To my wife, Yu-mei Guo
Declaration

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## Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table of Contents</td>
<td>i</td>
</tr>
<tr>
<td>List of Tables</td>
<td>viii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>xi</td>
</tr>
<tr>
<td>Acknowledgement</td>
<td>xv</td>
</tr>
<tr>
<td>Summary</td>
<td>xvi</td>
</tr>
<tr>
<td>Publications Related to this Thesis</td>
<td>xx</td>
</tr>
<tr>
<td>Foreword</td>
<td>1</td>
</tr>
<tr>
<td>Chapter 1: Literature Review</td>
<td>8</td>
</tr>
<tr>
<td>Part I: Growth Modification of the Temporomandibular Joint in Dentofacial Orthopaedics</td>
<td>9</td>
</tr>
<tr>
<td>1.1. Functional Appliances in Dentofacial Orthopaedics: An Overview</td>
<td>9</td>
</tr>
<tr>
<td>1.1.1. Dentofacial orthopaedic treatment principles</td>
<td>9</td>
</tr>
<tr>
<td>1.1.2. Aetiology of skeletal Class II malocclusion</td>
<td>10</td>
</tr>
<tr>
<td>1.1.3. Dentofacial orthopaedics and the TMJ</td>
<td>13</td>
</tr>
<tr>
<td>1.2. Clinical Evidence of the Growth Modification Effects on the TMJ Collected from Large Clinical Trials</td>
<td>18</td>
</tr>
<tr>
<td>1.2.1. Changes in maxillofacial morphology</td>
<td>18</td>
</tr>
<tr>
<td>1.2.2. Changed morphology of the TMJ</td>
<td>21</td>
</tr>
<tr>
<td>1.2.3. Changes in masticatory function</td>
<td>21</td>
</tr>
<tr>
<td>1.2.4. The quality of dentofacial orthopaedic clinical management and related questions</td>
<td>22</td>
</tr>
<tr>
<td>Part II: The Biology of Growth Modification in the TMJ</td>
<td>24</td>
</tr>
<tr>
<td>1.3. Biological Basis of the Mandibular Condylar Growth</td>
<td>24</td>
</tr>
<tr>
<td>1.3.1. Microanatomy of the mandibular condyle: the tissue and cellular components</td>
<td>24</td>
</tr>
<tr>
<td>1.3.2. Endochondral ossification</td>
<td>28</td>
</tr>
<tr>
<td>1.3.3. Intramembranous ossification</td>
<td>31</td>
</tr>
</tbody>
</table>


1.4. Experimental Evidence of the Growth Modification Effects in the TMJ

1.4.1. TMJ tissue responses to functional appliance treatment in animal studies: the tissue level

1.4.2. TMJ tissue responses to functional appliance treatment in animal studies: the cellular level

1.5. Re-evaluation of the Experimental Evidence for Growth Modification Effects in the Condylar Cartilage

1.5.1. Hypothesis No.1: functional appliance treatment increases condylar growth through inducing cartilage cell proliferation and cartilage matrix production

1.5.2. Hypothesis No.2: functional appliance treatment increases condylar growth by increasing both the life-span of cartilage cells and deposition of cartilage matrix during endochondral ossification

1.6. Re-evaluation of the Experimental Evidence for Growth Modification Effects in the Subchondral Bone

1.6.1. Hypothesis No.3: functional appliance treatment increases condylar growth through inducing more cells to differentiate into osteoblasts and produce more bone matrix

1.6.2. Hypothesis No.4: functional appliance treatment increases condylar growth by increasing both the life-span of bone cells and deposition of bone matrix during endochondral ossification

1.7. Re-evaluation of the Experimental Evidence for Changes in Mechanical Environment and Changed Direction of Growth

1.7.1. Hypothesis No.5: changed compressive force changes the pattern of angiogenesis resulting in the changed shape of the condyle

1.7.2. Hypothesis No. 6: changed mechanical environment of the TMJ following functional appliance treatment increases bone formation under the periosteum in some regions resulting in condylar change

1.8. Functional Appliances Mode of Action: An Ongoing Investigation

1.8.1. Theories about functional appliance treatment based on animal experiments

1.8.2. Limitations of the lateral pterygoid muscle hypothesis

1.8.3. To develop new theories to support our understanding of functional appliance treatment and related issues

1.8.4. Objectives and hypotheses to be tested
General Objectives .................................................................................................................. 60
Specific Objectives .................................................................................................................. 61

CHAPTER 2: MATERIALS AND METHODS ............................................................................ 63

Part I: Rationale of the Methodology ..................................................................................... 64

2.1. Analysis of the Mandibular Position ................................................................................. 64

2.1.1. The limitations of the interpretation of conventional two-dimensional cephalometry .................................................................................................................. 64

2.1.2. Innovative approaches to three-dimensional craniofacial imaging using conventional two-dimensional cephalometry .................................................................................. 66

2.2. Analysis of Bone Architecture in the Mandibular Condyle ............................................... 67

2.2.1. The measurement error in bone histomorphometry ...................................................... 67

2.2.2. Image magnitude and contrast in bone histomorphometry .......................................... 70

2.2.3. Statistical procedures to compare the data obtained from control and experimental groups .................................................................................................................. 71

Part II: Animal Experiment: The Protocol ............................................................................ 73

2.3. The Detail of the Protocol .................................................................................................. 73

2.3.1. Outline .......................................................................................................................... 73

2.3.2. Surgical placement of the implant markers ................................................................ 74

2.3.3. Dental casts .................................................................................................................. 75

2.3.4. Fabrication and placement of the appliance ................................................................ 76

2.3.5. Cephalograms .............................................................................................................. 77

2.3.6. Monitoring the weight gain of the animals .................................................................. 82

2.3.7. Fluorochrome administration ...................................................................................... 83

2.4. Tissue Sample Collection and Processing ....................................................................... 83

2.4.1. TMJ tissue sampling .................................................................................................... 83

2.4.2. Metacarpus tissue sample ............................................................................................ 87
2.5. Linear Measurements in Histological Sections

2.5.1. Condylar cartilage thickness

2.5.2. The growth within the metacarpus

2.5.3. Mandibular condylar growth

2.6. Error Study of the Linear Measurements

2.7. Bone Histomorphometry

2.7.1. Structural, static and dynamic indices of the trabecular bone in the mandibular condyle

2.7.2. Structural indices of the cortical bone in the mandibular condyle

2.7.3. Trabecular anisotropy in the mandibular condyle

2.7.4. The accuracy of using cubic function to fit the distribution of Tb.An

2.7.4.A. Method and results

2.7.4.B. Discussion

2.7.5. Statistical analysis of Tb.An

2.8. Error in the Bone Histomorphometric Method Used in This Study

2.8.1. Background

2.8.2. Procedures

2.8.3. Outcomes and conclusions

2.9. 3-D Measurement of the Distance Between Implants

2.9.1 Calibration

2.9.2 Landmark digitising

2.10. The Accuracy of three-dimensional Measurements

2.10.1. Background

2.10.2. Procedures

2.10.3. Outcomes and conclusions
CHAPTER 3: EXPERIMENTAL FORWARD MANDIBULAR DISPLACEMENT IN SHEEP

3.1 Introduction

3.2 Results

3.2.1 Procedure validation

3.2.2 Observations from dental casts

3.2.3 Observations from cephalograms

3.2.4 Histological Investigation

3.3 Discussion

3.3.1 Functional appliance and the mandibular displacement: static analysis vs. dynamic analysis

3.3.2 Appliance retention and mandibular displacement

3.3.3 Adaptations in the TMJ

3.4 Conclusion

CHAPTER 4: INDUCED MANDIBULAR CONDYLAR GROWTH IN A SHEEP MODEL

4.1 Introduction

4.1.1 Functional appliance and the animal model

4.1.2 Bone growth in the mandibular condyle

4.2 Results

4.2.1 Descriptive Analysis

4.2.2 Multivariate Analysis

4.2.2.A Evaluation of Assumptions

Homogeneity of within-group regression

Linearity of within-group regression
List of Tables

Table 2.1. The procedure for MMA embedding of the TMJ tissue ..................................86
Table 2.2. The accuracy of using cubic function to fit the distribution of Tb.An ...............109
Table 2.3. All the histomorphometric variables measured in this study ..............................113
Table 3.1. Weight gain and metacarpus growth of the animals in the control group and the experimental group ..........................................................135
Table 3.2. Microscopic measurements made of condylar cartilage thickness from all TMJs in the experimental and control groups ........................................139
Table 4.1. Body weight gain, metacarpus growth and mandibular condylar growth in induced forward mandibular displacement ........................................153
Table 4.2. Multivariate tests to determine homogeneity within groups ..............................155
Table 4.3. Tests of between-subjects effects to determine linearity within groups ..............156
Table 4.4. Multivariate tests ..........................................................................................157
Table 4.5. Parameter estimates ....................................................................................158
Table 4.6. Univariate tests ..........................................................................................158
Table 4.7. Estimates ....................................................................................................159
Table 4.8. Pairwise comparisons ..................................................................................159
Table 4.9. Adjusted condylar growth using metacarpus growth and weight gain as covariates ..............................................................................................160
Table 5.1. Median and range of bone structural indices for the subchondral and the central regions in the control group, experimental group and pooled data for both groups ..........................................................170
Table 5.2. P-value of Mann-Whitney test of bone structural indices between the control group and the experimental group in the subchondral region and central region ..................................................................................173
Table 5.3. P-value of Wilcoxon signed ranks test of bone structural indices between the subchondral region and the central region in the control group, experimental group and pooled data for both groups ..................................................173
Table 7.4. Mean and standard deviation of trabecular bone anisotropy (Tb.An) in the central and subchondral regions in control group, experimental group and difference between the two regions

Table 7.5. P-value of t-test for 2 independent samples without assuming equal variances between the control group and the experimental group in the subchondral region and central region

Table 7.6. P-value of t-test for 2 related samples between the subchondral region and the central region

Table 8.1. The correlation between mandibular position and time in the experiment

Table 8.2. Tests of Between-Subjects Effects: Dependent Variable was Zy-Co

Table 8.3. Tests of Between-Subjects Effects: Dependent Variable was Zy-Go

Table 8.4. The correlation between Zy-Co and time

Table 9.1. The Biology of Growth Modification

Table 9.2. The Mechanobiology of Growth Modification
List of Figures

Figure 1A. Illustration of the hypothesised theory which can be used to detect the skeletal changes induced by the functional appliance treatment ..................................................4

Figure 1.1. Left condyle from OPG images showing double contours of the condylar heads as well as on the cranio-posterior part of the ramus .................................................................14

Figure 1.2. CT-scanning of TMJ 3 months after insertion of Herbst appliances .................................................................15

Figure 1.3. Twenty-year-old male patient with a Class II Division 1 malocclusion treated with the Herbst appliance for 10 months .................................................................16

Figure 1.4. Scintigraphy: TMJ regions show different metabolic activity between the left and right sides .................................................................17

Figure 1.5. Layers of the mandibular condylar cartilage .................................................................26

Figure 1.6. Schematic representation of the differences in $[^3]$H-thymidine incorporation in the mandibular condylar cartilage between the experimental and the control rats .................................................................40

Figure 2.1. Surgical placement of the implants .................................................................75

Figure 2.2. Standard dental casts were used to study the change in occlusion during growth and functional appliance treatment .................................................................76

Figure 2.3. The appliance designed for forward mandibular displacement in sheep .................................................................78

Figure 2.4. Cephalostat designed for sheep .................................................................77

Figure 2.5. Taking three view cepholograms with the assistance of the cephalostat .................................................................81

Figure 2.6. Standard separation of the temporomandibular joint .................................................................85

Figure 2.7. Sagittal section of the left metacarpus along the midline .................................................................88

Figure 2.8. Thickness of the condylar cartilage .................................................................89

Figure 2.9. Measurements made from the mandibular condyles of sheep injected with fluorochrome bone labels .................................................................91

Figure 2.10. Mid-sagittal section of sheep TMJ viewed under ultra-violet light showing fossa, disc and condyle .................................................................95
Figure 2.11. Mid-sagittal section of sheep TMJ showing fossa and condyle as well as the defined regions of interest .................................................................96
Figure 2.12. Mid-sagittal section of sheep TMJ showing fossa and condyle ......................................................................................................................98
Figure 2.13. The orientation of the specimen at which the cortical bone thickness was measured in the anterior region ........................................99
Figure 2.14. The orientation of the specimen at which the cortical bone thickness was measured in the posterior region ........................................100
Figure 2.15. Mid-sagittal section of sheep TMJ showing the orientation where Tb.An was measured ..............................................................................102
Figure 2.16. Trabecular anisotropy (Tb.An) measured as the ratio of horizontal line intercepts to vertical line intercepts ($I_h/I_v$) from 0° to 180° 103
Figure 2.17. Trabecular anisotropy (Tb.An) measured as the ratio of horizontal line intercepts to vertical line intercepts ($I_h/I_v$) from 0° to 180° with the best-fit lines and the equations of the lines ..............................................104
Figure 2.18. Trabecular anisotropy (Tb.An) measured as the ratio of horizontal line intercepts to vertical line intercepts ($I_h/I_v$) from 0° to 180° with the best-fit lines and the equations of the lines as well as minimal and maximal values of Tb.An .................................................................106
Figure 2.19. The data set showing a similar distribution to Tb.An. ...............107
Figure 2.20. The data set showing a similar distribution to Tb.An and its best fit line generated on the chart using Microsoft Excel ®, Microsoft Office 2000™ ........................................................................................................................................108
Figure 2.21. Schematic illustration of the mandibular condyle model represented by four functions .................................................................112
Figure 2.22. Differences in the distribution of chord length in the anterior region of the mandibular condyle between the initial and repeated measurement ...........................................................................................................116
Figure 2.23. Differences in the distribution of chord length in the posterior region of the mandibular condyle between the initial and repeated measurement ...........................................................................................................116
Figure 2.24. Images from the three cephalograms and their corresponding calibrations .................................................................................................119
Figure 2.25. Epipolar line for zygomatic landmark from one cephalogram to the others according to the calibrated co-ordinates ........................................120
Figure 2.26. Systems used to evaluate the accuracy of the 3-D cephalometric computer programme .................................................................123

Figure 2.27. Differences in the distance between the ball bearings in repeated measurements .................................................................124

Figure 2.28. Differences in the distance between the ball bearings measured by 3-D cephalometry compared with the direct measurement when 3-D cephalometry was performed 6 times .................................................................125

Figure 2.29. Differences in the distance between the ball bearings measured by 3-D cephalometry compared with the direct measurement ........126

Figure 2.30. Differences in the distance between the implants in repeated measurements ............................................................................127

Figure 2.31. Differences in the distance between the implants measured by 3-D cephalometry compared with the direct measurements when repeated 9 times .........................................................................128

Figure 2.32. Differences in the distance between the implants measured by 3-D cephalometry compared with the direct measurement .........128

Figure 3.1. The weight of the animals during the experiment ..................134

Figure 3.2. Tooth wear pattern shows differences between the control and experimental animals .................................................................135

Figure 3.3. Functional appliance effects in sheep ..................................136

Figure 3.4. Ramal dimorphisms ..............................................................137

Figure 3.5. Mandibular condyle, disc and portion of fossa .......................138

Figure 3.6. The anterior region of the mandibular condylar cartilage of the sheep ......................................................................................139

Figure 3.7. Adaptive response in the posterior wall of the glenoid fossa following insertion of the functional appliances .................................141

Figure 4.1. Fluorochrome bone labels are clearly seen in embedded specimens from inner to outer parts of the mandibular condyle ..............152

Figure 4.2. Graphic presentation of the condylar growth measured in its largest dimension (variable 2) plotted according to weight gain and metacarpus growth .................................................................154
Figure 4.3. Comparison of the growth in sheep to that of humans; European boys (London), Asiatic boys (Hong Kong) and boys of African origin (Washington DC) ..................................................161

Figure 5.1. Bone formation rate in the control and the experimental condyles .................................................................171

Figure 5.2. Plot of OS/BS versus ES/BS in the central region and the subchondral region ..................................................178

Figure 6.1. A Normal Q-Q chart showing a good correlation of the observed value and the expected normal value along the straight line ..........188

Figure 7.1. The comparison of ratios of Tb.An-min and Tb.An-max describing the trabeculae alignment of the subchondral and the central regions ........................................................................201

Figure 8.1. Schematic representation showing changes in the position of the implants which indicates the possible positional changes of the mandible ........................................................................209

Figure 8.2. Plot of condylar displacement (Zy-Co) versus time .................215

Figure 9.1. The regions showing significant differences between the control and the experimental groups within the mandibular condyle ........225
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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 multivariate 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 \((E_t)\) 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:**


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:**


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.
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