European Journal of Orthodontics 19 (1997) 205–210

Effects of experimental unilateral condylectomy followed by altered mandibular function on the maxilla and zygoma

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SUMMARY The effect of protruded mandibular function on the maxilla and zygoma was studied in young unilaterally condylectomized growing rats. Forty-eight 4-week-old rats were divided into two experimental and two control groups as follows: group A, 12 animals unilaterally condylectomized on the right side; the mandible was allowed to function normally; group B, 12 animals unilaterally condylectomized on the right side; the mandible was protracted forwards immediately by means of an appliance; group C, 12 animals sham-operated on the right side; no condylectomy or mandibular protraction; and group D, 12 control animals not subjected to any operation or mandibular protraction.

The mandibular protraction was achieved by an appliance consisting of an acrylic collar brace fitted to the animal's neck and supporting rubber bands pulling on an intraoral part cemented on the animal's lower incisors. Twenty-five grams of pulling force and protrusion to a clinically and radiographically tested anterior crossbite was exercised for 12 hours per day. The experimental period was 30 days. Lateral and dorsoventral radiographs were taken on days 1 and 30 following condylectomies and mandibular protraction. Cephalometric analysis was performed for each animal with measurements evaluating the maxilla and zygoma. Statistical analysis and comparison of the findings in the four groups of animals can be summarized as follows: (i) condylectomy and altered mandibular function may produce remote skeletal reactions in other parts of the cranial complex; and (ii) the ipsilateral maxilla is affected by condylectomy of the mandible, but altered mandibular function by protraction compensates for the results of condylectomy.

Introduction

The influence of functional alterations on the growth process, as well as on the morphology of the craniofacial complex, is of great interest to orthodontists. It has been proven in the past that changes of the functional status of the mandible may have an effect on the growth and formation of the cranial skeleton (McNamara, 1973; Petrovic *et al.*, 1975; Harvold, 1979; Harvold *et al.*, 1981; Metaxas, 1983; Vargervik *et al.*, 1984; Kiliaridis *et al.*, 1985; Woodside *et al.*, 1987). Moreover, it has been pointed out that interaction of form and function cannot be limited only to isolated well-defined areas (Moss and Simon, 1968).

The close interelationship between form and function is a topic with a long history (Rushton, 1944). Although a large number of animal and human studies have been reported in the literature supporting modification of mandibular morphology after experimental or clinical alteration of function, the question of whether this alteration may induce other remote skeletal reactions and adaptations in other skeletal parts or units of the craniofacial complex has only been addressed recently (Kantomaa and Rönning, 1985; Carlson and Ellis, 1988; Curtis *et al.*, 1991).

Aim

The purpose of this study was to investigate the effects of unilateral condylectomy both with and without subsequent forced protruded mandibular function on the morphology of the maxilla and zygoma in young growing rats, as assessed by cephalometric radiographs.

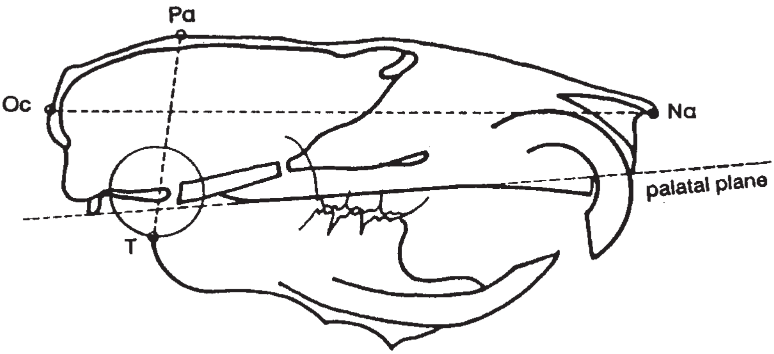

Figure 1 Landmarks on a traced lateral cephalometric radiograph. Pa, the most superior point of the parietal bone; T, the most inferior point of the tympanic bone; Oc, the most posterior point of the squama occipitalis; Na, the most anterior point of the nasal bone; O, the most posterior aspect of the skull at the external occipital protuberance in the midline; FMP, the most posterior aspect of the foramen magnum in the midline; FMA, the most anterior aspect of the foramen magnum in the midline; TB–TB′, the most anterior aspect of the right and the left tympanic bullae; TZ–TZ′, the intersection of shadows of the zygomatic process of the squamosal bone and the zygomatic bone bilaterally; HN–HN′, the most medial aspect of the hamular notch lateral to the origin of the pterygoid plates; TF–TF′, the most anterior aspect of the zygomatie process of the maxilla in the temporal fossa; ANS, the most anterior point of the palatal processes of the maxillae; TN–TN′, the lateral aspects of the

Materials and methods

Forty-eight 4-week-old male Wistar rats were used in this study, weighing from 38 to 52 grams. The animals were divided into four different groups—two control and two experimental—consisting of 12 animals each, as follows: group A, unilateral condylectomy was performed on the right side, and the mandible was allowed to function normally; group B, unilateral condylectomy was performed on the right side, followed immediately by application of a hyperpropulsive appliance; group C, a sham operation was performed on the right side without any condylectomy or mandibular protraction; and group D, control group without any operation or appliance. The experimental period was 30 days.The protruding appliance was worn for 12 hours each day. Lateral and dorsoventral radiographs were taken on days 1 and 30 following condylectomies and mandibular protraction. Cephalometric analysis comprising measurements evaluating the maxilla and zygoma was performed for each animal.

Description of the protruding appliance

The mandibular protraction was achieved by an appliance described elsewhere (Tsolakis and Spyropoulos, 1997) consisting of an acrylic collar brace fitted to the animal's neck and having wire extensions supporting rubber bands pulling on a band cemented to the animal's lower incisors. These rubber bands exerted a pulling force of 25 g for 12 hours per day.

Description of the condylectomy

The condyle was exposed and removed through a preauricular approach. Great care was taken not to harm the surrounding tissues. Trauma from the external dermic incision was kept to a minimum and careful suturing was performed. For each rat 50 mg/kg body weight of Terramycin Oxytetracycline was administered post-surgically.

Cephalograms

Lateral and dorsoventral cephalometric radiographs were taken for each animal on days 1 and 30, and enlarged ×9 in order to reduce tracing errors. The tracings were done on 0.003 inch acetate using an England Eagle Turquoise 10 pencil with 1H drawing leads.

Cephalometric landmarks

The landmarks listed in Figure 1 were identified on every tracing. All dashed landmarks represent the left side.

Cephalometric analysis

To facilitate direct measurements of each half of

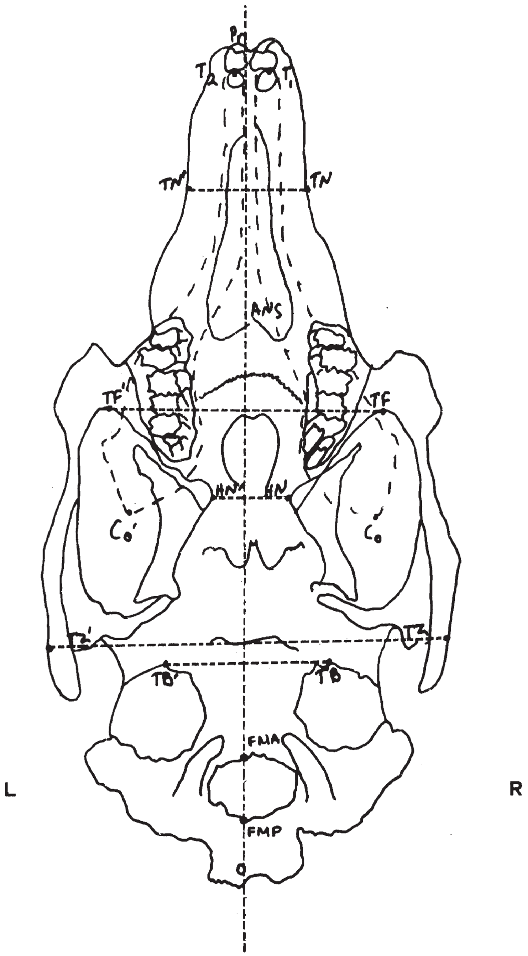

Figure 2 Landmarks, dimensions and angles on a traced dorsoventral cephalometric radiograph.

Measurements	Landmarks employed
Transverse cranial bone development	TB–TB′
Bizygomatic width	TZ–TZ′
Posterior maxillary width	HN–HN′
Mid-maxillary width	TF–TF′
Anterior maxillary width	TN–TN′
Cranial height	Pa–T
Cranial length	Oc–Na
Zygomatic width (left side)	TZ′–PrO
Zygomatic width (right side)	TZ–PrO
Mid-maxillary width (left side)	TF′–PrO
Mid-maxillary width (right side)	TF–PrO
Anterior maxillary width (left side)	TN′–PrO
Anterior maxillary width (right side)	TN–PrO

Dashed landmarks represent left side.

the head, and in order to establish a reference plane, a midpalatal line from point Pr through points EMP and FMA to point O was constructed and measurements were made from the various landmarks to line Pr–O.

A total of 13 measurements (Figures 1 and 2) were recorded to evaluate the size and position of the cranium and facial complex. The construction lines for the cephalometric points were bilateral. The various measurements are listed in the legend to Figure 2. Measurements were taken to the nearest 0.05 mm with dial vernier calipers (Helios Calipers, DCA Corporation, Washington, DC).

Results

Our findings are based on a Wilcoxon test statistical analysis and superimposition of mean tracings for each group of animals.

Since no statistically significant differences were found between groups C (sham-operated animals) and D (animals that were not subjected to any operation or mandibular protraction), when measurements obtained from radiographs were compared, both groups were used as controls.

Comparison of the final mean values of measurements on the dorsoventral cephalograms of all groups revealed that the mean values on day 30 of group B (animals with unilateral condylectomy and protraction) were not smaller than those of the control group (Table 1).

Comparison of differences of measurements performed on days 1 and 30, i.e. the amount of growth that had taken place in these 30 days, between group A (unilateral condylectomy) and controls revealed statistically significant differences related to the mid-maxillary widths (TE–TF′) as well as to the bizygomatic widths (TZ′–TZ), with lower values for group A. There were also statistically significant differences between the right and left sides of the maxilla and the zygomatic arch of the animals in group

A, with lower values for the condylectomized side of the animals (Table 2).

Comparison of differences of measurements on days 1 and 30 between group B and controls revealed higher values for the maxillary widths and the bizygomatic widths for the animal's left side that was not subjected to condylectomy (Table 3).

Comparison of differences of measurements on days 1 and 30 between group A and group B revealed statistically significant differences in maxillary and bizygomatic widths on both sides, with higher values for the animals of group B (Table 4).

Table 1 Means of measurements (mm) at day 30 for control (C+D) right unilateral condylectomy (A) and right unilateral condylectomy plus protrusion (B) groups.

Measurements	Group C+D	Group A	+ Group B
Pa–T	17.9	16.4	17.4
Oc–Na	40.8	40.8	41.0
TB′–TB	8.9	8.9	9.3
HN′–HN	2.0	1.9	2.0
TF′–TF	10.9	11.1	11.2
TN′–'I′N	7.1	7.1	7.3
TZ′–TZ	20.8	19.8	20.6
TZ′–PrO	10.4	10.2	10.3
TZ–PrO	10.4	9.5	10.2
TF′–PrO	5.4	5.4	5.6
TF–PrO	5.4	5.3	5.5
TN′–PrO	3.5	3.7	3.7
TN–PrO	3.5	3.4	3.6

Discussion

The findings of the present investigation indicate that the absence of the condyle plays a significant role in the morphology and growth of the maxilla and the zygomatic arch in animals subjected to condylectomy. On the other hand, protraction of the mandible influenced favourable growth, especially for the front part of the maxilla and the zygomatic arch.

Animals that were subjected to condylectomy showed statistically significant differences, with lower values in the growth and development of the upper jaw and the zygomatic arch of the ispilateral to the condylectomy side. Furthermore, condylectomy does not influence significantly the growth of the maxilla and the zygomatic arch whenever it is followed by mandibular protraction.

These findings support the conclusion that there is a close interelationship between the growth of the maxilla and the growth of the mandible. This agrees to some extent with the findings of previous authors (Kantomaa and Rönning, 1985: Curtis *et al.*, 1991).

Table 2 Differences (rnrn) between days 1 and 30 for control (C+D) and right unilateral condylectomy (A) groups.

Measurements	Controls			Group A			+ *P*
	Mean	SD	SE	Mean	SD	SE	
Pa–T	4.00	0.12	0.02	2.40	0.07	0.02	***
HN′–HN	0.43	0.02	0.00	0.27	0.03	0.01	***
TF′–TF	2.00	0.23	0.04	2.20	0.05	0.01	**
TZ′–TZ	3.90	0.33	0.06	2.80	0.10	0.03	***
TZ′–PrO	1.90	0.40	0.08	2.20	0.60	0.16	NS
TZ–PrO	1.90	0.17	0.03	1.00	0.14	0.04	***
TF′–PrO	1.00	0.12	0.02	1.30	0.07	0.02	***
TF–PrO	1.00	0.12	0.02	0.90	0.05	0.01	**
TN′–PrO	0.50	0.05	0.01	0.70	0.09	0.03	***
TN–PrO	0.50	0.05	0.01	0.40	0.12	0.03	***

**$P < 0.01$. ***$P < 0.001$.

Table 3 Differences (mm) between days 1 and 30 for control (C+D) and right unilateral condylectomy plus protrusion (B) groups.

Measurements	Controls			Group B			+ P
	Mean	SD	SE	Mean	SD	SE	
Pa–T	4.00	0.12	0.02	3.50	0.05	0.01	***
TB′–FB	1.80	0.05	0.01	1.90	0.04	0.01	*
TF′–TF	2.00	0.23	0.04	2.30	0.05	0.01	***
TN′–TN	1.10	0.09	0.02	1.30	0.11	0.03	***
TZ′–PrO	1.90	0.40	0.08	2.10	0.48	0.13	NS
TZ–PrO	1.90	0.17	0.03	1.70	0.08	0.02	***
TF′–PrO	1.00	0.11	0.02	1.20	0.03	0.00	***
TF–PrO	1.00	0.11	0.02	1.10	0.02	0.00	*
TN′–PrO	0.58	0.05	0.01	0.72	0.07	0.03	***
TN–PrO	0.58	0.05	0.01	0.64	0.04	0.01	***

*$P < 0.05$. ***$P < 0.001$.

Table 4 Significant differences between groups A (right unilateral conylectomy) and B (right unilateral condylectomy plus protrusion).

Measurements	Group A			Group B			+ P
	Mean	SD	SE	Mean	SD	SE	
Pa–T	2.40	0.07	0.02	3.50	0.05	0.01	***
HN′–HN	0.27	0.03	0.01	0.35	0.02	0.00	***
′FF′–TF	2.20	0.05	0.01	2.30	0.05	0.01	***
TZ′–TZ	2.80	0.10	0.03	3.60	0.11	0.03	***
TZ–PrO	1.00	0.10	0.04	1.70	0.08	0.02	***
TF′–PrO	1.20	0.07	0.02	1.30	0.03	0.00	***
TF–PrO	0.91	0.05	0.01	1.10	0.02	0.00	***
TN–PrO	0.41	0.12	0.03	0.64	0.04	0.01	***

***$P < 0.001$.

When condylectomy and altered mandibular function produce remote skeletal reactions in other parts of the cranial complex, the ‘morphogenic field hypothesis’ is supported (Spyropoulos and Burdi, 1987). According to this theory, structures that arise from the same morphogenic field may present reciprocal changes due to environmental and functional demands. Also, changes in a developmental unit may have an influence on structures that either arise from morphogenic fields adjacent to that unit or have a close interrelationship with the unit in a direct or indirect manner; this influence aims at providing an equilibrium between ipsilateral and neighbouring elements of a functional entity.

In this study, condylectomy and altered mandibular function produced remote skeletal reactions in the maxilla and the zygomatic arch of the same side. The maxilla and mandible represent developmental units of the same morphogenic field. Thus, the ipsilateral maxilla and the zygomatic arch are affected by condylectomy of the mandible; however, mandibular function by protraction compensates for the results of condylectomy as far as growth of these same ipsilateral skeletal elements is concerned.

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