European Journal of Orthodontics 25 (2003) 9–12

Evaluation of the effects of functional orthopaedic treatment on temporomandibular joints with single-photon emission computerized tomography

D. D. Güner*, Y. Öztürk** and H. B. Sayman***
*Private practice, Istanbul and Departments of **Orthodontics and *** Nuclear Medicine, Istanbul University, Turkey

SUMMARY The aims of this investigation were to evaluate the temporomandibular joints (TMJs) with single-photon emission computerized tomography (SPECT) in subjects treated with a mandibular advancement repositioning splint (MARS), and to compare the results with the total effect on dento-facial morphology. The study was undertaken on 17 Class II division 1 malocclusion subjects (nine males, eight females) with mandibular retrusion. Ten patients (five males, five females) formed the treatment group and seven (four males, three females) were used as the control. SPECT was performed only in the treatment group.

Cephalometric evaluation showed significant increases in NAPog ($P < 0.001$) and SNB ($P < 0.05$) angles. Increased bone formation in theTMJs was analysed with the aid of pre- and post-treatment scintigraphic studies. The results indicate that new bone formation in the mandibular condyles seems to contribute to the increase in mandibular prognathism resulting from functional jaw orthopaedics.

Introduction

The common aim of functional appliances is the stimulation of condylar growth as a result of anterior mandibular displacement (Björk and Skieller, 1972; McNamara, 1973). Beside conventional cephalometric analysis (Bishara and Ziaja, 1989), temporomandibular joint (TMJ) radiographs (Pancherz, 1979), computed tomography (CT) scanning (Hansen *et al*., 1990; Paulsen *et al*., 1995), dental tomographic and transpharyngeal radiography (Paulsen, 1997), and magnetic resonance imaging procedures (Ruf and Pancherz, 1998) have been used to investigate the response of TMJs to functional jaw orthopaedics. Bone scintigraphy is another imaging modality that has sensitivity to reflect skeletal metabolic activity. It is performed with Tc-99m-labelled bisphosphonates (Tc-99m MDP). The exact mechanisms involved in bisphosphonate uptake are not completely understood, but it is thought that they react through the phosphorus group by chemi-absorption onto the calcium of hydroxyapatite in bone. Because of its ability to detect functional change, a bone scan can often be more informative well before structural changes visible on radiographs occur. This method has been used recently for the diagnosis of condylar hyperplasia (Gray *et al*., 1994; Kerscher *et al*., 1995; Proffit, 2000). Cross-sectional images of single-photon emission computerized tomography (SPECT) have a higher resolution than planar scintigraphy and provide improved anatomical positioning of the TMJs in the coronal plane (Ota *et al*., 1996; Chan *et al*., 2000). This method is recommended for pubertal subjects as the radiation exposure is equivalent to that of a simple chest X-ray.

The aims of the present study were to evaluate the TMJs with SPECT in Class II skeletal subjects treated with a mandibular advancement repositioning splint (MARS), which is a fixed functional device (Clements and Jacobson, 1982), and to compare the results with the total effect on the dento-facial morphology.

Subjects and methods

The investigation was carried out on 17 (nine males, eight females) Class II division 1 malocclusion subjects caused by mandibular retrusion. Ten subjects (five males, five females) were treated and seven subjects (four males, three females) were selected as a control group. The age distribution and the time taken to complete the treatment are shown in Tables 1 and 2. Lateral cephalometric radiographs were taken in both groups before and after treatment and during untreated periods.

Table 1 The initial age distribution of the study sample (in years).

	Mean	SD	Min	Max
Treatment group (*n* = 10)	12.8	1.2	10.4	14.0
Control group (*n* = 7)	12.6	0.8	11.7	13.7

Table 2 The examination period of the study sample (in years).

	Mean	SD	Min	Max
Treatment group (n = 10)	0.5	0.1	0.4	0.8
Control group (n = 7)	0.5	0.1	0.4	0.6

Appliance design

After levelling and aligning, 0.017 × 0.022 inch rectangular stainless steel wire with first and third order bends was ligated and a preformed device (Dentaurum, Pforzheim, Germany) was used in order to achieve mandibular protrusion until the incisors were in an edge to edge position (approximately 7 mm). The treatment was completed when a Class I canine and molar relationship was established.

Bone scintigraphy

Ethical approval was not required as the examinations were performed only in the treatment group to monitor the effect of orthodontic treatment. In each subject 10 MBq/kg of Tc-99m MDP was administered intravenously and a cranial SPECT study was performed 3–4 hours later with a gamma camera. After computer reconstruction of the images, pre- and post-treatment scintigraphs were normalized to a constant count and those coronal slices covering the TMJs were visually assessed (Figure 1). The increase in metabolic activity of stimulated bone was easily recognized by brighter colours. These slice frames were then summed and isocount regions of interest (ROI) were drawn on both TMJs on the pre- and post-treatment SPECTs. A square ROI was also selected over the cranial space to use for background correction. Average count ratios of left and right TMJs to the backgrounds were calculated for each pair of scintigraphs.

Cephalometric evaluation

From lateral cephalometric radiographs of the patients in centric occlusion and orientated with the Frankfort plane horizontal, five angular and three linear measurements were obtained.

Statistical evaluation

The arithmetic mean and standard deviation (SD) were calculated for each cephalometric variable and scintigraphic counts of the right and left condyles. To assess the statistical significance of the changes that occurred during the examination period in the treatment and control groups, Wilcoxon signed rank tests were performed. To compare the differences between the control group and the treatment group Mann–Whitney *U*-tests were used.

Results

Lateral cephalograms

The mean values of the cephalometric measurements calculated before and after treatment and at the control periods and their statistical evaluation are given in Tables 3 and 4. In the control group none of the changes resulting from growth was found to be statistically significant. Among the cephalometric variables measured

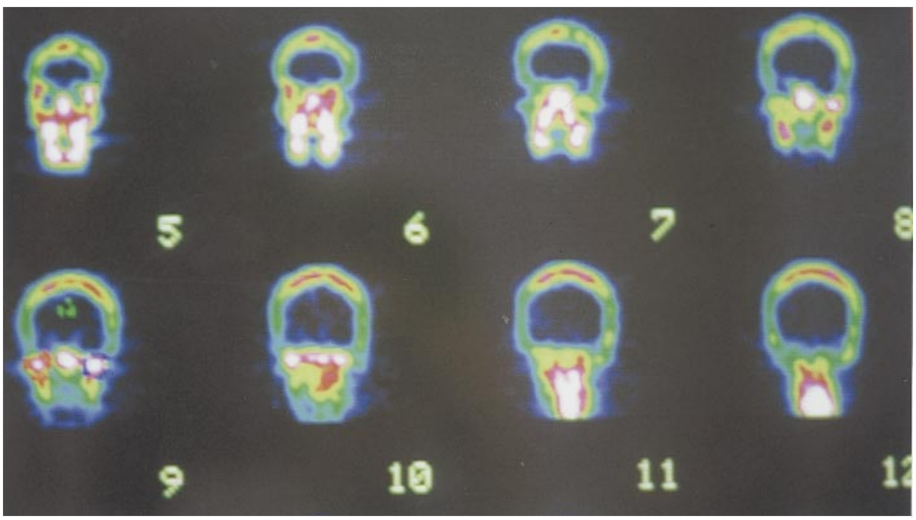

Figure 1 Coronal SPECT slices covering both TMJs. (Slices from 6 to 9 are shown.) The brighter tones represent higher radio-pharmaceutical uptake, which is consistent with an increase in bone metabolism.

Table 3 Cephalometric changes in the treatment group ($n = 10$).

	Pre-treatment		Post-treatment		Test
	Mean	SD	Mean	SD	
NAPog (°)	167.90	3.00	170.80	3.10	***
SNA (°)	80.30	2.40	79.80	2.40	NS
SNB (°)	72.90	3.10	74.30	3.10	*
ANB (°)	7.30	1.60	5.50	1.60	***
SN/GoGn (°)	34.50	2.10	34.60	2.10	NS
ANS–Me (mm)	64.80	4.72	66.80	4.30	NS
Na–Me (mm)	114.70	4.36	117.70	4.10	NS
S–Go (mm)	71.90	4.01	73.90	3.30	NS

NS, not significant; *$P < 0.05$; ***$P < 0.001$.

Table 4 Cephalometric changes in the control group ($n = 7$).

	Pre-control		Post-control		Test
	Mean	SD	Mean	SD	
NAPog (°)	167.4	4.3	168.0	4.4	NS
SNA (°)	82.3	2.7	82.4	2.6	NS
SNB (°)	75.1	2.5	75.4	2.7	NS
ANB (°)	7.1	2.3	7.0	2.4	NS
SN/GoGn (°)	33.6	4.1	33.2	4.3	NS
ANS–Me (mm)	64.7	5.1	65.6	6.3	NS
Na–Me (mm)	113.3	7.2	115.1	7.9	NS
S–Go (mm)	73.4	6.5	74.9	6.5	NS

NS, not significant.

in the treatment group, NAPog ($P < 0.001$), SNB ($P < 0.05$), and ANB ($P < 0.001$) angles showed statistically significant increases. When the changes from the treatment and control groups were compared, statistically significant differences were found in the variables SNB, ANB, and SN/GoGn (Table 5).

Bone scintigraphy

The values of average count ratios for the right and left TMJs calculated before and after treatment, their mean values, and statistical comparisons are given in Tables 6 and 7. Statistically significant ($P < 0.001$) increases were found between pre- and post-treatment values.

Table 5 Comparison of the cephalometric changes between the treatment and control groups.

	Treatment group ($n = 10$)		Control group ($n = 7$)		Test
	Mean	SD	Mean	SD	
NAPog (°)	2.90	2.00	0.40	1.80	NS
SNA (°)	–0.50	1.20	0.10	0.70	NS
SNB (°)	1.50	0.90	0.30	0.90	*
ANB (°)	–1.80	0.90	–0.10	0.40	***
SN/GoGn (°)	0.10	0.50	–0.40	0.50	*
ANS–Me (mm)	2.00	1.09	0.90	1.50	NS
Na–Me (mm)	3.00	1.05	1.90	1.60	NS
S–Go (mm)	2.00	1.50	1.50	1.40	NS

NS, not significant; *$P < 0.05$; ***$P < 0.001$.

Table 6 Pre- and post-treatment results (average count ratios) of the bone scintigraphy.

	Pre-treatment		Post-treatment	
	Right TMJ	Left TMJ	Right TMJ	Left TMJ
Patient 1	56.95	59.20	83.25	85.91
Patient 2	71.94	74.25	94.07	101.00
Patient 3	59.13	62.97	118.07	101.85
Patient 4	47.65	48.45	63.68	65.08
Patient 5	114.45	114.60	146.19	147.98
Patient 6	70.03	71.67	95.91	92.06
Patient 7	65.43	50.79	76.54	66.72
Patient 8	19.36	19.36	43.84	42.13
Patient 9	19.40	19.46	36.82	39.17
Patient 10	58.06	59.95	67.63	62.94

Table 7 Comparison of pre- and post-treatment results of the bone scintigraphy.

	Pre-treatment		Post-treatment		Test
	Mean	SD	Mean	SD	
Right TMJ	58.24	27.40	82.60	33.05	***
Left TMJ	58.07	27.50	80.48	32.51	***

***$P < 0.001$.

Discussion

Several studies have been conducted to investigate condylar cartilage response to an altered functional position of the mandible (McNamara, 1973). Histological studies in animals showed an adaptive response in the form of hyperplasia of the prechondroblastic and chondroblastic area of the posterior and postero-superior border of the condyle (Charlier *et al.*, 1969; Stöckli and Willert, 1971; McNamara and Carlson, 1979; McNamara *et al.*, 1982). In experiments with monkeys, full-time mandibular protrusion led to remodelling of the glenoid fossa and forward relocation of the TMJ (Woodside *et al.*, 1987). In a previous laminographic study, Birkebæk *et al.* (1984) noted alterations in the TMJ following activator treatment. It has been found that effective condylar growth can be significantly increased during treatment with the Herbst appliance, which is a fixed functional appliance similar to the MARS (Pancherz, 1979). New bone formation as a double contour in the articular fossa and on the posterior part of the condylar process was found on radiographs of a 14-year-old boy treated with the Herbst appliance (Paulsen *et al*., 1995). A similar treatment effect was described by Paulsen (1997): a double contour in the distocranial part of the condyle was generally registered 2–6 months after insertion of the same appliance. An average treatment period of seven months in Class II subjects treated with the Herbst appliance induced condylar and glenoid fossa remodelling and condyle–fossa relationship changes (Ruf and Pancherz, 1998). In a bone scintigraphic study of human TMJs during Herbst treatment (Paulsen *et al*., 1998) a differential condylar growth mechanism was shown in a patient with facial asymmetry. Cephalometric comparison of the treatment and control groups in the present study showed that mandibular prognathism can be significantly increased during MARS treatment for a mean period of six months. The evaluation of the metabolic activity in the TMJs before and after treatment by skeletal scintigraphy, indicating increased bone formation, supports this radiographic diagnosis and the results of the above-mentioned studies.

Conclusions

The findings show that treatment of skeletal Class II subjects with the MARS appliance induces significant condylar growth. Cross-sectional SPECT images allow examination of the stimulated bone growth.

Address for correspondence

Yıldız Öztürk
Istanbul University, Faculty of Dentistry
Department of Orthodontics
34390 Çapa, Istanbul
Turkey

References

Birkebæk L, Melsen B, Terp S 1984 A laminagraphic study of alterations in temporo-mandibular joint following activator treatment. European Journal of Orthodontics 6: 257–266

Bishara S E, Ziaja R R 1989 Functional appliances: a review. American Journal of Orthodontics and Dentofacial Orthopedics 95: 250–258

Björk A, Skieller V 1972 Facial development and tooth eruption: an implant study at the age of puberty. American Journal of Orthodontics 62: 339–383

Chan W L, Carolan M G, Fernandes V B, Abatti D P 2000 Planar versus SPECT imaging in the assessment of condylar growth. Nuclear Medicine Communication 21: 285–290

Charlier J P, Petrovic A, Herrmann-Stutzmann J 1969 Effects of mandibular hyperpropulsion on the precondroblastic zone of young rat condyle. American Journal of Orthodontics 55: 71–74

Clements R M Jr, Jacobson A 1982 The MARS appliance: report of a case. American Journal of Orthodontics 82: 445–455

Gray R J M, Horner K, Testa H J, Lloyd J J, Sloan P 1994 Condylar hyperplasia: correlation of histological and scintigraphic features. Dentomaxillofacial Radiology 23: 103–107

Hansen K, Pancherz H, Petersson A 1990 Long-term effects of the Herbst appliance on the craniomandibular system with special reference to the TMJ. European Journal of Orthodontics 12: 244–253

Kerscher A, Fleiner B, Bohulavski K H, Clausen M 1995 Die Skelettszintigraphie bei der Therapieplanung der Hemimandibularen Elongation. Nuclear Medicine 34: 101–114

McNamara J A 1973 Neuromuscular and skeletal adaptations to altered function in the orofacial region. American Journal of Orthodontics 64: 578–606

McNamara J A Jr, Carlson D S 1979 Quantitative analysis of temporomandibular joint adaptations to protrusive function. American Journal of Orthodontics 76: 593–611

McNamara J A Jr, Hinton R J, Hoffman D L 1982 Histologic analysis of temporomandibular joint adaptation to protrusive function in young adult rhesus monkeys—*Macacca mulatta*. American Journal of Orthodontics 82: 288–298

Ota T *et al*. 1996 Three-dimensional bone scintigraphy using volume-rendering technique and SPECT. Journal of Nuclear Medicine 37: 1567–1570

Pancherz H 1979 Treatment of Class II malocclusions by jumping the bite with the Herbst appliance. A cephalometric examination. American Journal of Orthodontics 76: 423–442

Paulsen H U, Karle A, Bakke M, Herskind A 1995 CT-scanning and radiographic analysis of temporomandibular joints and cephalometric analysis in a case of Herbst treatment in late puberty. European Journal of Orthodontics 17: 165–175

Paulsen H U 1997 Morphological changes of the TMJ condyles of 100 patients treated with the Herbst appliance in the period of puberty to adulthood: a long-term radiographic study. European Journal of Orthodontics 19: 657–668

Paulsen H U, Rabøl A, Sølvsten Sørensen S 1998 Bone scintigraphy of human temporomandibular joints during Herbst treatment: a case report. European Journal of Orthodontics 20: 369–374

Proffit W R (ed.) 2000 Orthodontic treatment planning. In: Contemporary orthodontics. Mosby Co, London, pp. 286–287

Ruf S, Pancherz H 1998 Temporomandibular joint growth adaptation in Herbst treatment: a perspective magnetic resonance imaging and cephalometric roentgenographic study. European Journal of Orthodontics 20: 375–388

Stöckli P W, Willert H G 1971 Tissue reactions in the temporomandibular joint resulting from anterior displacement of the mandible in the monkey. American Journal of Orthodontics 60: 142–155

Woodside D G, Metaxas A, Altuna G 1987 The influence of functional appliance therapy on glenoid fossa remodeling. American Journal of Orthodontics and Dentofacial Orthopedics 92: 181–198