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Soft diet causes greater alveolar osteopenia in the mandible than in the maxilla

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ABSTRACT

Objective: To investigate changes in the bony microstructure of the upper and lower alveolar bone during masticatory loading induced by soft diet feeding in growing rats.

Design: Three-week-old male Wistar rats were randomly divided into two groups. Rats were fed with either pellets [control group ($n = 6$)] or a soft diet [experimental group ($n = 6$)] for nine weeks. 3D-microstructure of the alveolar bone of the first molar region (M1) was examined by micro-CT analysis.

Results: Micro-CT images showed increased marrow spaces of the inter-radicular alveolar bone around the rat mandibular M1 in the experimental group compared with that in the control group. The bone volume/tissue volume ratio, trabecular thickness, trabecular number, mean intercept length, trabecular width and trabecular star volume for the mandibular M1 inter-radicular alveolar bone were lower in the experimental group than in the control group. Marrow space star volume was increased in the experimental group compared with the control group.

Conclusions: These results suggest that alveolar osteopenia is more extensive in the mandible than the maxilla in rats that experience low masticatory loading during growth.

1. Introduction

In rat models of occlusal hypofunction, bone formation is significantly suppressed in the bucco-lingual direction, and the stiffness of the alveolar bone is reduced.[1,2] The results of various studies have indicated that a soft diet during the developmental period causes a delay in the growth of the muscles of mastication and in jaw bone development[5,6] as well as changes in the growth of the viscerocranium.[7]

There are some disparities in the mechanisms of bone metabolism between the upper and lower jaw bones, particularly in terms of the pattern of bone resorption after the loss of teeth. Alveolar osteopenia in the edentulous mandible results in a knife-edge shape of the residual ridge, which contrasts to the smoother surface of the edentulous maxilla.[8] Differences in bone remodelling were observed between the maxilla and mandible in tooth extraction model in dogs.[9] Densitometry evaluation showed higher alveolar bone mineral density in the mandible as compared with the maxilla that was due to the thick cortical bone.[10] A finite element human model demonstrated that occlusal load induced greater displacement of the mandibular teeth than the maxillary teeth at the time of occlusal contact.[11] While the differential responses between the two jaw bones in response

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to diet have been examined, the changes to the bony microstructure between the maxilla and mandible in response to a soft diet are not thoroughly understood. The purpose of this study was to compare the alveolar bone microstructure in the upper and lower jaws in response to a soft diet during growth using micro-CT analysis.

2. Materials and methods

2.1. *Experimental model*

Three-week-old male Wistar rats were randomly divided into a control group ($n = 6$) and an experimental group ($n = 6$). Rats in the control group were fed a standard pellet diet, while the rats in the experimental group were fed a diet in gel form (DietGel 76A, ClearH2O, Portland, Maine, USA) for 9 weeks. Body weight was monitored daily. After the experimental period, all animals were anesthetized with an interperitoneal injection and killed by cervical dislocation. The maxilla and mandible of each animal were removed immediately, and the inter-radicular alveolar bone in the first molar region (M1) was examined by micro-CT analysis.

2.2. *Three-dimensional micro-CT analysis*

We chose the inter-radicular alveolar bone in the M1 in both maxilla and mandible as the region of interest (ROI) for structural morphometry, as this area is exposed to concentrated occlusal stimuli and is often used for alveolar bone histomorphometry (Fig. 1).[3,4] A scanning resolution of 20 μm was used to assess alveolar bone in the M1 using a desktop X-ray micro-CT system (SMX-100CT, Shimadzu, Kyoto, Japan). To distinguish between trabecular bone and bone marrow in the analysis, the adaptive threshold was adjusted in the three-dimensional image-analysis software (TRI/3-D-BON, Ratoc System Engineering, Tokyo, Japan) according to the software instructions. This was achieved by first constructing a CT level histogram of bone marrow to determine the ''adaptive threshold''. Bone marrow was then excluded from trabecular bone by the ''Discriminant Analysis Method''.[17] After the threshold was determined, the borders of the septum between the roots of the M1 were defined as the ROI in the TRI/3-D-BON software. Bone volume fraction was measured as the percent-

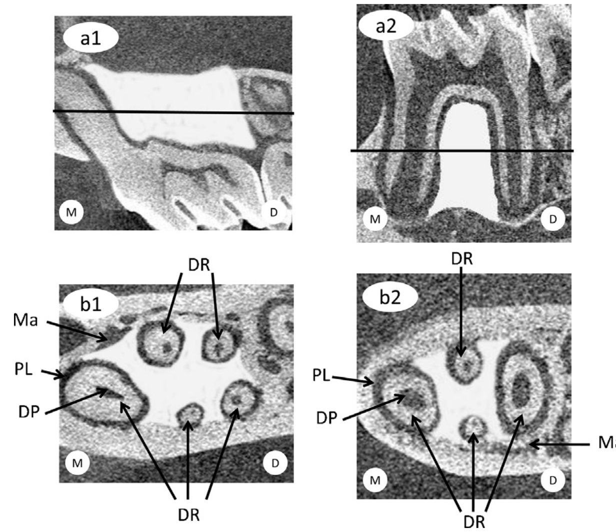

Fig. 1 – Three-dimensional micro-CT images. (a) Sagittal section of interradicular septal bone of the maxillary (a1) and mandibular (a2) first molar (M1) region. The region of interest (ROI; white-filled area) was interradicular septal bone which is between the dental roots the of M1. (b) Horizontal image of the ROI marked by the line in (a). ***Abbreviations*****: M, mesial; D, distal; DR, dental root; Ma, bone marrow; PL, periodontal ligament; DP, dental pulp.**

Table 1 – Comparison of bone volume/tissue volume (BV/TV), trabecular bone thickness (Tb.Th), trabecular bone number (Tb.N), mean intercept length (MIL), marrow space star volume (Vm), trabecular width (Tb.W) and trabecular star volume (Vt) in the maxillary and mandibular alveolar bone of animals fed a soft diet and those fed a control diet.

Material	Maxilla					Mandible				
Group	Control		Soft diet		Significance levels	Control		Soft diet		Significance levels
Parameter	Means	Standard deviations	Means	Standard deviations		Means	Standard deviations	Means	Standard deviations	
BV/TV (%)	89.7	8.89	79.3	5.00	n	86.1	7.01	64.0	9.27	–
Tb.Th (μm)	181.2	20.29	180.3	12.82	n	159.6	4.71	138.0	18.79	–
Tb.N (per mm)	2.47	0.45	2.18	0.17	n	2.64	0.12	2.12	0.31	**
MIL 1 (mm)	0.43	0.046	0.37	0.022	*	0.48	0.063	0.30	0.037	**
MIL 2 (mm)	0.28	0.040	0.31	0.029	n	0.31	0.013	0.24	0.018	**
MIL 3 (mm)	0.22	0.023	0.20	0.0087	n	0.18	0.018	0.16	0.015	*
MIL axis (MIL1/MIL3)	1.96	0.062	1.81	0.058	**	2.93	0.55	1.81	0.13	**
Vm (mm^3)	0.0057	0.0040	0.019	0.0057	**	0.0047	0.00027	0.026	0.014	**
Tb.W (μm)	308.8	81.02	297.7	31.21	n	250.1	20.33	197.3	25.96	*
Vt (mm^3)	0.49	0.10	0.39	0.037	n	0.57	0.064	0.27	0.077	**

* $p < 0.05$.
** $p < 0.01$.