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Impact of selective alveolar decortication on bisphosphonate burdened alveolar bone during orthodontic tooth movement

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ABSTRACT

Objective: To investigate the effect of Selective Alveolar Decortication (SADc) facilitated orthodontic tooth movement (OTM) on bisphosphonate burdened alveolar bone in a rodent model.
Design: OTM was accomplished by protraction of the maxillary right first molars. Four groups were included of which two groups were pre-treated for three months with alendronate sodium (BP + TM + SADc and BP + TM group) and two groups were given saline (TM + SADc and TM group). Selective alveolar decortication surgery was performed on day 1 of appliance insertion. OTM measurements were obtained at 0, 4, and 8 weeks using in-vivo μCT. Tissues were analysed by histology and EPMA.
Results: Tooth movement of 0.39 mm and 0.75 mm in the BP + TM + SADc group at 4 and 8 weeks respectively was achieved with 113% increase in tooth movement compared to BP + TM group at 4 weeks. In comparison, SADc + TM group showed 0.63 mm and 2.1 mm of tooth movement at 4 weeks and 8 weeks respectively with only 6% increase at 4 weeks and 2% increase at 8 weeks compared to TM group. Severe interproximal and buccal bone loss around the first permanent molar in the BP + TM + SADc group was seen with μCT imaging and histology. Animals in BP + TM + SADc group histologically showed signs of osteonecrotic bone with irregular borders, loss of osteocytes and absence of osteocytic lacunae.
Conclusion: This study demonstrated selective alveolar decortication accelerates tooth movement in a bisphosphonate burdened alveolar bone in the short term but the potential of such an invasive injury can have adverse effects.

1. Introduction

Orthodontic tooth movement occurs as a result of orchestrated activity of bone cells (osteoclasts and osteoblasts) that remodel alveolar bone to facilitate the required tooth movement (TM). The force system acting on the tooth generates strains in the surrounding periodontal ligament and the alveolar bone. This, in turn leads to areas of compression and tension with bone resorption on the pressure side and bone formation on the tension side (Krishnan & Davidovitch, 2006). The rate and amount of tooth movement is affected by the rate of bone turnover (Verna, Dalstra, & Melsen, 2000). To date, various treatment modalities have been investigated to accelerate tooth movement (Iino et al., 2007; Wang et al., 2009; Hassan et al., 2010; Baloul et al., 2011; Cano et al., 2012; Cruz, Kohara, Ribeiro, & Wetter, 2004; Yamaguchi, Hayashi, & Fujita, 2010; Nishimura, Chiba, & Ohashi, 2008; Showkatbakhsh, Jamilian, & Showkatbakhsh, 2010; Kim, Park, & Kang, 2008; Liou &

Abbreviations: BA, bone area; BP, bisphosphonate; BRONJ, bisphosphonate induced osteonecrosis; Ca, calcium; EPMA, electron-probe microanalysis; IV, intravenous; μCT, micro-computed tomography; NK, Neelambar Kaipatur; OTM, orthodontic tooth movement; PAOO, periodontally accelerated osteogenic orthodontics; P, phosphorous; PBS, phosphate buffered saline; PDL, periodontal ligament; RANKL, receptor activator of nuclear factor kappa-B ligand; RAP, regional acceleratory phenomenon; ROI, region of interest; SADc, selective alveolar decortication; Sr, strontium; TM, tooth movement; TSAD, temporary skeletal anchorage device.

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Huang, 1998; Sayin et al., 2004; Iseri, Kisnisci, Bzizi, & Tuz, 2005; Iglesias-Linares et al., 2001; Kanzaki et al., 2006). A recent systematic review by Long et al. showed that corticotomy is an effective modality to accelerate tooth movement and is relatively safe compared to any other method (Long et al., 2013).

Corticotomy is a surgical procedure to accelerate rate of orthodontic tooth movement by causing localized osteopenia and accelerated bone metabolism as a result of controlled surgical damage (Köle, 1959). Frost (1983) coined the term "Regional Acceleratory Phenomenon (RAP)" to explain this tissue response. The sequence of events during RAP associated tissue injury include; initiation within a few days of injury, peaking at 1–2 months and effects typically lasting 4 months (Schilling, Müller, Minne, & Ziegler, 1998; Wilcko & Wilcko, 2013). Many animal (Iino et al., 2007; Duker, 1975; Ren et al., 2007; Mostafa et al., 2009) and human studies (Wilcko et al., 2009) have demonstrated the phenomenon of reversible osteopenia and accelerated tooth movement using corticotomy. Wilcko et al. patented a technique called "Periodontally Accelerated Osteogenic Orthodontics (PAOO)" that allowed for faster activation of orthodontic appliance at two week intervals to accelerate tooth movement (Murphy et al., 2009).

A rat model (Sebaoun et al., 2008) was used to demonstrate the actual biological response to corticotomy induced tissue damage. The authors presented that the increased rate of turnover in the alveolar bone is a result of anabolic and catabolic modelling; which increases by third week of tissue injury. This is followed by a decrease to normal level of remodelling by seventh week and stabilization by eleventh week of alveolar decortication surgery (Sebaoun et al., 2008).

Wilcko and Wilcko (2013) proposed that corticotomy accelerated tooth movement should be contraindicated in moving ankylosed teeth; and tooth movement in areas of devitalized bone such as with long term use of bisphosphonates or steroid therapy. The ability of bisphosphonate molecules to be trapped in large quantities in the bone and released during normal and active bone remodelling, can lead to apoptosis of osteoclasts (Russell, 2007), the cells needed for bone resorption associated with orthodontic tooth movement (Yamaguchi, 2009). Prolonged use of bisphosphonate drugs have been shown to cause atypical fractures of femur and spine (Abrahamsen, 2010) and osteonecrosis of the jaws especially with invasive dental procedures such as tooth extractions and dental implant placement (Ruggiero, Mehrotra, Rosenberg, & Engroff, 2004; Marx, Sawatari, Fortin, & Broumand, 2005). We have recently shown that bisphosphonate burdened alveolar bone from long term bisphosphonate use, can significantly inhibit the amount of tooth movement in a rat model (Kaipatur et al., 2013). To date, there have not been any published studies that looked at the effect of selective alveolar decortication on remodelling changes in bisphosphonate burdened alveolar bone and associated tooth movement. We hypothesize that the transient osteopenia associated with selective alveolar decortication would open up the underlying marrow vascular spaces, to maintain a stable state of bone but at the same time leach out enough bisphosphonate drugs from the alveolar bone to allow for normal remodelling process to occur; thereby increasing tooth movement without any adverse effects.

The objective of this animal study was to evaluate and quantify the acceleration of tooth movement associated with selective alveolar decortication in the alveolar bone of a bisphosphonate burdened rat model and to further investigate the tissue effects of such an invasive injury.

2. Materials and methods

2.1. Research design

Ethics approval was obtained from the University of Alberta animal care and use committee. The study initially included 34 female Sprague-Dawley rats (age, 12 weeks) purchased from Biosciences, University of Alberta and randomly assigned to 4 cohort groups. The animals were housed with two in a cage with 12-hour dark-and-light cycles. All animals were fed a standard laboratory soft diet ad libitum. The final sample size was reduced to thirty rats ($n = 30$) due to loss of four animals from the study. Two groups were pre-treated for 12 weeks with Alendronate sodium (0.015 mg/kg subcutaneously) (BP + TM group ($n = 7$) and BP + TM + SADc group ($n = 8$)) and two other groups were pre-treated with saline (TM group ($n = 7$) and TM + SADc group ($n = 8$)). Following 12 weeks of BP/saline drug administration, all groups had the orthodontic appliance inserted to facilitate tooth movement. The two groups with selective alveolar decortication surgery (SADc); had the surgical procedure completed on the day of orthodontic appliance insertion. Left hemi-maxillae were used as an intra-animal negative control in both control and BP burdened rats. The experimental design and dosing schedule are shown in Fig. 1.

2.2. Surgical procedure and appliance insertion

Selective alveolar decortication surgery was executed as per Baloul et al. (2011). Briefly, full thickness mucoperiosteal flap was raised; following a sulcular incision made using a Bard Parker No. 15 blade around the sulcus of the maxillary first right permanent molar both buccally and palatally extending 5 mm mesially into the edentulous space. Five decortication indentations each; buccal and palatal of right first permanent molar 0.25×0.25 mm in diameter were made using No. 1/4 round bur on a slow speed electric hand piece (NSK; Brassler, Savannah, GA). Flaps were sutured back using 6-0 Vicryl bioresorbable suture (Ethicon,

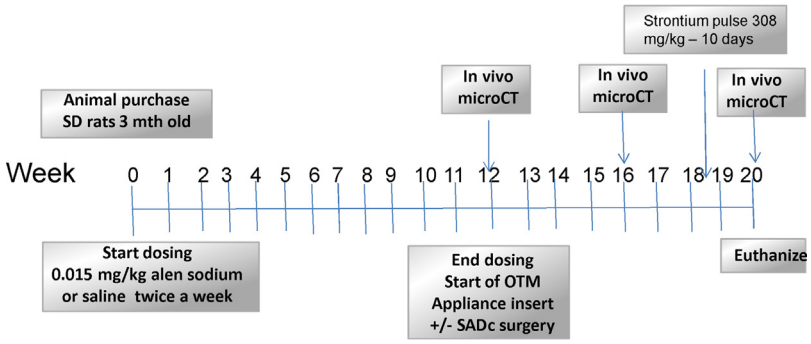

Fig. 1. Experimental design and time schedules for experimental groups and their respective controls.