Effects of temporal muscle detachment and coronoidotomy on facial growth in young rats

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Abstract: This study analyzed the effects of unilateral detachment of the temporal muscle and coronoidotomy on facial growth in young rats. Thirty one-month-old Wistar rats were distributed into three groups: detachment, coronoidotomy and sham-operated. Under general anesthesia, unilateral detachment of the temporal muscle was performed for the detachment group, unilateral coronoidotomy was performed for the coronoidotomy group, and only surgical access was performed for the sham-operated group. The animals were sacrificed at three months of age. Their soft tissues were removed, and the mandible was disarticulated. Radiographic projections—axial views of the skulls and lateral views of hemimandibles—were taken. Cephalometric evaluations were performed, and the values obtained were submitted to statistical analyses. There was a significant homolateral difference in the length of the premaxilla, height of the mandibular ramus and body, and the length of the mandible in all three groups. However, comparisons among the groups revealed no significant differences between the detachment and coronoidotomy groups for most measurements. It was concluded that both experimental detachment of the temporal muscle and coronoidotomy during the growth period in rats induced asymmetry of the mandible and affected the premaxilla.

Descriptors: Temporal Muscle; Mandible; Maxillofacial Development; Growth and Development.

Introduction

The coronoid process of the mandible is the insertion site of the temporal muscle. Any disturbance of this site can potentially affect mandibular and facial growth. Mandibular growth has been associated with a primary growth center represented by the mandibular condyle and with a secondary growth center influenced by the action of the masticatory muscles.[1] An injury to these structures may have adverse effects on mandibular growth.[2,3]

Experimental studies have demonstrated that temporal muscle detachment during a growth period leads to a reduction in the size of the coronoid process itself.[4] The anatomy of the coronoid process reflects the relative development of the temporal muscle.[5] Additionally, in growing rats, bilateral resections of the masseter muscle induced an inferior mandibular rotational pattern, while bilateral resections of the temporal

Declaration of Interests: The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

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Received for publication on Feb 06, 2012
Accepted for publication on May 08, 2012

muscle induced a superior rotational pattern.[6] However, it is known that when the temporal muscle is removed from its cranial origin, no coronoid process changes take place. This is explained by the maintenance of an intact blood supply to this structure.[7]

Hypertrophy of the coronoid process is associated with limitations in mandibular movement, and coronoidectomy is considered the treatment of choice.[8,9] However, coronoidotomy has been recommended because it causes less surgical trauma and less postoperative fibrosis and because the sectioned part of the coronoid heals onto the mandibular ramus in a posterior position.[10] An experimental study in rats demonstrated that after coronoidotomy, the coronoid process readily reattaches to the mandibular ramus by callus formation.[11] However, no studies have examined the effects of coronoidotomy on facial growth in experimental animals.

Some clinical situations involve the coronoid process or the temporal muscle insertion. Fractures of the coronoid process are relatively rare and are generally caused by an indirect mechanism.[12] The possibility of reflex fractures has been reported.[13] In general, conservative management allows the symptoms to resolve.[12,13] Furthermore, surgical procedures in the mandibular ramus region for access to neoplasms and for reconstructions frequently require detachment of the masseter and medial pterygoid muscles and often the temporal muscle.[14] However, the role of the temporal muscle in facial bone growth is not well understood.

The purpose of this study was to analyze the effects of unilateral detachment of the temporal muscle and coronoidotomy on facial growth in young rats.

Methodology

The study animals were 30 one-month-old female Wistar rats. All the animals were fed an ordinary diet of rodent feed (Labina, Agribands Purina, Paulínia, Brazil) and water. They were distributed into three groups:

- detachment (n = 10),
- coronoidotomy (n = 10) and
- sham-operated (n = 10).

The study was approved by the local research ethics committee.

Under general anesthesia induced by 10 mg/kg body weight of xylazine hydrochloride (Rompum, Bayer, Porto Alegre, Brazil) and 25 mg/kg body weight of ketamine hydrochloride (Dopalen, Vetbrands, Paulínia, Brazil), a single dose of 16,000 UI of benzylpenicillin (Benzetacil, Fontoura-Wieth, Itapevi, Brazil) was given, and the right side was shaved and cleansed with a povidone-iodine solution (Riodeine, Rioquímica, São José do Rio Preto, Brazil). A 1-cm preauricular incision was made and followed by blunt dissection through the masseter muscle just below the zygomatic arch, and the lateral surface of the mandibular ramus was exposed. The detachment group underwent complete detachment of the temporal muscle from the coronoid process. In the coronoidotomy group, the coronoid process was sectioned using a surgical bur. The sham-operated group was submitted to exposure of the mandibular ramus. The procedures were concluded by suturing in layers. The animals were sacrificed at three months of age, and their heads and mandibles were carefully macerated. Following formalin fixation, radiographs with axial projections of the skull and lateral projections of the hemimandibles were obtained. These were taken with a dental machine (Spectro II, Dabi-Atlante, Ribeirão Preto, Brazil) at 56 kV and 10 mA, with an exposure time of 0.4 s for the skulls and 0.3 s for the hemimandibles. Periapical films were used (Ektaspeed Plus, Eastman Kodak, Rochester, USA).

The radiographs were subjected to a computerized cephalometric evaluation and were digitized using an optical reader (Fotovix II, Tamron Co, Tokyo, Japan). Measurements were obtained with Imagelab software (Softium Informática, São Paulo, Brazil). Using skull radiographs, the following distances were measured bilaterally:

- tympanic bulla to the mesial root of the first molar (TB-MR),
- tympanic bulla to infraorbital foramen (TB-IF) and
- infraorbital foramen to incisal point (IF-IP) (Figure 1).

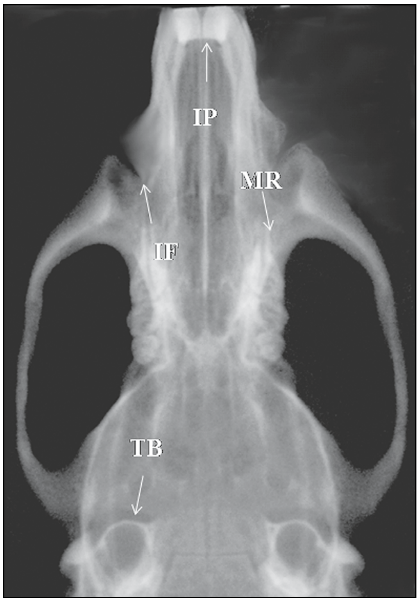

Figure 1 - Axial radiograph of the skull. **TB =** tympanic bulla, **MR =** mesial root of the first molar, **IF =** infraorbital foramen, **IP =** incisal point.

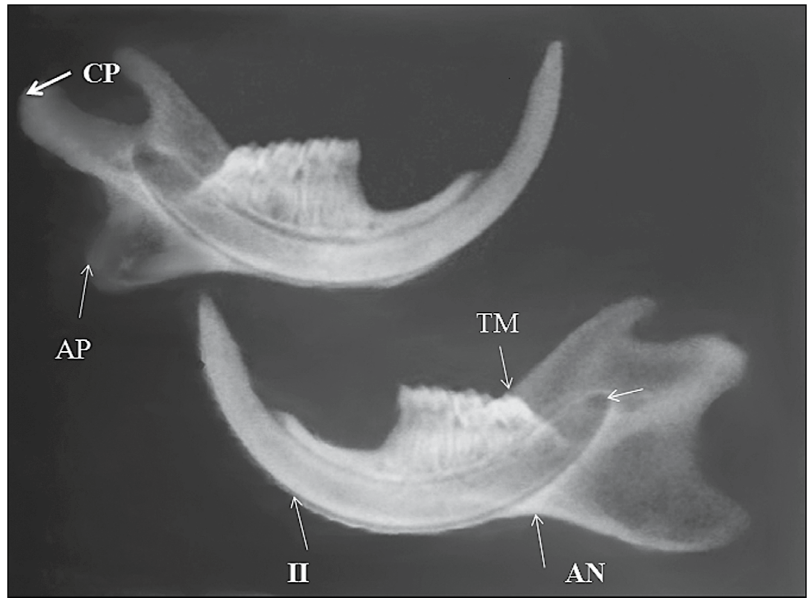

Figure 2 - Lateral radiograph of hemimandibles. **CP =** condylar process, **AP =** angular process, **II =** insertion of incisor, **TM =** distal face of the third molar, **AN =** antegonial notch, **IA =** incisor apex.

On the radiographs of the hemimandibles, the following distances were measured bilaterally:

- condylar process to angular process (CP-AP),
- distal face of the third molar to antegonial notch (TM-AN),
- lower insertion of incisor to angular process (II-AP) and
- incisor apex to condylar process (IA-CP) (Figure 2).

To evaluate the differences between the mean values for the right and left sides in each group, the paired student's t-test was used, while analysis of variance (ANOVA) and Tukey's tests were used for the mean values of the three groups. Statistical Package for the Social Sciences (SPSS) Version 16.0 software was used to conduct the analyses (SPSS Incorporated, Chicago, USA). The level of significance was set at 5% ($p < 0.050$).

Results

Macroscopic examination of the specimens revealed facial asymmetry with deviation of the mandible to the right side in the detachment and coronoidotomy groups and discrete asymmetry in the sham-operated group. The main macroscopic findings for the macerated specimens are shown in Figure 3.

The mean values of the distances found on the axial radiographs of the skulls are presented in Table 1. There was a significant difference between sides in the following measurements:

- TB-IF in the detachment and sham-operated groups and
- IF-IP in the detachment and coronoidotomy groups.

Comparing the maxillary measurements among groups, the ANOVA demonstrated that there were differences in all measurements except the IF-IP on the left side (Table 2). According to Tukey's test, there were no significant differences between the detachment and coronoidotomy groups, but there were significant differences between these groups and the sham-operated group.

The mean values of the distances found on the lateral radiographs of the hemimandibles are presented in Table 3. There was a significant difference between sides for all measurements except II-AP.

Comparing the mandibular measurements

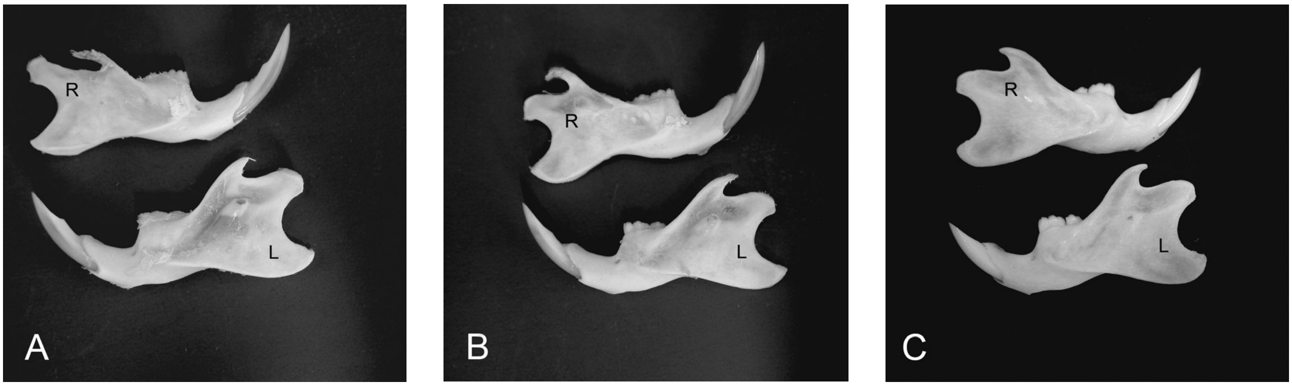

Figure 3 - Macerated hemimandibles. **A =** detachment group and **B =** coronoidotomy group, showing atrophic mandibular rami on the right **(R)** side; **C =** sham-operated group, with similar R and left **(L)** sides.

Table 1 - Mean values (mm) of distances found on the axial radiographs of all the groups and the significance of paired student's t-tests.

Group		Measurements		
		TB-MR Mean ± sd	TB-IF Mean ± sd	IF-IP Mean ± sd
Detachment	Right side	18.12 ± 0.50	22.18 ± 0.59	8.71 ± 0.32
	Left side	18.07 ± 0.45	21.79 ± 0.42	10.11 ± 0.32
	p value	0.546	0.022	< 0.001
Coronoidotomy	Right side	18.41 ± 0.61	22.44 ± 0.67	8.73 ± 0.35
	Left side	18.23 ± 0.46	22.16 ± 0.44	9.72 ± 0.40
	p value	0.229	0.124	0.001
Sham-operated	Right side	20.04 ± 2,23	23.66 ± 0.83	9.73 ± 0.37
	Left side	19.33 ± 0.71	23.42 ± 0.62	10.21 ± 0.72
	p value	0.314	0.029	0.082

Table 2 - Significance of the analysis of variance for measurements taken from axial radiographs.

Measurement	Side	p value	Groups and Tukey's test		
			Detachment	Coronoidotomy	Sham-operated
TB-MR	Right	0.008	a	a	b
	Left	< 0.001	a	a	b
TB-IF	Right	< 0.001	a	a	b
	Left	< 0.001	a	a	b
IF-IP	Right	< 0.001	a	a	b
	Left	0.096	–	–	–

Different letters indicate a statistically significant difference ($p < 0.050$).

among groups, the ANOVA demonstrated that there were differences in all measurements on the right side (Table 4). Tukey's test showed no significant differences between detachment and coronoidotomy groups, but there were significant differences between these groups and the sham-operated group for most measurements. Only the IA-CP measurement showed a significant difference between the detachment and coronoidotomy groups.

Discussion

The effects of temporal muscle detachment or coronoidotomy on the growth of the maxilla and mandible were analyzed in young rats. Thus, when

Table 3 - Mean values (mm) of distances found on lateral radiographs of the hemimandibles of all the groups and the significance of paired student's t-tests.

Groups		Measurements			
		CP-AP Mean ± sd	TM-AN Mean ± sd	II-AP Mean ± sd	IA-CP Mean ± sd
Detachment	Right side	10.12 ± 0.55	7.31 ± 0.42	23.79 ± 1.01	6.18 ± 0.35
	Left side	11.57 ± 0.47	7.66 ± 0.35	25.42 ± 1.05	7.35 ± 0.27
	p value	< 0.001	0,022	< 0.001	< 0.001
Coronoidotomy	Right side	9.65 ± 0.41	7.18 ± 0.32	24.15 ± 0.80	7.03 ± 0.49
	Left side	11.38 ± 0.64	7.87 ± 0.35	25.63 ± 0.65	7,67 ± 0.58
	p value	< 0.001	< 0.001	< 0.001	0.007
Sham-operated	Right side	11.52 ± 0.41	8.01 ± 0.37	25.74 ± 0.94	7.20 ± 0.60
	Left side	11.25 ± 0.60	7.89 ± 0.37	25.89 ± 1.08	7.56 ± 0.69
	p value	0.046	0.002	0.271	0.007

Table 4 - Significance of the analysis of variance for measurements taken from the lateral radiographs of the hemimandibles.

Measurement	Side	p value	Groups and Tukey's test		
			Detachment	Coronoidotomy	Sham-operated
CP-AP	Right	< 0.001	a	a	b
	Left	0.464	–	–	–
TM-AN	Right	< 0.001	a	a	b
	Left	0.317	–	–	–
II-AP	Right	< 0.001	a	a	b
	Left	0.553	–	–	–
IA-CP	Right	< 0.001	a	b	b
	Left	0.432	–	–	–

Different letters indicate a statistically significant difference ($p < 0.050$).

the animals reached adult age, radiographic projections were obtained and used to perform cephalometry on a computer system. Through statistical analyses, it could be seen that changes occurred in both the mandible and the maxilla. The final result was shortening of the maxilla and asymmetry of the mandible associated with either homolateral detachment of the temporal muscle or coronoidotomy.

Mandibular deformities comprising a reduction in size of the coronoid process have been related to disinsertion of the temporal muscle.[4] However, the present study detected actual asymmetry of the mandible, likely because of the refined measurements taken and the statistical analyses used. Gross modifications of the mandible are reported after temporal muscle resection in young rats, supporting the functional matrix theory of mandibular growth.[5,15] Another significant finding was shortening of the maxilla. The possibility of maxillary growth influencing mandibular growth and vice versa by occlusal intercuspation has been described.[1,16] Occlusal disturbances have been described as the main cause of asymmetry of the maxilla after experimental fractures[17] and as a complication of condylar fractures.[18]

Cephalometric evaluations based on radiographs of the skulls and hemimandibles of dissected specimens using a computerized system lead to reliable measurements.[19] The distances in this study were similar to those in other studies.[17,19,20] A new distance—incisor apex to condylar process—was used to improve the evaluation of the mandibular ramus, and this measurement demonstrated the negative influence of detachment. Mandibular distances between sides were significantly different in all the groups, but the comparison among groups demonstrated no significant differences between the detachment and coronoidotomy groups, both of which were significantly different from sham-operated group.

The effects of coronoidotomy were similar to those of temporal muscle detachment. After coronoidotomy, the sectioned part of the coronoid heals onto mandibular ramus by callus formation.[10,11] The effects of muscle reattachment allow new bone formation to envelop the reorganizing tendon,[21] and this may have influenced the similar results for the detachment and coronoidotomy groups. To the best of our knowledge, no previous studies in the literature have evaluated this aspect.

It has been reported that the effects of masticatory muscle action on mandibular growth in the angular and condylar processes in rats is intense.[22] Similar findings have been reported for pigs, with bone apposition on the posterior, inferior and lateral borders of the mandible.[23] In sum, studies have demonstrated that the lateral pterygoid muscle has an effect on the growth of the condylar process,[24] the masseter muscle has an effect on the angular process,[16] and the temporal muscle has an effect on the growth of both the coronoid process[5] and the entire mandibular ramus and body, as demonstrated.

Conclusion

Temporal muscle detachment and coronoidotomy in young rats had the same effects on facial growth. Asymmetry of the mandible was induced and led to shortening of the premaxilla.

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