis; synthetic bone is slow in degradation and high price [1-3]. With the innovation of material technology, a new bone graft material has emerged. The demineralized dentin matrix (DDM, also known as autogenous dentin particles) has good biocompatibility, no immune response or foreign body reaction, and does not involve the risk of disease infection. It is gradually used in clinical treatment [4-7]. In this paper, the preparation methods, characteristics and clinical application of demineralized dentin matrix were reviewed, and the basic research of demineralized dentin matrix in repairing bone defect was clarified, which laid a foundation for its extensive application in the field of oral and maxillofacial surgery.

Materials and Methods

Biological characteristics of demineralized dentin matrix

In terms of embryonic development, teeth and jaw tissues come from neural crest cells [8]. Although the tissue structure of teeth and bones is different, the proportion of organic and inorganic content is similar (i.e. 70% minerals, 20% collagen, 10% body fluids). Clinically, most of the demineralized dentin matrix comes from the third molars, orthodontic teeth, residual roots or crowns, loose teeth and deciduous teeth that need to be removed. After demineralization, the demineralized dentin matrix is mainly composed of dentin matrix and part of cementum. It is found that dentin contains many kinds of growth factors, such as insulin growth factor II (IGF-II), bone morphogenetic protein-2 (BMP-2), and transforming growth factor (TGF - β), which are considered as effective graft materials [9]. The cementum also contains transforming growth factor, insulin growth factor (IGF-I), type I and type III collagen, etc. [10]. In view of the multiple proteins and growth factors contained in dentin and cementum, which have osteoinductive, osteoconductive, rapid osteogenic and vascularization properties, and the homology of tooth and jaw tissue in histological development, some scholars have found that inorganic and organic substances in teeth can be used as new bone grafts [11].

Preparation of demineralized dentin matrix

The preparation methods of demineralized dentin matrix include freeze-drying, demineralization, calcination and boiling, which can promote the healing of bone defects in varying degrees. The demineralized dentin matrix can induce osteogenesis in 4 weeks, but common dentin in 8 to 12 weeks [12]. The delayed osteoinductive ability of common dentin may be related to the inhibition of
BMP release by apatite crystal. Because of its high crystalline calcium phosphate and poor bone guidance, it is necessary to remove the enamel from the crown before repairing bone defect with the demineralized dentin matrix. The routine preparation methods are as follows: the teeth are extracted, the enamel, pulp and soft tissues such as periodontal membrane, caries, dental calculus, fillings, restorations, etc., are removed. Then teeth are dealt in the ultrasonic instrument, broken into particles with the self-bone powder preparation system. The particles are dehydrated, demineralised, sterilized at room temperature, washed twice with distilled water or sterile phosphate buffer. According to the needs of the operation, the particles can finally be made into massive or powder, then heated and dried [13,14].

Basic research on demineralized dentin matrix

In 1967, Yeomans and Urist made rabbit dentin as bone graft material to obtain new bone formation [15]. Since then, the research on demineralized dentin matrix has begun [16-18]. There has been a lot of related research about demineralized dentin matrix recently. Some scholars have made the demineralized dentin matrix without enamel and pulp for bone regeneration to repair the bone defects of adult sheep, and found that new bone formation have been observed in the area of demineralized dentin matrix [19]. The demineralized dentin matrix, as a new bone regeneration material, has great value in clinical application. The deproteinized bovine bone grafts (Bio-Oss) and human demineralised dentin particles were respectively implanted into the bottom of the maxillary sinus during the maxillary sinus elevation operation, and the animals were killed at 2 and 8 weeks after the operation. The histomorphometry of the two kinds of bone grafts was analyzed by hematoxylin eosin staining and masson trichrome staining. It was found that the new bone was formed in both groups, but the area of new bone formation in the human demineralised dentin particles was significantly higher than that in the Bio-Oss group [20]. The demineralised dentin particles with different particle sizes and densities were used to repair skull defects of rabbits. Rabbits were killed after 2, 4 and 8 weeks respectively. Bone tissue samples were detected by histology, histomorphometry and quantitative RT-PCR. It was found that the demineralised dentin particles with a diameter of 200 micrometres had best osteogenic effect. It shows that the material with smaller particle size is more suitable for bone transplantation [21]. Kim et al. implanted implants and demineralized dentin matrix in the extraction fossa of mandible molars with vertical bone defects in small pigs, then calculated the ratio of new bone formation (NBF) to overall bone defect, and the ratio of the length of alveolar bone to implant contact area (BIC) to implant length. The results showed that the ratio of NBF and BIC in the demineralized dentin matrix group was higher than that in control group at the 4th, 8th and 12th week; NBF was (77.13 ± 15.30)% in the demineralized dentin matrix group and (1.33 ± 2.31)% in the control group at 12th week; BIC was (75.13 ± 16.55)% in the demineralized dentin matrix group and(1.33 ± 2.31)% in the control group at 12th week. These results indicated that the effect of bone reconstruction in the demineralized dentin matrix group at the 12th week was better than that of the control group. The results of CT showed that the bone density of the demineralized dentin matrix group was significantly higher than that of the control group at the 12th week, and the bone formation of the demineralized dentin matrix group was significantly higher than that of the control group (P < 0.05), the immature bone of the demineralized dentin matrix group (25.71%) was less than that of the control group (55.98%) [22].

Some scholars have compared the osteogenic effect of demineralised dentin matrix and recombinant human bone morphogenetic protein-2 (rhBMP-2) with that of inorganic bovine bone (ABB) and rhBMP-2 in the treatment of rabbit skull defect. Circular defects with a diameter of 8mm were formed on each rabbit skull. Each defect was treated by one of the following methods: 1) DDM, 2) ABB / rhBMP-2, or 3) DDM / rhBMP-2. The histology was observed after two weeks. DDM group and ABB / rhBMP-2 group showed conductive bone formation, while DDM / rhBMP-2 group showed conductive and induced bone formation. Compared with DDM group, new bone volume of DDM / rhBMP-2 group increased significantly at 8th week. It should be noted that the new bone volume of ABB / rhBMP-2 group decreased slightly at 8th week. DDM with rhBMP-2 is suitable for autogenous graft material [23].

Clinical application of demineralised dentin matrix

Demineralised dentin matrix have been widely used in clinical practice, such as post extraction alveolar site preservation, implant bone graft, guided bone regeneration, maxillary sinus elevation and bone reconstruction after extraction of impacted mandibular teeth [24].

In the study of maxillary sinus elevation, the demineralised dentin matrix was absorbed gradually and replaced by new bone in histology, and the bone at the bottom of the sinus was reconstructed. So the demineralised dentin matrix can be used as the bone graft material in maxillary sinus elevation, and the effect is satisfied [25,26].

As a new type of bone substitute, demineralised dentin matrix has been used for post extraction site preservation and bone incremental surgery. Some scholars had implanted demineralised dentin matrix in the alveolar fossa after tooth extraction. The cone beam CT and bone density measurement showed that the average alveolar bone absorption height decreased the width of cancellous bone decreased, and the bone density increased in assay group, compared with the blank control group [14] [27-28]. Joshi et al. implanted demineralised dentin matrix and beta-tricalcium phosphate alloplast respectively after tooth extraction. The CBCT was performed immediately after operation, and the height and width of alveolar ridge in both groups were rechecked at 4 months after operation. The results showed that there was more new bone formation in the demineralised dentin matrix site than that in the beta-tricalcium phosphate site [14]. After the average follow-up period of five years, it showed that the formed...
cortex and cancellous bone were well maintained after demineralised dentin matrix was implanted, which was consistent with other short-term follow-up studies [4]. Demineralised dentin matrix can be used as a good material for bone transplantation, even in patients with severe periodontitis [6,29-32]. Demineralised dentin matrix can promote early osteogenesis to achieve good osseointegration with implant surface [33,34].

The autologous bone is considered by some authors the gold standard for bone regeneration. Autologous bone can be gotten from different regions, for example the iliac crest, rib or fibula. Nevertheless, they provide limited quantities of bone, and are associated with morbidity [35]. Allogeneic bone blocks offer a viable alternative to autologous bone, as they can be obtained in almost unlimited quantities. But they are antigenic, and present a risk of disease transmission thanks to a complex process of delipidization, oxidation, dehydration, and gamma irradiation [36]. The synthetic bone is difficult to shape, does not permit fibro-osseous ingrowth, and has a much higher modulus of elasticity than bone [37]. Teeth and bones have a very similar chemical composition. Research on graft materials that can overcome the limitations of autogenous bone and other substitutes has led to the development of demineralised dentin matrix, which is an ideal substitute and has many sources. The demineralised dentin matrix has excellent osteoinductive and osteoconductive abilities, and the recovery process induced by demineralised dentin matrix histologically resembles that induced by autogenous bone [38].

Conclusion

As a new bone graft material, demineralised dentin matrix not only has the function of osteoconduction and osteoinduction, but also has the advantages of good biocompatibility, no rejection, simple process and convenient operation. Basic and clinical research showed that it had a good osteogenic effect, and had been initially used in periodontal and implant fields. However, the research on the physical and chemical stability of autogenous teeth after long-term storage is also in progress and the long-term clinical cases of demineralised dentin matrix is less. However, we believe that the extracted teeth of patients should be kept properly. When patients need bone transplantation, they can be used. Demineralised dentin matrix will be a better choice in bone transplantation in the future. It has a good development prospect and is expected to be widely used and promoted in the world.

Compliance with Ethical Standards

Conflict of Interest: Ming Ding declares that he has no conflict of interest. Lingli Xue declares that she has no conflict of interest. Yan Zeng declares that she has no conflict of interest. Chuan Fang declares that he has no conflict of interest. Wei Cheng declares that she has no conflict of interest. Yadong Li declares that he has no conflict of interest.

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