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Review Article

Bone Grafting in Dentistry: Biomaterial Degradation and Tissue Reaction: A Review

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Abstract

Bone graft biomaterials were routinely used in various dental applications especially in implantology, prosthodontics and maxillofacial surgery. The graft material might be transferred from one area to the other area in the same patient (autografts), obtained from another patient (allografts), received from different species (xenografts) or implanted synthetic (alloplastic raft). Experimentally, it had been reported that, all those tissue grafts had various advantages and disadvantages considering the effect of many factors that relied mainly on the physico-chemical characteristics of graft materials. Those biomaterials were found to produce different patterns of tissue reactions. Therefore, it was crucial issue to review the recent articles concerning selection, study and prognosis of the optimum reliable bone graft substituting material for management of bone dehiscences. An overview about the attempted biomaterials used in bone lesion is presented in this review article.

Keywords: *Bone; Biomaterials; Grafts; Tissue Reaction; Inflammation; Biodegradation*

Introduction

In dentistry, bone grafts were widely implemented in various clinical applications particularly in implantology, Periodontology, Endodontics and Oral Surgery [1]. Autografts were found to be the best bone substitution compared to allografts, xenografts and synthetic material [1-5]. The recent biomimic bone substitutes were found to markedly enhance the alveolar bone regeneration, periodontal regeneration, horizontal and vertical hard and soft tissue augmentation [1]. The prognosis of the biomaterial implantation depend on many factors related to the structural, biological and physico-chemical properties of the implanted biomaterial as well as the size and site of the bony defect area [1,5].

Bone Grafts

Autogenous bone graft had certain disadvantages; because it need surgical procedure to be harvested; which created certain complications including; increased operative time and blood loss [1,3]. It had been reported that the autografts from the ramus of the mandible might cause injury to the inferior alveolar and buccal nerve producing post-operative trismus [1]. Allografts could be either mineralised or demineralised. Mineralised allografts were available in several forms fresh, frozen and freeze dried [1]. It was known that fresh allografts were not frequently preferred as they might induce the human immune response [1]. Frozen allografts were to be maintained below -60°C to avoid biodegradation by enzymes. Freeze-drying technique included removal of liquid content from the frozen tissue by sublimation. Unfortunately, allografts might transmit biohazards like HBV, HCV and HIV [1].

Xenografts were bone minerals derived from animals where the organic components were eliminated in order to reduce the recipient immune reactions [1,2]. The coral and algae derived bonelike minerals were found to have less osteoconductivity than other bone substitutes [1]. Completely synthetic alloplastic materials seem to be biocompatible and had no risk of infections or disease transmission. Therefore, it was necessary to synthesize a suitable alloplastic biocompatible bone substituting material which excluded all adverse effects of both the autografts and allografts [6]. Evidently, there was no available synthetic biomaterial that perfectly mimics the structure and properties of human bone [7].

Postoperative Implant-Tissue Reactions

After the implantation of biomaterials, postoperative inflammation in a living host was inevitable; due to injury to the surrounding tissues during the surgical implantation process. The surgical injury was subsequently followed by inflammation, blood - biomaterial interaction and tissue fibrosis. Accordingly, inflammation might last from few minutes to few days depending on the tissue response. Furthermore, the proliferation of blood vessels and connective tissue might occur as a result of chronic inflammation [8,9]. After 2 or 4 weeks of bone substitute implantation, the biomaterial surface characteristics critically modulate the surface response [1]. Although there were few biomaterials available, their specification were not clear and their potency was not reported [4]. Therefore, further standardization was required to monitor the potential of the alternative biomaterials [10].

In modern dentistry, implant therapy was the ideal conservative treatment to restore the edentulous jaw; which required sufficient alveolar margin for implantation [11]. Successful dental implant could be achieved, when the edentulous ridges were augmented by many surgical techniques including; guided bone regeneration (GBR) that was using synthetic barrier membranes without bone substituting materials [11]. Application of GBR techniques for the human bone regeneration took place by migration of osteoblasts would migrate from the periosteum and adjacent bone tissue to the bone site defects [12-14]. For a successful bone augmentation, regrowth of bone tissue defect, rate of bone growth from the surrounding bony margins should be faster than the rate of fibrogenesis developing from the circumferential soft tissues [14]. To obtain successful GBR, there should be an initial wound closure, stability of the fibrin clot, space maintenance and no incorporation of epithelium or connective tissue [15]. Mineralization by osteoid tissue resulted in the formation of woven bone [16], which later forms the template for apposition of lamellar bone [17].

Bone Regenerative Stages

Bone regeneration involved various mechanisms including; osteoinduction, osteoconduction and osteogenesis. Osteoinduction was the differentiation of the undifferentiated mesenchymal stem cells into bone osteoblasts. Osteoconduction was the process of production organic ground bone substances which were essential for the deposition of bone minerals from the surrounding bone [18]. Osteogenesis was the process of osteoblastic formation and mineralization of bone tissue. In autografts, the tissue was transferred from one location to another location within the same patient as they form new bone by osteogenesis, osteoinduction and osteoconduction [11]. Preferred site for obtaining autografts were extra-oral sites like the tibial plateau, or the iliac crest while; intra-oral sites could be the maxillary tuberosity, the mandibular symphyses, the eight to twelve weeks post-extraction healing sites [19], the mandibular rami, the torior the exostoses [18]. In fact, autogenous bone provided required proteins, osteogenic substrates, vital bone cells, minerals to the recipient site; which enhanced the implant grafting procedure; which usually gave an excellent success rate [18,20].

The spongy bone had greater osteogenic potential than that of cortical bone because of the presence of hematopoietic marrow and a large number of pleuripotent cells within cancellous bone and cortical graft had little amount of osteogenic cells, but provided more bone morphogenetic protein (BMP) [21]. Additionally, that morphogenic protein gave strength to the graft structureless resorption of the implanted bone substitutes, thus disrupting the in-growth of the adjacent soft tissue. However, it might increase the time required for blood capillaries to penetrate the graft [21-23]. Greatest amount of bone could be obtained from the posterior iliac crest. The other sites were anterior iliac crest and tibial plateau. Intra-oral sites are the ascending ramus, followed by anterior mandible and the maxillary tuberosity [11].

Synthetic Bone Grafting Materials

For the regeneration of vital bone considering their mechanical and biological properties, grafting biomaterials were often combined in order to optimize the prognosis [11]. Calcium sulphate, calcium carbonate, ceramic materials and bioactive glass polymers including

synthetic hydroxyapatite and tri-calcium phosphate; were the most commonly used inert synthetic graft materials [11]. The autografts, allografts, xenografts, or alloplasts were used depending on the patient's rate of wound healing, the bone formation capacity of the osteoblasts in recipient site and the time required for bone graft maturation [11]. Autogenous bone should be added progressively for large bony defects, and for dehiscences that had predicted slow osteogenic potential. In addition, excellent results were observed while using barrier membranes [18,24].

In the early 1969, an expanded polytetra-fluoro-ethylene (e-PTFE) had been developed and in 1990s that polymer became the standard for bone regeneration [25]. The fibroblasts and other connective-tissue (CT) cells migration into the bony defect was inhibited by the synthesized e-PTFE membrane; which acted as mechanical barrier and slowed down the osteogenic potential of the proliferating CT cells. Studies had reported that when the e-PTFE was exposed to the oral fluids, it had induced the invasion by pathogenic micro-organisms through the highly porous synthetic membrane and it provoked serious complications. In 1993, aiming to overthrow that invasion by micro-organisms, the high-density PTFE membrane (d-PTFE) possessing porosity size ≤ 0.3 μm had been fabricated. The potency of the d-PTFE membranes used for guided tissue regeneration had been markedly demonstrated in experimental animals as well as in humans [26,27]. During the healing processes, wound dehiscences were found to be common complication during implementation of non-resorbable membranes, because of certain gingival recessions [28]. Aiming to eliminate the second surgical procedure for membrane removal, to increase feasibility and to decrease patient mortality rate, resorbable polymeric and collagen membranes derived from various animal sources were found to be highly advantageous [29].

For preserving alveolar bone and repairing alveolar bone defects and ridge augmentation adjacent to the exposed dental implants, biopolymer membranes; which were fabricated from synthetic polyesters, polyglycolic acid (PGAs), polylactic acid (PLAs) or copolymers were highly useful. The polymers and copolymers of PGA and PLA were also promising; as they were completely biodegraded into water and carbon dioxide through Krebs cycle, thus a second surgical intervention was not mandatory [30].

Membrane Bone Grafts

The collagen membranes which; were synthesized from type I collagen or prepared by combining of type I and type III collagen had an optimal preference for a bioresorbable GTR or GBR barrier [31]. Weak immunogenicity, easy manipulation, tissue biocompatability, hemostasis, chemotaxis for gingival and periodontal ligament fibroblasts were the greatest advantages of those collagen membranes [11]. It had been reported that, after the implantation of biomaterials, foreign tissue reactions and biocompatibility and inflammatory markers of the host cells began to appear rapidly [31]. The actual significance of the present foreign body giant cells FBGCs might reflect the normal biodegradation process of the implanted resorbable biomaterials or the incompatibility of the implanted biomaterials.

Evidently, scientists had different interpretation opinions concerning the role of FBGCs; which developed at the implantation sites as response to the biomaterials. In addition, the variety biomaterials upon and into which FBGCs might proliferate as a tissue response, were also discussed and still not yet established [31]. Recently, various graft biomaterials were selected in GBR technique. Moreover; various related factors should be considered such as; patient clinical and radiographic examination, recognition of graft biomaterials, bone defect site and surgical procedures. The implanted grafts should not induce any inflammatory response, on the other hand; they should be osteoconductive in order to maintain trophism beneath the synthetic membranes and they should be rapidly reabsorbed. The outcomes and the performances obtained from different biomaterials (membranes and grafts) did not clearly show significant differences in the quality of the bone tissue regenerated that was induced by heterologous animal and synthetic biomaterials. However, many adverse effects had been clarified, the resorbable synthetic polymers still had certain adverse effects that might produce negative effects and inhibited degradation from clinical evaluation causing adverse effects and excluding degradable polymers from clinical assessments [32].

Various scientific fields were oriented to lead to a profitable and patient-friendly treatment plan. For management of bone defects, a multidisciplinary approach was essential. Once growth factor release systems, pre-mineralization, and other biomimetic substances were clinically available for running proper mechanical test, biodegradable polymers would get their second chance in clinical trials. Computer technology would be useful in selection of appropriate biopolymers as well as it would predict their properties during manufacturing, the tissue interactions and their physico-chemical properties after implantation over the degradation process [33]. Deproteinized bovine bone mineral (DBBM) was considered suitable as bone substituting material, according to the histomorphometric data analysis without addition of any autologous bone particles [34].

Conclusion

A successful biomaterial implantation depends on many factors which are related to the structural, biological and physico-chemical properties of the implanted biomaterial as well as the size and site of the bony defect sites. Although there are few biomaterials available, their rationale is not precise and their actual effectiveness is not clearly reported. Therefore, further standardization is recommended to reveal the potential of the alternative biomaterials.

Bone particulates of autografts, allografts, xenografts, or alloplasts grafting biomaterials combined with resorbable or non-resorbable barrier membranes techniques; guided bone regeneration (GBR) implemented in bony defect sites and dental restorations.

New technology in biomaterial surfaces should be attempted to improve the implant -tissue reaction and ameliorate the bone regeneration potential. Therefore, further researches were recommended for: i) inhibition of human body immunity towards the non-degradable implants by incorporation of certain antibodies, ii) physico-chemical characterization for the biodegradable or non-degradable implanted biomaterials, iii) modulation of beneficial functions of macrophage i.e., expression of antigenicity and other human growth factors Evidently, FBGCs and macrophages will be always a part of the tissue immune response towards degradable biomaterials and will never be completely eliminated. Continuous investigation of immunological essays are still essential for minimizing the undesirable tissue reactions and to improve both the quantity and the quality of the deposited mineralized new bone tissue.

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