Review Article

Periosteal distraction in cranio-maxillofacial region

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Abstract

Although many different materials, techniques and methods have been used to repair various bone defects in the in cranio-maxillofacial region, Reconstructive management of the atrophic, edentulous mandible and maxilla continues to pose a clinical challenge for the oral and maxillofacial surgeon. Recently, the idea of osteogenesis by periosteal distraction without a corticotomy for the treatment of bone deficiencies in the atrophic and edentulous area has been suggested. The purpose of this article to review the literature on the role of periosteal distraction in osteogenesisin cranio-maxillofacial region.

Key words: Cranio-maxillofacial region, Distraction osteogensis, Periosteal distraction, Periosteal elevation, Periosteal expansion, Periosteum

Introduction

In recent years the idea of osteogenesis by periosteal elevation for the treatment of bone deficiencies has been described and called "periosteal distraction osteogenesis" (PDO). Although this technique is based on the principles of osteodistraction, osteotomy or corticotomy is not necessary.[1-3] This method is based on the concept that under tension the inner layer of periosteum is capable of produce new bone formation in the gap between the periosteum and the surface of the bone.[4,5] This is because of the vascularised internal osteoblastic layer of periosteum which is composed of mesencymal stem cells[6]. The periosteum itself is able to promote osteoblast differentiation and osteogenesis by sensing mechanical stretching and regulating the expression levels of genes involved in BMP signaling pathways, which is the basic principle of PDO[7,8]. Despite good results that have been achieved by this technique there are a lot of variations existed regarding the rate of augmentation, site and surgical technique and the length of consolidation period.[2,4,9-11] The purpose of this article to review the literature on the role of periosteal distraction in osteogenesis in cranio-maxillofacial region.

Periosteum andosteogensis

Periosteum is a dense connective tissue membrane covering the outer surface of all bones except for sites of articulation and muscle attachment.[12] Histologically the periosteum is thought to comprise of at least two layers, an inner cellular or cambium layer, and an outer fibrous layer.[13] The outer fibrous layer contains fibroblast, blood vessels, sensory and sympathetic nerve fibres, collagen fibers and extracellular matrix, The inner layer serves as a reservoir of undifferentiated progenitor cells able to differentiate into chondrogenic and osteoblastic cell lineages.[14] Periosteum can be described as an *osteoprogenitor cell-containing bone envelope*, capable of being activated to proliferate by trauma, retroviruses and tumors[15]. The structure, cell populations and osteogenic potential of periosteum is found to be different at different periosteal sites.[16,17] The osteogenic potential of periosteum has been investigated in several studies[18-23]. The periosteum is known to play an important role in bone healing and osteoeogenesis. It has been shown that in long bones, up to 90% of woven bone in early fracture callus is derived from the periosteum[7] Previous studies have reported the existence of osteogenic progenitors, similar to mesenchymal stem cells (MSCs) in the periosteum. Under the appropriate culture conditions, periosteal cells secrete extracellular matrix and form a membranous structure.[24-26] Further, once the cells are removed from the periosteum, they have the potential to proliferate at much higher rates than bone marrow, cortical bone or trabecular bone-derived progenitor cells[27]. Periosteal progenitor cells are able to differentiate not only into bone and cartilage cells but also into adipocyte and skeletal myocyte cells[28].

Distraction osteogenesis and periosteum

Distraction osteogenesis (DO), also known as callus distraction, callotasis, osteo-distraction, and distraction histogenesis, is a biological process of producing new bone and overlying soft tissue by gradual and controlled traction of the surgically separated bonesegments[29]. The bone and its periosteum act as a guide for new bone formation in a manner that the newly formed bone and soft tissues have the same size and morphology as the native tissues.[30] In DO there are three sequential phases of different biologic phenomena, *Latency period* (from 0 to 7 days), *Distraction period (*0.25 mm four times/day or at a rate of 1 mm/day), and *Consolidation period* (6–12 weeks for adults).[31,32] Distraction osteogenesis in the oral and maxillofacial region is an adaptation of orthopedic distraction osteogenesis principles, and the mechanisms of osteogenesis are the same in the facial bones as they are in the long bones.[33-36] The regenerative potential of periosteum has been effectively used in “osteodistraction” which has the benefit of simultaneously increasing the bone length and the volume of surrounding tissues.[6] Distraction osteogenesis is successful because under appropriate levels of stimulation periosteal mesenchymal stem cells differentiate into osteoblasts and produce early subperiosteal callus within the osteotomized gap.[37-39] The subperiosteal callus matures to form the peripheral part of the newly generated bone.[40] The contact between the periosteal flap or graft and the underlying bone is crucial to stimulation of osteogenesis.[41,42]

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Previous study demonstrated that the immediately elevated periosteum of adult animals did not contribute to the supraosteal bone formation.[43] Kostopoulos et al,[5] showed that tension on the periosteum alone can lead to the production of subperiosteal bone but his study cleared that the outer surface of periosteum exhibits significantly more bone fill than inner surface of the elevated and repositioned periosteum. However, recently the idea of osteogenesis by periosteal distraction for the treatment of bone deficiencies in the atrophic and edentulous area has been suggested[1-4]. PDO does not require osteotomy or corticotomy, only distraction of the periosteum from the cortical surface of the bone[4].

In 2002 Schmidt et al,[4] developed extra oral custom-made periosteal distraction device which was rigidly fixed to the lateral surface of the mandible in rabbit model. The latency period was 7daysand the mesh of device was further distracted 1 mm every 3 days for the next 15. Histomorphometric analysis showed that the distraction of the periosteum without corticotomy induces osteogenesis. In contrast in the study of Estrada et al, the[10] distraction of calvarial bone in 12 rabbits at 0.25mm a day caused formation of bone in just 3 animals, and distraction at 0.5mm a day caused formation of bone in 2 in addition, constant dehiscence of soft tissues with exposure of the distraction device, leading to an inflammatory infiltration of the augmented sites and subsequent treatment failure in dogs trail. Also Sencimen et al,[2] reported an abundance of adipose tissue and insufficient mature bone in the PDO gap area, therefore, they concluded that this newly formed bone is not suitable for occlusal forces, and it would be impossible to insert an endosteal implant into the area.

Lately, Oda et al,[3] investigated the effect of using decorticating holes in the PDO protocol for improving bone regeneration in a rabbit model. They postulated that decorticating holes can be effective in improving the new bone regenerate. Another attempts to promote bone formation at the gap created by periosteal distraction by adding bone marrow mesenchymal stem cells (MSCs)[44], vascular endothelial growth factor VEGF[45], PRF[46] and administration of hyperbaric oxygen (HBO) therapy during PDO[47] have been investigated and showed positive results. However the local appilacation of simvastatin on the formation made no significant contribution to the procedure.[48]

Several devices have been developed to mechanically elevation the periosteal statically or gradually, one is that most devices penetrate the skin or mucosa and need manual mechanical activation to create the space between the periosteum and underlying bone. It is also difficult to close the wound with the periosteum over a bulky device. Sufficient closure with the periosteum is an important factor to acquire newly formed bone as a result of periosteal DO. Yamauchi et al,[11] investigated the utility of periosteal expansion osteogenesis by using a highly purified b-tricalcium phosphate (b-TCP) block, instead of titanium devices, in a dog model. The b-TCP block, acted as a space-maker under the periosteum. The same group reported the development a self-activated mesh device composed of NiTi shape memory alloy (SMA) for periosteal expansion used to create an ideal space without the need for manual activation,[49] the measured volume of newly formed bone was ∼30% of the area created under the periosteum by the SMA device. This was considered an insufficient volume of alveolar bone for implantation in the clinical environment. Later in another study[50] the periosteal expansion using the same device with decortication, the newly formed bone ratio was 70% after a 6-week consolidation period. Sotobori et al,[51] showed that bone regeneration can be induced by periosteal elevation using conventional orthodontic wire and an unsintered hydroxyapatite mesh in rabbit frontal bone, the wire created a continuous force during the entire distraction periods, such that the surgeon did not need to adjust the screws a couple of times a day. Zakaria et al,[52] developed a new device composed of a biodegradable mesh for distracting periosteum over the calvarial bone in rabbit model and they concluded that new device induced osteogenesis and distracted soft tissue successfully in a 6 weeks. Dziewiecki et al,[53] compared the bone generation rates between degradable and non-degradable devices with static periosteal elevation, the results showed that new bone formation could be observed for all materials with no statistically significant differences.

Kessler et al,[9] showed that the ratio of newly formed bone was considerably higher in the dynamic than in the immediate group. In contrast the in another studies newly formed bone in the static periosteal shielding procedure was almost the same as that in the dynamic periosteal elevating procedure[54,55]. Sensimenet al, clearly[2] demonstrated that the quality of newly formed bone depends on the distraction rate. Zakaria et al.[56] also reported that the ideal rate of periosteal distraction for optimal bone augmentation was 330 μmper day or less. Altug et al,[1] compared different latency periods along with different consolidation periods in periosteal distraction in rabbit model, Histomorphometric measurements in their study revealed that there were no significant differences between the groups and the newly formed bone by PDO was mostly filled with fatty tissue, and they claimed that lack of bone marrow cells might play a role in the occurrence of fatty tissue.

Conclusion

In spite of good results that have been achieved by this technique, the reviewed papers presented evident heterogeneity with respect to several aspects including surgical technique, the used device, distraction rate, latency period, the length of consolidation period and adjunctive techniques also to the best of our knowledge no study has evaluated the this technique in humans.

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