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Osteodistraction of mandibles with a small bone defect at the planned osteotomy site: A histological pilot study in dogs

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ABSTRACT

Aim: To develop a treatment plan for cases in which a bone defect is located on the osteotomy line of mandibular osteodistraction (DO).
Subjects and methods: Bilateral DO was performed in 17 Mongrel dogs. Prior to surgery, the 34 hemimandibles were randomly allocated to three groups: C ($n = 10$; a standard DO was performed), D − G ($n = 12$; a bone defect was created on the DO osteotomy line), and D + G ($n = 12$; the bone defect on the osteotomy line was grafted). After one week of latency, 8 days of distraction, and 4 weeks of consolidation the animals were sacrificed, and the newly formed bone were examined.
Results: In group C, two zones of immature trabecular bone originating from host bone margins were separated by a central fibrous zone. In group D + G uniform new bone formation of the entire distraction gap was observed. In group D − G the distraction gap was mainly filled with fibrous tissue. The values for the newly formed bone volume and trabecular thickness were not significantly different between groups D + G and C, but were higher than values in group D − G ($p < 0.05$).
Conclusion: When a mandibular defect is located at the site of distraction osteotomy, DO can be performed simultaneous with bone grafting of the defect.

1. Introduction

Distraction osteogenesis (DO) is a novel modality for the treatment of various craniofacial abnormalities including maxillofacial deformities and posttraumatic and postsurgical defects. DO offers several advantages over orthognathic surgery and conventional maxillomandibular reconstruction techniques including elimination of bone grafting and donor site morbidity, simultaneous distraction of bone and surrounding soft tissue envelope, and the ability to lengthen the maxillofacial bones to a degree that is impossible with the conventional techniques. Since its first application to the craniofacial skeleton by Synder et al. (1973), extensive experimental and clinical investigations on craniofacial DO have been conducted (Farhadieh et al., 2000; Kim et al., 2002; Cho et al., 2003; Singare et al., 2006; Djasim et al., 2007; Shang et al., 2012; Wiberg et al., 2012; Doucet et al., 2013; Ugurlu et al., 2013). Some of these studies were performed to optimize the distraction parameters such as the length of the latency and consolidation periods, and the rhythm and rate of the distraction (Farhadieh et al., 2000; Cheung et al., 2006; Singare et al., 2006; Djasim et al., 2007; Faysal et al., 2013), while other studies aimed at finding approaches to accelerate bone regeneration, and to decrease the length of the consolidation phase (Kim et al., 2002; Cho et al., 2003; Kılıç et al., 2008; Ding et al., 2009; Polat et al., 2009; Wei et al., 2011; Liu et al., 2012).

A problem with DO that has not been evaluated in previous studies is treatment planning for patients who have an impacted tooth or a small benign lesion located at the planned osteotomy site of mandibular osteodistraction. The routine protocol is to remove the tooth or lesion and to postpone the DO surgery for several weeks or months until the surgical defect heals with bone. The disadvantages of this protocol include the necessity for a second operation, a more prolonged treatment period, and associated psychosocial effects. The question arises as to whether it is possible to perform DO osteotomy simultaneously with removal of an impacted tooth or lesion. If yes, is it necessary to place autogenous bone graft in the postsurgical defect before osteodistraction? To

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answer these questions, we decided to conduct an animal experiment.

The aim of the present study was to develop a treatment plan for cases in which a small postsurgical bone defect was located on the line of mandibular distraction osteotomy.

2. Material and methods

2.1. Animals and study design

The protocol for this animal study was approved by the Hamedan University of Medical Sciences Ethics Committee.

In this investigation, 17 skeletally mature male Mongrel dogs weighing 12–15 kg underwent osteodistraction of both sides of the mandible (totally, 34 hemi-mandibles). Prior to surgery, the 34 hemi-mandibles were randomly allocated to three groups: group D + G ($n = 12$), group D − G ($n = 12$), and group C ($n = 10$).

2.2. Operative procedure

After preoperative injection of antibiotic (1,000,000 IU Procaine Penicillin intramuscularly), each dog was anaesthetized using an intramuscular injection of ketamine (5 mg/kg) and xylazine (2 mg/kg). The surgical area was shaved and then sterilized with betadine solution. After subcutaneous injection of local anaesthetic (2% lidocaine with 1:100,000 epinephrine), a 4-cm skin incision was made parallel to the inferior border of the mandible, and the periosteum was elevated. For hemi-mandibles in group C, a vertical corticotomy was performed in the body of the mandible immediately anterior to the first molar tooth. In group D − G, the same vertical corticotomy was performed, but a through-and-through ostectomy of 5 × 5 mm was done over corticotomy line, between the root apices and the inferior border of the mandible. Group D + G underwent the same procedure as group D − G, but the bone defect was filled with compacted autogenous particulate cortico-cancellous bone graft. The bone graft was obtained from the ostectomized bone, and if more graft was required the ipsilateral mandibular ramus was used. In all three groups, a custom-designed extraoral DO device was applied and fixed by 2 mm diameter titanium screws, and then osteotomy was completed (Fig. 1). The skin incision was closed with a nonabsorbable monofilament suture, and dressed with antibiotic ointment (Bacitracin and Polymyxin B sulphate). Postoperatively, an intramuscular injection of Procaine Penicillin G and analgesics was performed, and the routine wound care was provided.

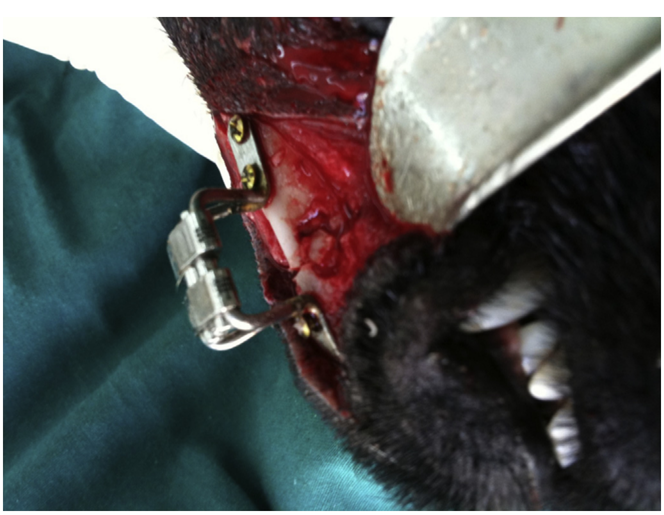

Fig. 1. A through-and-through defect is created over distraction osteotomy line and is filled with autogenous bone graft. A distractor is adapted to the area.

After seven days of latency period, distraction was initiated at a rate of 0.5 mm twice per day for 8 days (a total of 8 mm). All 17 dogs were sacrificed after 4 weeks of consolidation, and the distracted bone (including 1 cm of adjacent original bone on each side) was excised.

2.3. Histological examination

The excised bones were fixed in 10% formalin solution, decalcified, and embedded in paraffin. The samples were sectioned into 5 μm slices and stained with haematoxylin and eosin. In our investigation, the pathologist was blind to which group the hemi-mandibles had been assigned to. In microscopic examination of the regenerated tissue, type of the tissues (fibrous connective tissue, cartilage, and bone), ratio of the newly formed bone volume to total tissue volume (%), mechanism of bone formation (intramembranous and/or endochondral), and direction and thickness of the new trabeculae were evaluated and compared between 3 groups.

2.4. Statistical analysis

We used one-way analysis of variance (ANOVA) and when appropriate, a post-hoc multiple comparisons test to compare the statistical differences between 3 groups. All statistical analyses were carried out using SPSS version 16.0 software. In this study, $p < 0.05$ was considered significant.

3. Results

3.1. Clinical evaluation

The surgical procedures were well tolerated by all animals, and none died. In all subjects the distractors remained stable until the animals were sacrificed. Minor superficial pinhole infection was observed in one of the dogs (in the control group), which was controlled by topical treatment.

In this experiment, 34 hemi-mandibles were taken into data analysis: group D + G ($n = 12$), group D − G ($n = 12$), and group C ($n = 10$). Gross examination of the hemi-mandibles in groups D + G and C showed osteogenesis and union between osteotomized bone margins, while in the group D − G, the gap between original bone ends was filled with fibrous tissue.

3.2. Histological analysis

In group C, immature trabecular bone with fibrovascular stroma could be observed extending from the original bone edges toward the central area of the distraction gap. These two zones of immature bone were separated by a central narrow zone of fibrous tissue. The newly formed trabeculae were surrounded by a layer of active osteoblasts and were oriented parallel to the axis of distraction (Fig. 2). We found that the thickness of the trabeculae in the regenerated bone was less than 50% of the trabecular thickness in adjacent original bone. Although bone formation in the distracted zone occurred predominantly through intramembranous ossification, some focal regions of cartilaginous tissue were seen at the margins of the osteotomized bone, indicating the endochondral bone formation.

In group D + G, the grafted bone was seen in the centre of the distracted zone and was bounded on either side by areas of homogeneous trabecular bone formation. We found that the new trabeculae not only formed from the host bone margins toward the centre of the distraction zone, but also from the both sides of the