Archives of Oral Biology 80 (2017) 136–143

Contents lists available at ScienceDirect

Archives of Oral Biology

journal homepage: www.elsevier.com/locate/aob

Response of mandibular condyles of juvenile and adult rats to abnormal occlusion and subsequent exemption

Guang Zeng[a,1], Bin Kuang[b,1], Wen-xing Xun[a], Gao-tong Ren[c], Ke-wen Wei[a,*]

[a] Department of Dentistry, Tangdu Hospital, Forth Military Medical University, Xi'an, 710038, China
[b] Department of Stomatology, First People's Hospital, Lanzhou, 730050, China
[c] Department of Immunology, Forth Military Medical University, Xi'an, 710032, China

ARTICLE INFO

Article history:
Received 15 November 2016
Received in revised form 25 March 2017
Accepted 27 March 2017

Keywords:
Temporomandibular joint (TMJ)
Condyle
Subchondral bone
Abnormal occlusion
Remodeling

ABSTRACT

Objective: The adaptation capacities of the mandibular condyle in response to mechanical stimuli might be different between juveniles and adults, but has not been compared. This study aimed to investigate whether abnormal molar occlusion and subsequent molar extraction could lead to different remodeling responses in the mandibular condyles of juvenile and adult rats.
Methods: Abnormal molar occlusion (AMO) was established in the 5- and 16-wk old rats by moving their maxillary left and mandibular right third molars distally. AMO was removed in the molar extraction group at 4 weeks but remained in the AMO group. All rats were sacrificed at 8 weeks. Micro-computed tomography, histomorphology, immunohistochemistry and real-time PCR were adopted to evaluate the remodeling of condylar subchondral bone.
Results: Condylar subchondral bone loss and increased osteoclastic activities were observed in both juvenile and adult AMO groups, while increased osteoblastic activities were only seen in the juvenile AMO group. Decreased bone mineral density, bone volume fraction and trabecular thickness, but increased trabecular separation, number and surface of osteoclasts and mRNA levels of TRAP, cathepsin-K, RANKL in the juvenile AMO group were all reversed after molar extraction (all $P < 0.05$). However, these parameters showed no difference between adult AMO and extraction groups (all $P > 0.05$).
Conclusions: Abnormal molar occlusion led to degenerative remodeling in the mandibular condyles of both juvenile and adult rats, while exemption of abnormal occlusion caused significant rescue of the degenerative changes only in the juvenile rats.

1. Introduction

The osseous elements forming the temporomandibular joint (TMJ) are the fossa and the articular eminence of the temporal bone in the upper portion, and the mandibular condyle in the lower portion. The mandibular condyle has been of much interest in orthodontics, not only because of its role in mandibular growth (pre- and postnatal), but also because of its capacity to undergo remodeling in response to external stimuli throughout life (Galhardo, Caldini, Battlehner, & Toledo, 2012; Shen & Darendeliler, 2005; Willems, Langenbach, Everts, & Zentner, 2014). This remodeling is responsible for the adaptation of the condyle to orthodontic functional therapy, and has been shown extensively in animal studies (Gredes et al., 2012; Leung, Rabie, & Hägg, 2004; Patil, Sable, & Kothari, 2012; Proff et al., 2007; Rabie, Xiong, & Hagg, 2004; Tang, & Rabie, 2005; Xiong, Rabie, & Hagg, 2005). For example, in juvenile animals, mandibular advancement induces remodeling changes of the condylar cartilage and subchondral bone, including chondrocyte proliferation, cartilage matrix synthesis and subsequent bone deposition in the posterior and posterosuperior direction (Gredes et al., 2012; Leung et al., 2004; Patil et al., 2012; Proff et al., 2007; Tang, & Rabie, 2005). Furthermore, studies in adult rats also indicated that the mechanical strain produced by mandibular advancement could induce neovascularization and osteogenesis in mandibular condyles, leading to adaptive growth of the condyle (Rabie et al., 2004; Xiong et al., 2005). These results highlight the remodeling capacities of the mandibular condyle in response to the changes in the bio-mechanical environment. Furthermore, it has been shown that increasing age may diminish the capacity of the TMJ to adapt to altered function, suggesting that the adaptation capacities of the mandibular condyle in response to mechanical stimuli might be different between juveniles and adults (Bouvier, 1988).

* Corresponding author.
E-mail address: weikewen1010@126.com (K.-w. Wei).
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.archoralbio.2017.03.019

Molars occlusion is the predominant influential factor in the biomechanical environment of the TMJ. Abnormal molar occlusion, such as unilateral molar lingual crossbite (Henrikson, Ekberg, & Nilner, 1997), non-working side interferences (Egermark, Magnusson, & Carlsson, 2003) and the loss of molar support (Tallents, Macher, Kyrkanides, Katzberg, & Moss, 2002), have been reported as associated with specific diagnostic groups of temporomandibular disorders (TMD). Animal data indicate the occurrence of degenerative remodeling of the mandibular condyle in response to abnormal molar occlusion, such as experimentally disordered occlusion (Jiao et al., 2009, 2011; Jiao, Wang et al., 2010; Kuang et al., 2013; Wang et al., 2012; Zhang et al., 2013), unilateral molar extraction (Huang, Opstelten, Samman, & Tideman, 2002) and bite raise (Mao, Rahemtulla, & Scott, 1998). These changes include decreased thickness of the condylar cartilage, loss of the cartilage extracellular matrix, altered morphology, death of chondrocytes, local lesions, loss of condylar subchondral bone and increased osteochondral angiogenesis (Huang et al., 2002; Jiao et al., 2009, 2011; Jiao, Wang et al., 2010; Kuang et al., 2013; Mao et al., 1998; Wang et al., 2012; Zhang et al., 2013). However, because the mandibular condyles posses remodeling capacities in response to external stimuli, whether the exemption of abnormal molar occlusion could promote recovery of the degenerative mandibular condyle, and whether juveniles and adults respond differently during this recovery process remain unknown.

The fibrocartilage and the subchondral bone of the mandibular condyle form a functional entity that withstands the mechanical forces generated during jaw movement and clenching, and the latter provides very important structural support to the former (Willems et al., 2014). The remodeling process of the subchondral bone is accomplished by a precise coordination of the activities of two cell types: osteoblasts, which deposit the calcified bone matrix, and osteoclasts, which resorb bone (Tang et al., 2009; Zaidi, 2007). Disturbances to the bone remodeling process are often associated with joint diseases. However, little is known about the remodeling process of the mandibular condylar subchondral bone in response to the abnormal molar occlusion and subsequent exemption.

Therefore, the aim of this study was to test whether abnormal molar occlusion and subsequent exemption caused different degenerative and rehabilitative remodeling changes in the mandibular condylar subchondral bone of juvenile and adult rats. Micro-computed tomography analysis, histomorphological assessment and immunohistochemical staining were used to evaluate the microstructure and remodeling activities of the condylar subchondral bone. Changes in mRNA expression of genes related to osteoclast activity, such as TRAP, cathepsin K, RANKL and OPG, and genes related to osteoblast activity, such as ALP, osteocalcin, Col1a1 and Col1a2 were examined by real-time polymerase chain reaction (RT-PCR). The null hypotheses tested were as follows: (1) The remodeling activities of the condylar subchondral bone caused by abnormal molar occlusion are not different between juvenile and adults rats. (2) The rehabilitative changes of the condylar subchondral bone after exemption of abnormal molar occlusion are not different between juvenile and adults rats.

2. Materials and methods

2.1. Animal model

The lifespan of a laboratory rat is 2.5 years on average, and the somatic growth puberty for Sprague–Dawley rats occurs between 5 and 8 weeks of age (Shen, Hagg, Rabie, & Kaluarachchi, 2005). The rapid developmental changes of the mandibular condyle of female rats occurs before 4 months of age (Jiao, Dai et al., 2010). In addition, previous studies have shown that the mandibular condyles of the female rats are more susceptible to the abnormal occlusal loading model we used in the present study (Jiao et al., 2009). Therefore, female rats of 5- and 16-weeks old were used in the present study. Forty-five juvenile rats (5-week old, weight 130–150 g) and forty-five adult rats (16-wk old, weight 280–300 g) were obtained from the Animal Center of Fourth Military Medical University. All procedures and animal care were approved by the University Ethics Committee and performed according to institutional guidelines. For the rats in experimental groups, an elastic rubber band was placed between the maxillary left second and third molars and between the mandibular right second and third molars. In this way, the third molars were moved approximately 0.8 mm distally by the elastic force of the rubber bands. One week later, the rubber band was replaced with self-curing resin to maintain the gap (Fig. 1A) (Jiao, Wang et al., 2010). For the rats in sham-treated groups (control groups), the same procedure was

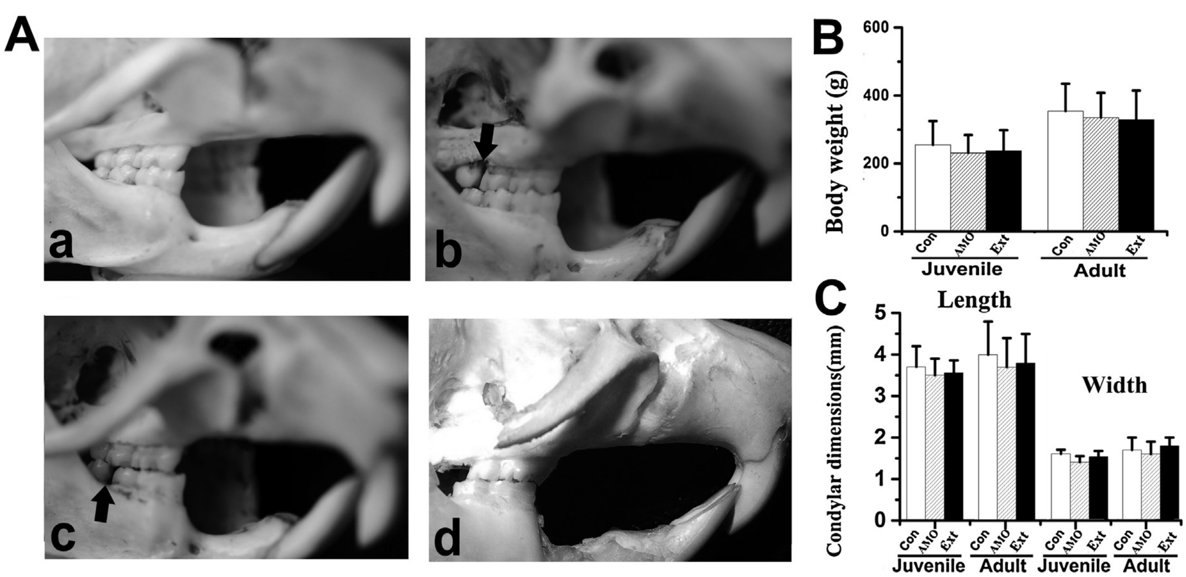

Fig. 1. A: Examples of the occlusal relationship among the rats of the control (a), AMO (b, c) and extraction groups (d). B and C: Comparison of the body weight (B), and the length and width of the mandibular condyle (C), of juvenile and adult rats at the end of 8 weeks. Control, Con; abnormal molar occlusion, AMO; extraction, Ext.