ARCHIVES OF ORAL BIOLOGY 59 (2014) 1368–1376

Available online at www.sciencedirect.com

ScienceDirect

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

Mechanical loading leads to osteoarthritis-like changes in the hypofunctional temporomandibular joint in rats

Yuhei Ikeda [a], Ikuo Yonemitsu [a,*], Maki Takei [a], Shunichi Shibata [b], Takashi Ono [a]

[a] Orthodontic Science, Department of Orofacial Development and Function, Division of Oral Health Sciences, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan

[b] Maxillofacial Anatomy, Department of Maxillofacial Biology, Division of Maxillofacial/Neck Reconstruction, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan

ARTICLE INFO

Article history:
Accepted 18 August 2014

Keywords:
Temporomandibular joint hypofunction
TMJ-osteoarthritis
Growth
Mechanical loading
Matrix metalloproteinase-13

ABSTRACT

Objectives: Temporomandibular joint (TMJ) hypofunction secondary to feeding a liquid diet in the growing period leads to morphological hypoplasia. However, few studies have evaluated the results of mechanical loading on the hypoplastic TMJ. This study investigated whether TMJ hypofunction in rats causes osteoarthritis (OA)-like changes when exposed to mechanical loading.

Design: Male 21-day-old Wistar rats were divided into four groups. The first group (C) served as the control. In the second group (W), mechanical loading was applied to the TMJ by continuous steady mouth opening (3 h/day for 5 days) from 63 days of age. A jaw-opening device was used to hold the mandible open in the maximal mouth-opening position with a cobalt–chromium (Co–Cr) wire (φ: 0.9 mm). Groups C and W both received a normal hard diet. The third group (L) and fourth group (LW) were fed a liquid diet and group LW were subjected to the same loading as group W. We evaluated the TMJ using micro-CT, toluidine blue staining and immunohistochemistry of matrix metalloproteinase (MMP)-13.

Results: In group LW in the superior and posterior regions of the condyle, bone volume fraction, trabecular thickness and trabecular number were significantly decreased and trabecular spacing was significantly increased. The ratio of MMP-13 immunopositive cells was significantly higher than in the other groups. OA-like changes were also observed, including reduced thickness of the cartilage, irregularities in the chondrocytic layer, and cell-free areas.

Conclusions: TMJ hypofunction in rats is likely to lead to OA-like changes when exposed to mechanical loading.

* *Corresponding author*. Tel.: +81 3 5803 5530.
E-mail addresses: yoneman.orts@tmd.ac.jp, yoneorts@tmd.ac.jp (I. Yonemitsu).

http://dx.doi.org/10.1016/j.archoralbio.2014.08.010
0003–9969/

1. Introduction

Temporomandibular joint disorder (TMD) is multifactorial disease and an important pathological condition in clinical orthodontics. TMDs include temporomandibular joint osteoarthritis (TMJ-OA), which is mainly characterized by condylar dysplasia, cartilage degradation and subchondral bone resorption.[1] It has been reported that degenerative changes in the condyles like OA could influence acquired maxillofacial skeletal morphology.[2]

OA is a degenerative joint disease with a high prevalence, especially in older people. Because of the current ageing society, the number of patients affected by OA of the knee and hip joints is expected to increase, highlighting the importance of establishing prophylaxis and treatment methods for this condition.

The causes of OA include deformity of the joints, muscular weakness, instability, overloading, injury and genetic factors.[3–6] TMJ-OA is similar to OA in other joints.[7] Clinical investigations reveal that condylar resorption, which is the main symptom of TMJ-OA leads to clockwise rotation of the mandible and deficient growth of the ramus.[8,9] It has been reported that unexpected occlusal changes caused by condylar resorption may occur during orthodontic treatment,[10] so the condition of the TMJ should be taken into account when establishing a treatment plan for TMD patients. In terms of the craniofacial morphology of orthodontic patients, it has been reported that patients with a Class II open bite or TMD have a significantly steeper mandibular plane and larger gonial angle.

Retrognathic patients are typically characterized by a high occlusal plane angle, dolichofacial type and skeletal Class II relationships, and require treatment not only with orthodontic techniques, but also with orthognathic surgery with mandibular advancement[11] or distraction osteogenesis.[12] However, such patients sometimes suffer from skeletal relapse owing to exceeding the adaptation of the condyle of the TMJ to mechanical loading.[8,9] Although radiographs confirm that these patients have small mandibular condyles that are less resistant to loading, little is known about the mechanism by which such condyles are likely to lead to bone loss under loading.

Basic animal research on the TMJ of growing rats has shown that bilateral resectioning of the masseter muscles or feeding the rat a liquid diet induces a shortened ramal height and a thinner chondroblastic layer in the condyle.[13–15] These findings confirm that masticatory muscle weakness during the growth period results in a hypofunctional TMJ.

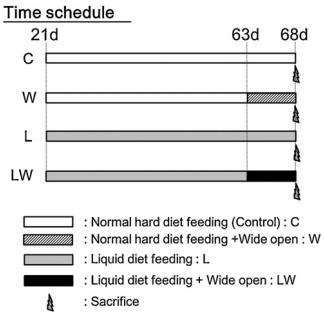

Fig. 1 – Experiment schedule.

Condylar cartilage plays an important role in shock absorption and overload prevention, and facilitates smooth jaw movement. Cartilage degradation affects these basic functions and leads to changes in the structure and composition of the extracellular matrix (ECM). Type II collagen, the main component of condylar cartilage, is decomposed by collagenase, which is involved in cartilage matrix resorption.[16] Matrix metalloproteinases (MMPs) are active in the degradation of the ECM at the initiation and progression of joint disease[17] and are particularly effective at cleaving type II collagen.[16] Although the activity of chondrocytes in OA is not fully understood, MMP-13 is elevated in knee OA cartilage,[18] and expressed higher in the condylar cartilage of TMJ-OA.[19] Therefore MMP-13 is widely used to investigate correlations with OA.

Earlier studies of OA have used animal models involving induction of malocclusion,[20,21] genetic modification,[22,23] local application of chemicals to the TMJ,[1,24] surgical manipulation of the joint structure,[25,26] and simulated loading by enforced mouth opening.[27–29] Imposing mechanical loading on the TMJ by mouth opening allows the resistance to loading to be evaluated. Although TMJ hypofunction secondary to feeding a liquid diet during the growth period leads to hypoplasia, few studies have evaluated the results of mechanical loading on the hypoplastic TMJ. We produced TMJ dysplasia in rats by feeding them a liquid diet, and evaluated the changes induced by excessive jaw opening under mechanical loading to investigate whether TMJ hypofunction in growing rats causes OA-like changes under loading. We evaluated OA-like changes using morphological assessment of the subchondral bone of the condyle, and histology and histomorphometry of the condylar cartilage using toluidine blue staining and immunostaining for MMP-13.

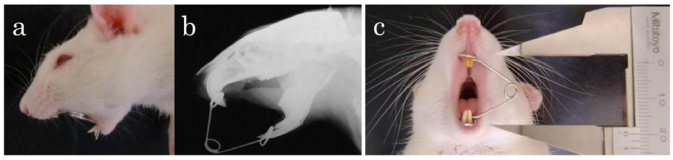

Fig. 2 – Experimental mouth opening device. (a) Lateral view during mouth opening. (b) Radiograph of anesthetized rat showing maximal mouth opening (40 cm, 25 kV, 2 mA, 45 s; Softex CMB-2, Softex Co. Ltd., Tokyo, Japan). (c) Maximal mouth opening (approximately 20 mm) achieved with a Co–Cr wire device (φ: 0.9 mm).