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Evaluation of bone regenerative capacity following distraction osteogenesis of goat mandibles using two different bone cutting techniques

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ABSTRACT

Purpose: To compare the regenerative capacity of goat mandibles following sagittal split osteotomy and distraction osteogenesis with a vertical body osteotomy.
Animals and methods: Bilateral vertical and sagittal body osteotomy was performed on the left and right sides of the mandibles in 18 goats. The distraction period lasted for 10 days at 1 mm/day. Animals were sacrificed at 0, 10, and 35 days post-distraction. Bone mineral density (BMD) and bone volume (BV) were analysed by microcomputed tomography (MCT). Types of bone and cells present in the regenerated defect sites were analysed histologically.
Results: At 0, 10, and 35 days, BMD was 0.358 ± 0.012, 0.410 ± 0.012, and 1.070 ± 0.019, respectively, for vertical osteotomy and 0.420 ± 0.013, 0.421 ± 0.009 and 1.182 ± 0.030, respectively, for sagittal osteotomy. BV was 973.310 ± 5.048, 1234.589 ± 4.159, and 2121.867 ± 6.519, respectively, for vertical osteotomy and 995.967 ± 2.781, 1755.938 ± 4.379, and 2618.441 ± 21.429, respectively, for sagittal osteotomy at these three time points. BMD and BV differed significantly at all three times. Histological analysis shows that sagittal splitting was characterized by more robust lamellar bone formation bridging the distraction gap than vertical body osteotomy.
Conclusion: Both MCT and histological analyses showed that distraction using the sagittal osteotomy technique resulted in significantly higher BV and BMD than using vertical body osteotomy.

1. Introduction

Distraction osteogenesis (DO) is a surgical technique used to generate new bone in the area between two vascularized bone surfaces that are gradually separated mechanically by a distractor (Figueroa and Polley, 2002). DO is frequently used in the treatment of bony loss, pseudoarthrosis, and chronic osteomyelitis, and for biological reconstruction after wide tumour resection and deformity, and limb length discrepancy (Nakase et al., 2007). DO is widely used for the repair of human calvarial defects (Cho-Lee et al., 2010), to correct oral and maxillofacial deformities (Park et al., 2011), for the treatment of micrognathia, obstructive sleep apnoea syndrome (Shang et al., 2012), transverse mandibular discrepancies (de Gijt et al., 2012), and large cleft alveolus and palate reconstruction (Rachmiel et al., 2013).

Ilizarov's (1989) technique of DO consists of four steps. In the first, a cut (osteotomy) is made around the perimeter of the bone requiring elongation. In the second step, a rigid fixator (distractor)

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is applied, followed by a latency period of 5–7 days for initial healing. In the third step, distraction forces are gradually delivered, and, in the fourth step, the newly formed bone is allowed to consolidate (regenerate) while the fixator remains in place (Ilizarov, 1989). Mandibular distraction osteogenesis (MDO) is used to treat a variety of craniofacial disorders ranging from simple asymmetries to hypoplasia of the entire mandible (Mandell et al., 2004). Various MDO procedures, using different types of distraction devices, have been tested in animal and clinical studies (Snyder et al., 1973; McCarthy et al., 1992; Perrott et al., 1993; Al Ruhaimi, 2000). In addition, more sophisticated devices have since been developed to improve the results of mandibular lengthening (Choi et al., 2001).

Osteotomy of the mandible is a common procedure performed in orthognathic surgery. During the early development of orthognathic surgery, subcondylar osteotomy, horizontal osteotomy of the ramus and mandibular body or step osteotomy were used to treat mandibular prognathism (Bell et al., 1980). Bilateral sagittal split osteotomy (BSSO) was initially introduced as a surgical treatment of mandibular prognathism (Trauner and Obwegeser, 1957). Several modifications have been found to reduce morbidity and improve stability (Dal Pont, 1961); but complications of these procedures include up to 75% loss of function of the inferior alveolar nerve, 1 year after surgery (Schreuder et al., 2007).

Although various osteotomy techniques were developed after Ilizarove's technique, none has been shown to be optimal for the formation and remodelling of bone in patients with DO (Ilizarov and Shreiner, 1979; Brutscher et al., 1993; Frierson et al., 1994; Krawczyk et al., 2007). We have used microcomputed tomography (MCT) and histological analysis to evaluate the amount of bone generation following sagittal split osteotomy and DO, compared with vertical body osteotomy, in goat mandibles.

2. Materials and methods

2.1. Ethical guidelines

The present study was approved by the College of Dentistry Research Centre Ethical Consideration for Animals, in conformity with the NIH-guidelines for the care and use of laboratory animals (NIH Publication #85-23 Rev.1985).

2.2. Preparation of animals

Eighteen male goats, with a mean body weight of 24 ± 2.2 kg and mean age of 18 ± 1.5 months, were kept in the animal holding facility in the Laboratory Animal Center of King Khalid University Hospital, King Saud University, under veterinary supervision.

2.3. Surgical operations

The goats were anaesthetized by intramuscular injection of xylazine (5 mg/kg, Lloyd Laboratories, Shenandoah, IA, USA), acepromazine (1.5 mg/kg, Vedco, St. Joseph, MO, USA), and ketamine (20 mg/kg, Sigma Chemical, St. Louis, MO, USA). Following the subcutaneous injection of 1.8 mL of local anaesthetic (lidocaine 2%, Parhawk Laboratories, Inc., Lenexa, KS, USA) into the surgical area (Long et al., 2009), a 5 cm horizontal incision was made along the inferior border of the mandible using a surgical blade (No. 15) held on a Brad–Parker blade handle number 3 (Fig. 1a).

2.4. Distraction protocol

After reflection of the periosteum, the distractor devices (Arnaud-Marchac cranial monobl, KLS Martin, Tuttlingen, Germany) were adapted to fit the bone. Using Ilizarov's technique

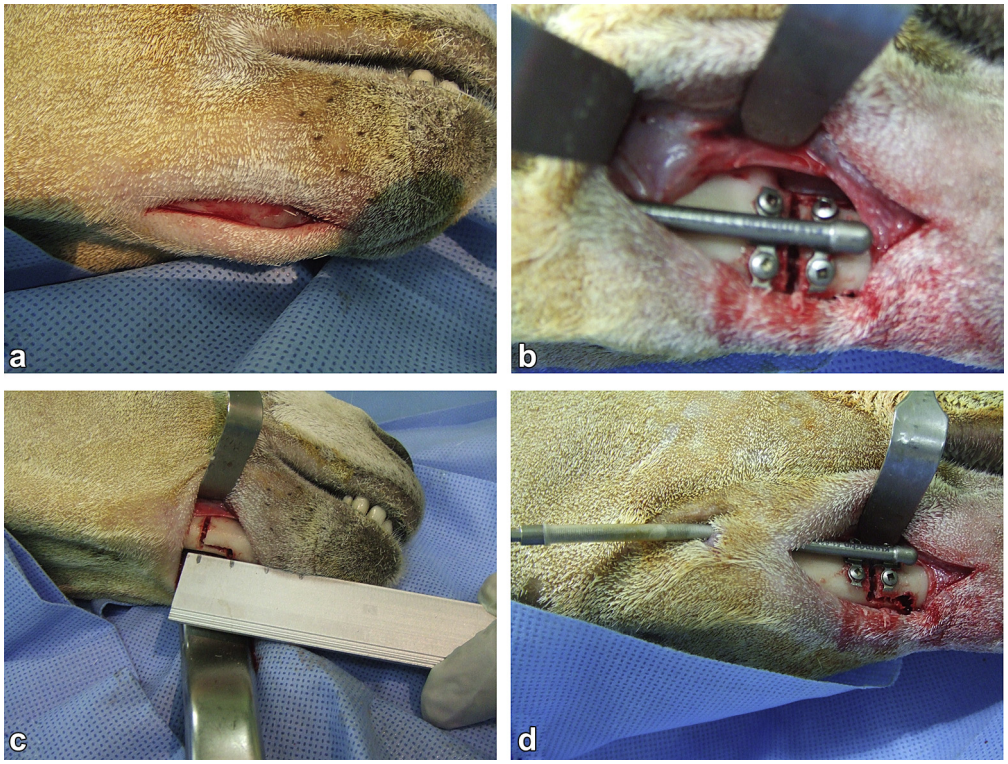

Fig. 1. Photographs showing the horizontal incision along the inferior border of the mandible (a), vertical osteotomy with the distraction device in place (b), the sagittal split osteotomy with a 1 cm width between the lateral and medial cuts (c) and the distraction device on the lateral border of the mandible (d).