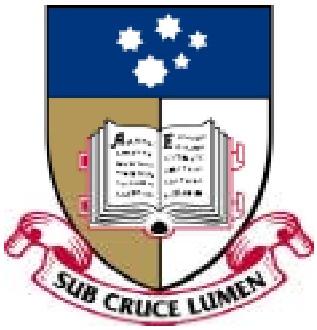
GROWTH MODIFICATION OF THE TEMPOROMANDIBULAR JOINT BY FUNCTIONAL APPLIANCES: A HISTOMORPHOMETRIC STUDY USING SHEEP

A thesis submitted for degree of Doctor of Philosophy
by

Bingkui Ma



Orthodontic Unit
Dental School
Faculty of Health Sciences
The University of Adelaide
South Australia
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To my wife, Yu-mei Guo

Declaration

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Summary

In order to investigate growth modifications of the temporomandibular joint (TMJ) during dentofacial orthopaedic treatment, various functional appliances have been used to prompt the mandible into a protrusive position in various animal experimental models. The general purpose of this project was (i) to test the effectiveness of a functional appliance specially designed for sheep; (ii) to clarify whether or not forward mandibular displacement in sheep is associated with faster and/or redirected condylar growth; (iii) to evaluate the sheep as a model for dentofacial orthopaedic research by comparing the similarities of mandibular condylar growth in sheep and humans; (iv) to detail the position of the mandible during forward mandibular posturing and the effects of mandibular forward displacement on modelling and remodelling of the mandibular condyle. The specific purpose of this project was to reveal whether functional appliance treatment increases the quantity of bone formed during the treatment, or changes the distribution of the bone, or both.

Eight, 4-month old, castrated male Merino sheep were randomly assigned to experimental or control groups with 4 in each group. Cast functional appliances were fabricated for the animals in the experimental group. The treatment period was 15 weeks. Calcein (day 1) tetracycline (13 weeks) and alizarin red S (3 days before sacrifice) fluorochromes were administered to all animals. Dental casts, endosseous implant markers and cephalograms were used to analyse the 3-D displacement of the mandible. Undecalcified mid-sagittal sections of TMJ were used to evaluate the tissue responses induced by the appliances. Dynamic parameters of bone formation, static indices of

bone-forming and resorbing activity as well as structural indices of trabecular bone were estimated using histomorphometry. The trabecular bone was sampled from two regions: (i) a "subchondral region" (determined by 2nd and 3rd labels), believed to comprise bone newly-formed during the experimental period; and (ii) a "central region" (labelled by all the three fluorochromes), believed to comprise bone which existed before the experiment. The cortical bone was divided into anterior and posterior regions for analysis. The weight of the animals was measured monthly to monitor their growth. Metacarpus growth was also evaluated.

During the experimental period, the animals were found to maintain their weight within the normal range and grew normally. The appliance was found to displace the mandible to a downward and forward position with a net condylar displacement of 2.4 mm. The observed adaptive responses in the TMJ induced by the appliances included; the condylar process was less tapered and rounder in the experimental group than in the controls, and anteriorly thickened condylar cartilage and a thickened compact bone layer along the anterior surface of the posterior wall of the glenoid fossa. The mandibular condylar growth vector in sheep was found to be in a postero-superior direction. Condylar growth in the control sheep during the experimental period varied from 8.8 to 11.9 mm, with the mean being 10.6 mm, which is quantitatively similar to two years of condylar growth in human adolescents. In the experimental sheep, the condylar growth varied from 8.5 to 13.3 mm, with the mean being 11.4 mm. When metacarpal growth and weight gain were taken into consideration using multivariant analysis, the

coefficients for growth in the postero-superior and posterior direction were found to be high, with adjusted r^2 as 0.84 and 0.82 respectively. The induced condylar growth was estimated to be largest in the posterior direction (2.3 mm), which is also similar to previous reports in humans. Regional differences in adaptive response within the mandibular condyle were found in this study. In the experimental group, bone volume fraction (BV/TV) of the subchondral regions decreased, although the specific bone surface and bone formation rates increased. This low BV/TV was associated with decreased trabecular thickness and increased trabecular separation. In the central region of the experimental group's condyle, BV/TV was unchanged. However, an increased osteoid surface (OS/BS) was defined when the eroded surface (ES/BS) was taken into consideration.

The sheep were found to cope well with the experimental procedures and the appliance used in this study has been effective in inducing adaptive responses in the TMJ. Consequently, it is believed that the sheep is an appropriate animal model for quantitative histological analysis of the responses to functional appliance treatment.

The first null hypothesis, that functional appliance treatment has no effect on bone matrix mineralisation was rejected. The second null hypothesis, functional appliance treatment has no effect on the mineralisation lag time, was rejected. The results indicated that the treatment effects of functional appliances involve reorganisation of the TMJ through bone modelling and remodelling. An important mechanism of functional appliance treatment is,

therefore, suggested to be a change in the distribution of bone rather than an increase in the quantity of bone. Posterior rotation of the principle tensile strain angle (*Et*) suggested an posteriorly altered direction of the condylar growth. Increased new bone formation in the glenoid fossa suggested an anterior re-positioning of the temporomandibular joint.

Publications Related to This Thesis

Referred Journals:

1 **MA B**., SAMPSON W., FAZZALARI N., WILSON D. and WIEBKIN O., Induced mandibular condylar growth in a sheep model after functional appliance treatment, *Australian Orthodontic Journal* 2001; 17(2): 81-8.

2 **MA B**., SAMPSON W., FAZZALARI N., WILSON D. and WIEBKIN O., Experimental forward mandibular displacement in sheep, *Archives of Oral Biology* 2002; 47(1): 75-84.

3 **MA B**., SAMPSON W., WILSON D. WIEBKIN O. and FAZZALARI N., A histomorphometric study of adaptive responses of cancellous bone in the sheep mandibular condyle following experimental forward mandibular displacement, *Archives of Oral Biology* 2002; In press.

4 **MA B**., SAMPSON W., WILSON D. WIEBKIN O. and FAZZALARI N., Increased mandibular condylar length is associated with re-distribution of the bone matrix in experimental functional appliance treated sheep, *Journal of Dental Research* 2002; Submitted for publication.

Short or Abstract Publications:

5 **MA B**., SAMPSON W., FAZZALARI N., WILSON D. and WIEBKIN O., Adaptive responses in mandibular condylar cartilage following mandibular displacement in sheep (abstract), Matrix Biology Society of Australia and New Zealand Silver Jubilee Meeting; 2001 Oct 4-7; Canberra, Australia.

6 **MA B**., FAZZALARI N., SAMPSON W.J., WILSON D.F. and WIEBKIN O., Changes in condylar cancellous bone volume fraction (BV/TV) and turnover in sheep following forward mandibular displacement (abstract), Australian

and New Zealand Bone and Mineral Society 11th Annual Scientific Meeting; 2001 Oct 7-10; Auckland, New Zealand.

7 **MA B**., SAMPSON W.J., FAZZALARI N., WIEBKIN O., and WILSON D.F. The bone adaptation in the mandibular condyle of functional appliance treated sheep (poster), 18th Australian Society of Orthodontics Congress; 2002 March 15-19; Perth, Australia.