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THE EFFECTS OF BITE PLANE THERAPY ON MANDIBULAR GROWTH: A CATASTROPHE AVERTED

by

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Submitted in partial fulfillment of the requirements

for the Degree of Master of Science in Dentistry

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August 1987

THE EFFECTS OF BITE PLANE THERAPY ON MANDIBULAR GROWTH: A CATASTROPHE AVERTED

Abstract

by

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The occlusal bite plane has been an adjunct in orthodontic therapy for over a century. Its applications are well known, but the underlying basis for the observed clinical results are not fully understood. The effects of mandibular growth in the correction of skeletally based malocclusion are well appreciated by most clinicians, but the relationship between occlusal intercuspation and mandibular growth has only recently been investigated.

The purpose of this study was to investigate the relationship between the absence of an intercuspating occlusion and mandibular growth. The study was carried out using fourteen male Sprague-Dawley rat pups. Six pups served as untreated controls and eight pups served as experimental animals. At the age of 22 days, the experimental rats were anesthetized and their maxillary posterior teeth covered with composite. The surfaces of the maxillary and mandibular posterior teeth were then ground flat to provide a cuspless, flat plane occlusion at

the rat's original vertical dimension of occlusion. This occlusal scheme mimics the disoccluded state present in orthodontic patients who are undergoing bite plane therapy, yet without an increase in the vertical dimension of occlusion. Vital dyes were injected into all rats at ages 17, 22, 32 and 42 days. The rats were sacrificed at 43 days of age and their skulls recovered.

Measurements were made to determine the final dimensions of the skull in order to compare the treated and untreated animals. The skulls were then processed for ground section histology.

The results of the experiment revealed that no significant differences existed between the experimental and control groups in terms of the final dimensions of either the upper of lower jaw. This analysis led to the conclusion that the role of occlusion in the modulation of mandibular growth is one of a component part in a larger whole rather than a principle governing factor and that within the limits of this study, intercuspation per se does not appear to provide the primary guiding influence on mandibular growth.

DEDICATION

I would like to dedicate this work to my father, Dr. Joseph A. Petrone and my grandfather, Felix A. Petrone, and to the glory of God, for it is but a description of a small portion of His creation.

ACKNOWLEDGMENT

I would like to express my sincere appreciation to Dr. Howard Kossoff, whose kind and generous assistance with the technical aspects of word processing made this manuscript such an excellent learning experience.

I would like to thank my classmate and colleague, Dr. Michael T. Kim, who throughout my graduate education provided a constant source of academic, personal, intellectual and professional challenge.

My sincerest thanks, though, go to my parents Joseph and Beverly, without whose love and support I would not have succeeded in fulfilling my life's dream.

TABLE OF CONTENTS

ABSTRACT..... ii

DEDICATION..... iv

ACKNOWLEDGMENT..... v

TABLE OF CONTENTS..... vi

ILLUSTRATIONS..... viii

LIST OF TABLES..... ix

INTRODUCTION..... 1

STATEMENT OF THESIS..... 3

BACKGROUND..... 4

MATERIALS AND METHODS..... 13

- Sample
- Vital Dyes
- Anesthesia
- Cephalometrics
- Composite Application
- Experimental Design
- Sacrifice
- Hard Tissue Recovery
- Morphometrics
- Analysis of Data
- Histologic Processing

RESULTS..... 27

- Morbidity
- Weight Gain

Morphometry of Bone

Histology

DISCUSSION..... 40

SUMMARY AND CONCLUSION..... 49

LITERATURE CITED..... 51

ILLUSTRATIONS

Figure		Page
1.	Preoperative lateral cephalogram of a 22 day old pup.....	16
2.	Postoperative lateral cephalogram of a 22 day old pup.....	17
3.	Inferior view of the rat skull.....	21
4.	Right lateral view of the rat mandible.....	22
5.	Superior view of the rat mandible.....	23
6.	Superior view of the rat skull.....	25
7.	Incisor alveolus from control rat.....	34
8.	Inferior border of corpus from control rat..	36
9.	Incisor alveolus from experimental rat.....	37
10.	Inferior border of corpus from experimental rat.....	38

LIST OF TABLES

Table		Page
1.	Weight Data: Initial Weight, Final Weight and Weight Gain.....	28
2.	Morphometry of Bone.....	29
3.	Operator Error.....	30
4.	Morphometric Ratios.....	32

INTRODUCTION

The occlusal bite plane has been an adjunct in orthodontic therapy for over a century. It has taken the form of the Hawley retainer, a fixed lingual archwire with an acrylic bite plane or even a full coverage occlusal splint. While its applications are numerous, its purpose is simple: disclusion of the teeth.

One of the many applications of the bite plane is in early treatment of a skeletal Class II malocclusion. Empirical and anecdotal evidence suggests that early intervention with a bite opening appliance will serve to "unlock the bite" and allow the mandible to grow into a more harmonious relationship with the maxilla, thereby correcting a relative mandibular skeletal deficit. Such clinical observations suggest that the occlusion acts as a regulating element in the overall control process of the growing facial skeleton. But, the discluding effect of the bite plane results from the mechanical opening of the bite. Thus, a new vertical dimension of occlusion is established in the patient's discluded state. A true test of the effect of disclusion alone would therefor need to take place without the opening of the bite. This could only occur in an occlusion characterized by cuspless or flat plane teeth.

The purpose of this experiment was to describe the growth of the facial skeleton in rats whose occlusion was characterized by a cuspless posterior dentition. Such a description may lead to a better understanding of the role that occlusal intercuspation plays in the regulation of facial growth.

STATEMENT OF THESIS

The purpose of this study is to further explore the underlying basis of the observed changes in the anteroposterior relationship of the dental bases which occur during growth. A description of the altered growth of the mandible in the absence of an intercuspating occlusion will prove to be significant in the orthodontic treatment of patients presenting with skeletal base discrepancies. Petrovic (1984) states that once established, a pattern of facial growth will be propagated under the influence of an existing occlusal scheme. The growth patterns of the mandible in the absence of intercuspal consequences may reveal a latent growth differential which will facilitate correction of such skeletal incongruities.

My hypothesis is that mandibular growth will be augmented in the absence of intercuspal occlusion.

BACKGROUND

Occlusal bite plane therapy has often been utilized in the treatment of dental and skeletal malocclusion. The observed effects of such treatment are well known (Salzmann, 1957), yet the basis for the underlying clinical change is a matter of debate (Menezes, 1975). The clinically observable effects are, according to Salzmann (1957):

1. Forward positioning of the head of the condyle of the mandible on the eminentia articularis
2. Opening of the bite, diminishing the overjet of the teeth.
3. Elevation of the posterior teeth; the anterior teeth may be slightly depressed or both.
4. A more normal anteroposterior relationship of the occlusal relationship.
5. Facial outline is usually improved.

It was Kingsley (1880) who first utilized the bite plane in treatment of malocclusion characterized by distal relationships of the mandibular to the maxillary dental arches. He attained the desired treatment effect by "jumping the bite" from the retruded to the more normal occlusion. Numerous investigators subsequent to Kingsley (i.e. Hemley, 1939; Callaway, 1940) chose to explore the effects of bite plane therapy on the vertical dimension of occlusion, putting forth arguments based on clinical measurement as to the underlying basis of observable changes. Arguments centering on whether the changes in occlusal vertical dimension were attributable to

mandibular incisor intrusion or bimaxillary molar extrusion occupied the literature. Investigations into the basis of anteroposterior change through the use of a bite plane were noticeably absent during the same period of time. This may be attributable to the introduction of intermaxillary anchorage by H. A. Baker (1904) which provided a more reliable method for the correction of distoclusion.

The purpose of this study is not to argue the use of bite plane therapy in the treatment of distoclusion, but to further explore the underlying basis of the observed clinical change in the anteroposterior relationship of the dental bases which facilitates such a correction. The basis for this correction is assumably complex, but in its purest form may be attributable, at least in part to growth of the mandible. Mandibular growth has been thoroughly described by Enlow (1982) but a definitive explanation of the underlying basis of observable phenomena has not been synthesized. The mechanisms of mandibular growth are subjects of continued investigation and not to be discussed here. It is the bite plane and its relationship to the underlying component of corrective mandibular growth that is of interest. Of particular interest is the fact that this component of growth is seen when the bite plane acts to disarticulate the teeth from their normal occlusal relationship.

A model for mandibular growth as modified by occlusion was proposed by Petrovic and coworkers (Petrovic 1974; Petrovic and Stutzmann, 1977; Petrovic et al., 1975; Lavergne and Petrovic, 1983; Petrovic, 1984). This cybernetic model for the control of growth of the secondary cartilage of the mandible is based on a servosystem approach to the maintenance of stable occlusal relationships in the changing environment found in facial growth. Periosteal contributions to mandibular growth reflect the influences of both systemic and local factors such as muscular contractions. The contribution of the condylar cartilage to mandibular growth is subject to local control through the confrontation of the maxillary and mandibular dental arches as they occlude during function.

During growth, the position of the maxillary dental arch is constantly changing. In order for an efficient occlusion to be maintained, the position of the mandibular dental arch must be adaptable to the change in its maxillary counterpart. Incongruities in growth changes between the two jaws will be manifest in occlusal disharmony and an inefficient occlusion, which gives rise to "deviation signals" detectable by sensory apparatus in the periodontal membrane, temporomandibular joint, muscles of mastication and oral mucosa. Repositioning of the

mandible facilitates a more harmonious occlusion characterized by a minimal level of deviation signals.

The lateral pterygoid muscle is the muscle primarily involved in reposturing of the mandible to facilitate harmonious occlusion. An increase or decrease in tonic activity of the lateral pterygoid will produce either a corresponding increase of decrease in the growth rate of the condylar cartilage (Petrovic, 1974; Petrovic et al., 1975; Petrovic, 1984). Thus, the result of the confrontation of the maxilla and mandible at the occlusal table is harmony of growth changes.

The amount and direction of mandibular reposturing is determined by a central comparator (Petrovic, 1984) and may not vary in a linear fashion with maxillary growth displacement. Efficient occlusal relationships found in confrontations allowing maximal cuspal interdigitations provide a minimum of undesirable deviation signals, and are referred to as steady-state positions (Petrovic, 1984). Angle Class I occlusion is purported to be the optimal steady-state occlusion, but other suboptimal occlusions corresponding to full cusp Angle Class II and Class III relationships provide steady-state confrontations. These suboptimal occlusions may then also serve as "set points" of reference upon which harmonious growth of the jaws is coordinated (Petrovic et al., 1975; Petrovic, 1984).

Steady-state occlusions are separated by unbalanced states corresponding to cusp-to-cusp relationships. These confrontations provide a maximum of deviation signals and define the outer limits within which the central comparator seeks a steady-state occlusion. Thus, it is unlikely that a suboptimal Class II or Class III occlusion will be optimized to Class I by reposturing and subsequent growth as such an occurrence would necessitate growth through an unbalanced state. However, a cusp-to-cusp relationship present at critical periods of growth represents a situation in which both the amount and direction of future growth may vary in a non-linear fashion (Petrovic, 1984). Growth patterns in such a situation become discontinuous and divergent, with otherwise inconsequential perturbations serving to establish the future patterns of growth. Such discontinuous and divergent phenomena are described by the catastrophe theory (Zeeman, 1976), which purports a mathematical model for describing such non-linear phenomena.

Cusp-to-cusp relationships present at critical periods of growth allow for such things as tooth loss, oral habits, random growth variations or orthodontic tooth movement to establish a pattern of skeletal growth in the jaws. When teeth (particularly posterior teeth) meet in a

cusp-to-cusp occlusion, small changes in their anteroposterior relationship facilitate an occlusion which is directed toward either full cusp Class I or Class II with the concomitant skeletal patterns occurring as well. Thus, the pattern of growth from the time in which the cusp-to-cusp occlusion is present until well after a fully intercuspated occlusion is established is determined by what occurs at this critical period in growth. Should a tendency toward Class I occlusion develop, mandibular growth will tend to be accelerated as the mandible is actively postured forward by the lateral pterygoid muscle to further facilitate a full cusp Class I occlusion (Petrovic, 1974; Petrovic, et al., 1975; Petrovic, 1984). In contrast to a state of augmented growth, a state of retarded mandibular growth would occur if a tendency toward Class II occlusion developed and no forward posturing of the mandible occurs as such would tend to counteract any tendency toward full Class II intercuspation.

It can then be seen how divergent patterns of growth can be when perturbations in occlusion and function act at critical times during growth. The dichotomy of resultant growth patterns illustrates how a single precursory pattern can become divergent and proceed in one of two different directions. This phenomena of dichotomous

growth is referred to in the catastrophe theory as a bifurcation-type situation, and the sudden, discontinuous growth pattern which occurs at critical periods of growth are labeled "catastrophes" (Petrovic, 1984).

Petrovic (1984) goes on to state antithetically that the absence of interdental contacts corresponds to neither a steady-state nor a functionally discontinuous situation. Thus, mandibular growth in the presence of a cuspless occlusion may not be described by a cybernetic model. A valuable test of the role of occlusal interdigitation in facial growth would be to examine jaw growth in the presence of a flat plane occlusion. In such a state the patterns of growth would be less likely to involve bifurcation-type situations because no instances of cusp-to-cusp occlusion are likely to occur. The cuspless occlusion then serves not only to avert the catastrophe of discontinuous growth possible in animals possessing intercuspating occlusions, but also to uncouple the mandible from the maxillary dentition and allow patterns of mandibular growth to be observed in a state free of influence of maxillary growth as transmitted through intercuspation. Such a state of occlusion is present in orthodontic patients whose therapy includes certain forms of bite plates and functional appliances. Vig and Vig (1986) postulate that disocclusion may have a theoretical

deregulating or promoting influence on mandibular growth. Johnston (1986) proposes that disruption of occlusal intercuspation allows the mandible to advance relative to the maxilla. Bakker and Johnston (1985) propose that incisor occlusion may be the mechanism that serves to coordinate maxillary and mandibular growth.

An interesting contrast to Petrovic's cybernetic model is provided by Kantomaa, who conducted animal studies involving artificial synostosis in an effort to observe morphologic changes in the mandible secondary to induced alterations in the neurocranium and maxilla. A study in which the interparietal, temporoparietal and lambdoidal sutures of young New Zealand rabbits were fused with glue (Kantomaa, 1984) resulting in an opening of the cranial base flexure and lengthening of the mandible led Kantomaa to conclude that tissues connecting the mandible to neighboring structures are more important than growth of the condyle in determining the sagittal intermaxillary relationship. Furthermore, the magnitude of the resultant morphologic alterations in the neurocranium was greater than the compensatory lengthening of the mandible, indicating that the mandible was necessarily protruded in its functional state. Kantomaa stated that with a difference of this magnitude a change in intercuspation would have been expected to occur. However, since the

sagittal interdental relationship appeared unaltered, his observations did not lend support to the catastrophe theory. He then concluded that the forward growth of the maxilla carries the mandible passively forwards, thus directing condylar growth.

A second study conducted by Kantomaa (Kantomaa and Ronning, 1985) involved artificial synostosis of the frontonasal, frontopremaxillary and frontomaxillary sutures in 78 young rats. Additionally, in 10 experimental and 10 control rats, the incisors were cut twice a week and the cusps of the molars ground. The resultant restriction of maxillary growth was mimicked in the mandible, both in the presence and absence of a cusped occlusion. Kantomaa concluded that his findings did not support the hypothesis of Petrovic involving occlusion as an important factor regulating the intermaxillary relationship during growth.

MATERIALS AND METHODS

Sample

The animal sample comprised 20 male Sprague-Dawley pups (Zivic-Miller Laboratories Inc., Allison Park, PA) equally distributed into experimental and control groups. Two groups of 10 pups, each with a foster mother were placed in 17"x 13"x 18" cages in a climate controlled environment at 23°C and 10-20% humidity. On delivery, one group of pups was 12 days old, and the other group was 11 days old. This separation in age by one day facilitated the logistics of the experimental procedure. The pups in both groups were fed Purina rat chow (Ralston Purina Co., St. Louis Missouri) and water ad libitum.

Vital Dyes

Polychrome fluorescent dyes were used throughout the experiment as markers of bone formation. The first dye to be used was Oxytetracycline HCL (OXY-BIOTIC, 50 mg/kg, The Butler Company, Columbus, Ohio) and it was injected via an intramuscular route into pups in both experimental and control groups at age 17 days. The experimental period began when the pups were 22 days old, at which time they were given intraperitoneal injections of DCAF [(2,4Bis)-N,N'DI (Carboxymethyl), 15 mg/kg mixed in 2% HCO_3, Polysciences Inc., Warrington PA]. On the tenth

experimental day, pups in both groups were given intraperitoneal injections of Alizarin Complexon (No. A-3882, 30 mg/kg, Sigma Chemical Company, St. Louis, MO) and on the twentieth day pups in both groups were given intraperitoneal injections of Xylenol Orange (tetrasodium salt, No. X-3500, 90 mg/kg, Sigma Chemical Company, St. Louis, MO).

Anesthesia

Initial anesthesia for vital stain injection, composite placement and grinding of incisors was induced by inhalation of anesthetic grade ethyl ether (Fischer Scientific, Pittsburgh, PA) in a closed bell jar until the animal was unconscious. A subsequent, more profound anesthesia for composite placement was attained by intraperitoneal injection of Sodium Pentobarbitol (Diabutol, 45 mg/kg, Diamond Laboratories Inc., Des Moines, Iowa).

Cephalometrics

Lateral cephalograms of the pups in the experimental group were made before and after placement and grinding of the composite in an effort to document that the original vertical dimension of occlusion had been maintained.

Once the pups were anesthetized, a small elastic band was placed around the upper and lower jaws of the pup to ensure that the occlusal surfaces were in full occlusion. The pup was then placed on an occlusal radiographic film, (Kodak Ektaspeed Dental X-Ray Film, size 4, EO-41, Eastman Kodak Company, Rochester New York) with the left side of its head against the film to reduce and standardize the amount of enlargement. Exposure was made at 90 kvp, 15 ma for 3/10 seconds (Figure 1). The composite was then placed and ground flat. The elastic band was then again placed and another radiograph was taken (Figure 2). The radiographs were developed and the distance between the junction of the alveolar processes of the molar and the incisor on the upper and lower jaws was measured with calipers. A 1.0 cm. wire was included in each of the radiographs as a standard of measurement. The amount of composite on the maxillary teeth was adjusted until the vertical dimension of occlusion was restored to within $\pm$ 0.5 mm of its original value, as it was to within this degree of error that the entire cephalometric procedure was felt to be precise.

Composite application

Rats in the experimental group were profoundly anesthetized and placed in a supine position on the lab

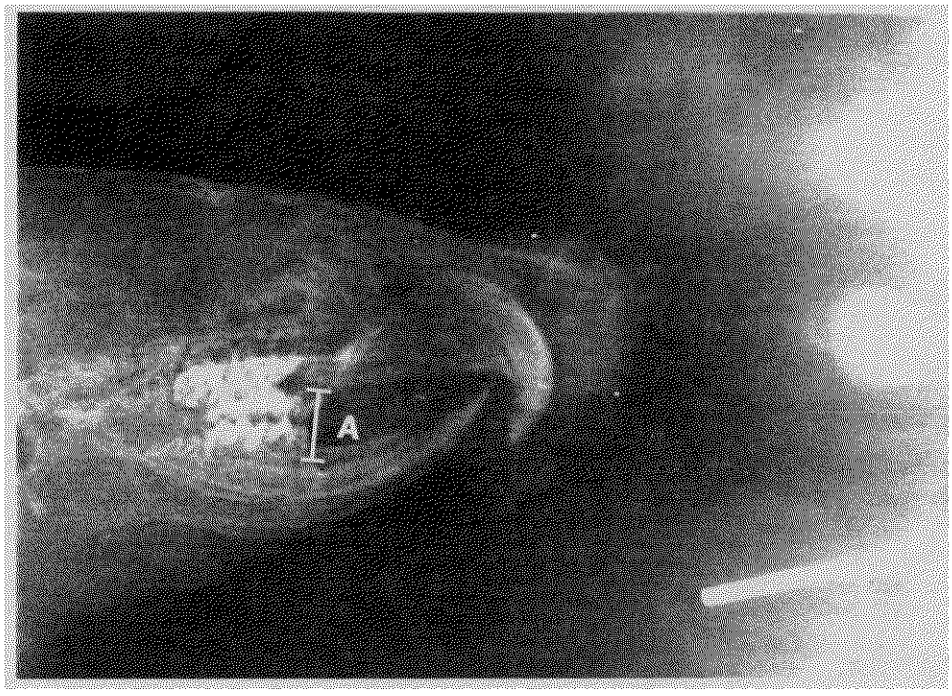


Figure 1. Preoperative lateral cephalogram of a 22 day old pup: A, reference distance.

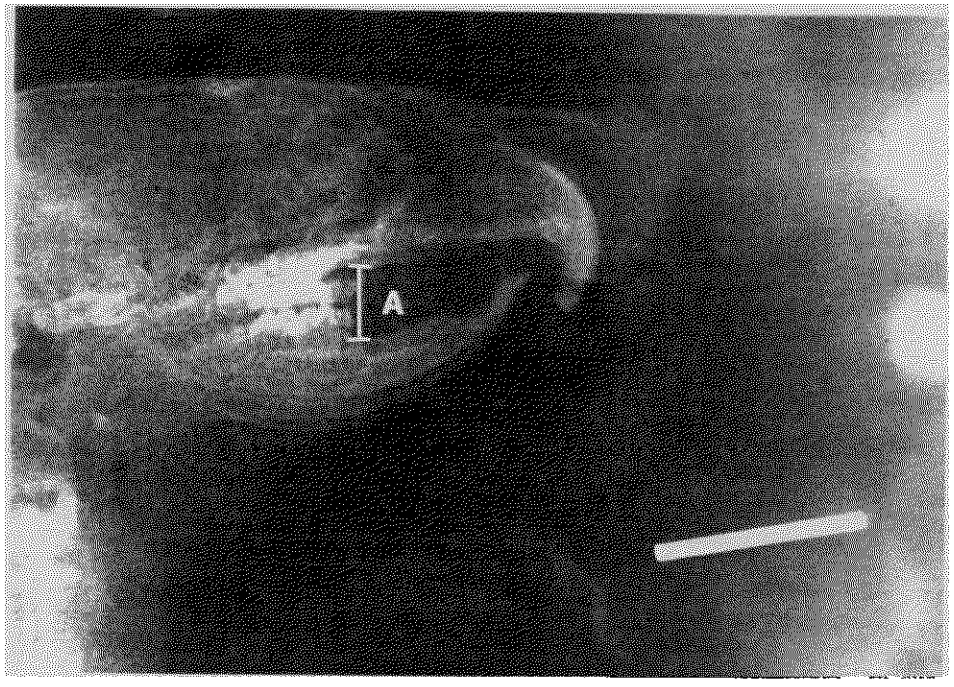


Figure 2. Postoperative lateral cephalogram of a 22 day old pup: A, reference distance.

bench. One quadrant of the maxillary posterior teeth was isolated with a portion of a gauze and the posterior teeth were dried with compressed air. The teeth in the isolated quadrant were etched with phosphoric acid for 2 minutes and 20 seconds, and then rinsed with water from moist cotton pellet and again dried with compressed air.

Scotchbond Dental adhesive (Dental Products/3M, St. Paul, MN) was applied and the excess solvent desiccated with compressed air. A second application of adhesive was applied and again desiccated. Light-curing composite (P-30 Resin Bonded Ceramic, Dental Products/3M, St. Paul, MN) was applied in a quantity sufficient to fill the fossae between the cusps, and cured with visible light (Getz Focus Activator Light, Teledyne Getz, Elk Grove Village, Illinois) for 40 seconds. The occluding surface of the composite was flattened with a diamond bur (Shofu #0898/033, Menlo Park, CA). The entire placement procedure was then repeated on the contralateral side of the maxillary dental arch.

Experimental Design

Twenty male pups were equally divided into experimental and control groups. At 22 days of age, pups in the experimental group were anesthetized and

then radiographed. The composite was applied and the pups were again radiographed. Injections of vital dyes were given at ages 17, 22, 32 and 42 days of age. The incisors of pups in both groups were ground out of occlusion twice during the experimental period in order to alter their functional state. On the twenty-first experimental day, at 43 days of age, the rats were sacrificed.

Sacrifice

Sacrifice of the animals took place 21 days after the start of the experiment. The rats were initially anesthetized by inhalation of anesthetic grade ether, and then sacrificed by a lethal intracardiac injection of Sodium Pentobarbitol (Diabutol, 150 mg/kg, Diamond Laboratories Inc., Des Moines, Iowa 50304)

Hard Tissue Recovery

The heads of the rats in both groups were separated from their bodies and the skin removed. The specimens were then fixed in 90% ethanol for 48 hours.

Debridement of the osseous tissue was achieved by placing each skull in a boiling solution of detergent (Biz bleach, Proctor and Gamble, Cincinnati, Ohio) for 4 minutes, and the remaining soft tissue was scraped away using a scalpel.

Morphometrics

Linear measurements of the recovered skulls and mandibles were done by caliper to within 1/20 mm. Measurements were made of the following dimensions:

1. L_1: the distance from the posterior nasal spine (PNS) to the midpoint between the most posterior points of the orifices of the two incisive canals (Figure 3).
2. L_2: the distance from PNS to the alveolus between the two maxillary incisors (Figure 3).
3. L_3: the distance from the most posterior point on the condylar cartilage to the mental foramen (Figure 4).
4. L_4: the shortest distance from the inferior border of the mandible to the level of the alveolus at the middle of the buccal surface of the first molar (Figure 4).
5. L_5: the distance between the middle of the buccal surface of the mandibular first molar at the level of the alveolus and the similar point on the contralateral side (Figure 5).
6. L_6: the distance between the middle of the buccal surface of the maxillary first

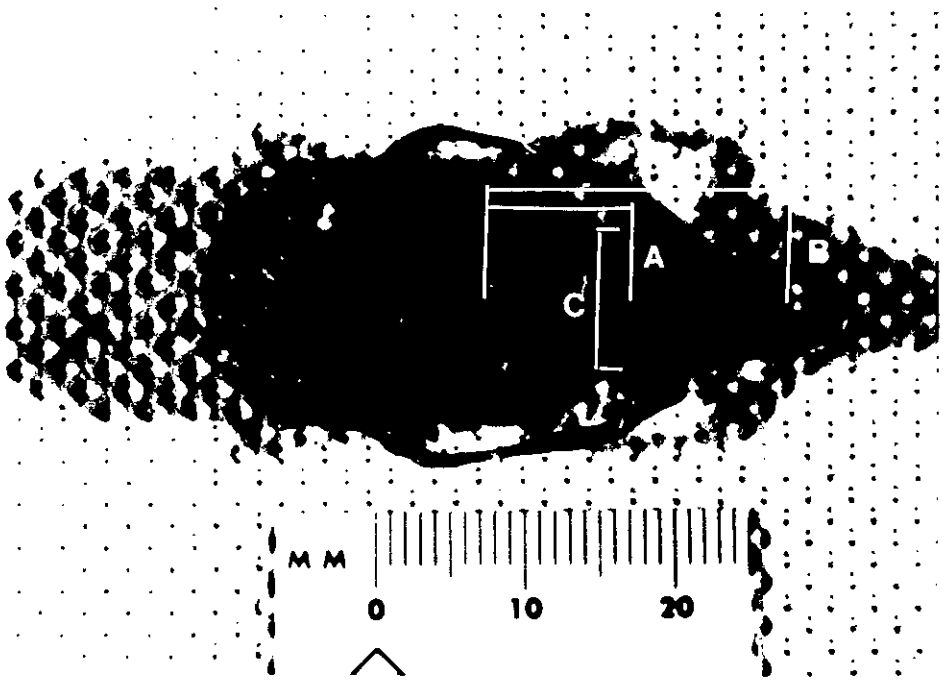


Figure 3. Inferior view of the rat skull: A, (L_1), the distance from the posterior nasal spine (PNS) to the midpoint between the most posterior points of the orifices of the two incisive canals. B, (L_2), the distance from PNS to the alveolus between the two maxillary incisors. C, (L_6), the distance between the middle of the buccal surface of the maxillary first molar at the level of the alveolus and the similar point on the contralateral side.

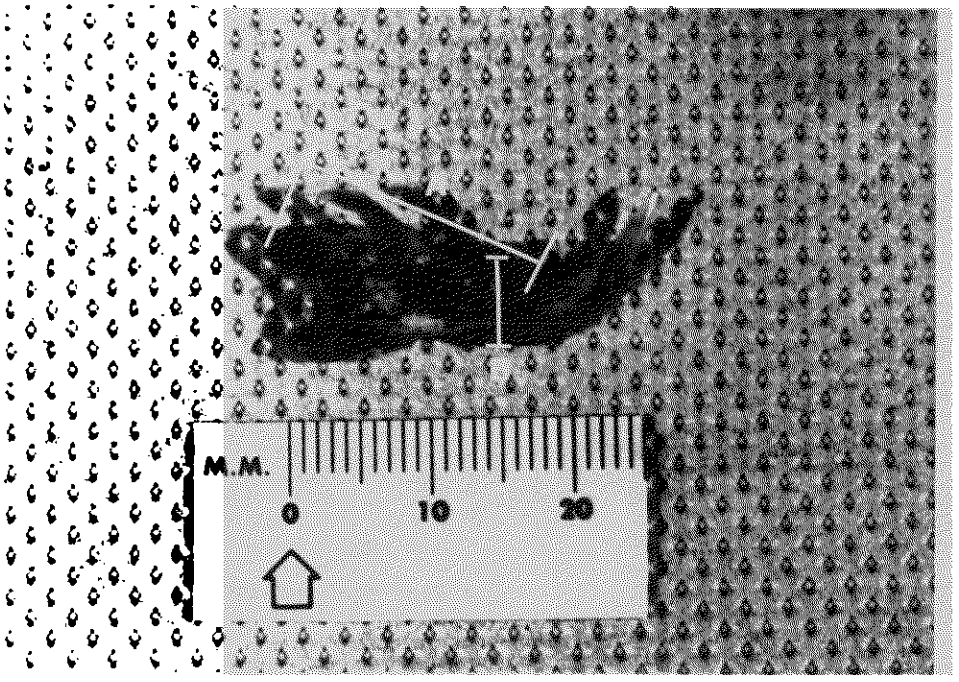


Figure 4. Right lateral view of the rat mandible: A, (L_3), the distance from the most posterior point on the condylar cartilage to the mental foramen; B, (L_4), the shortest distance from the inferior border of the mandible to the level of the alveolus at the middle of the buccal surface of the first molar.

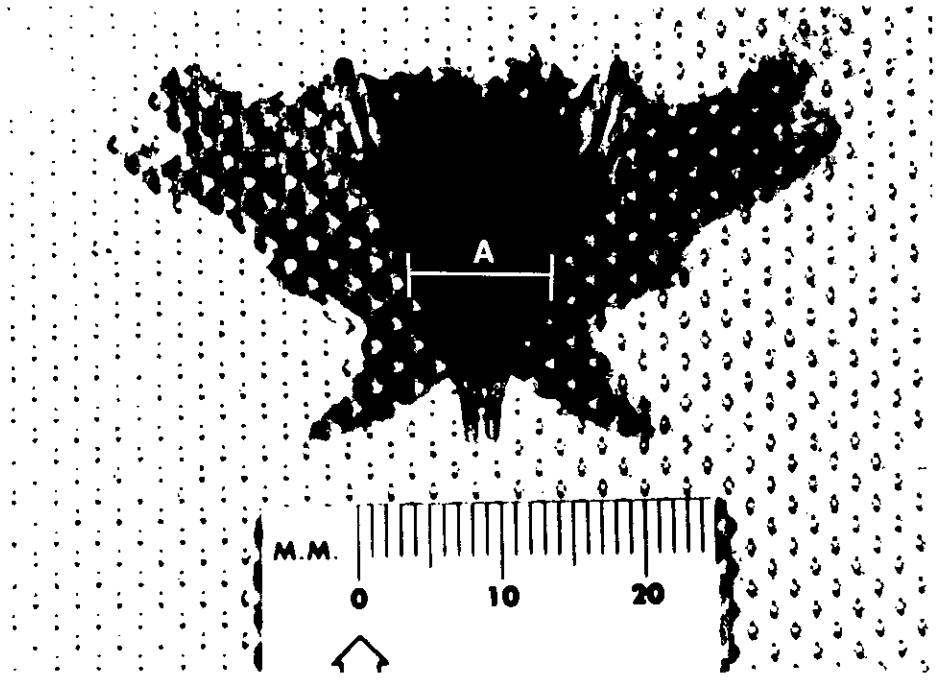


Figure 5. Superior view of the rat mandible: A, (L_5), the distance between the middle of the buccal surface of the mandibular first molar at the level of the alveolus and the similar point on the contralateral side.

molar at the level of the alveolus and the similar point on the contralateral side (Figure 3).

7. L_7: the distance from lambda to the junction of the left and right frontonasal sutures (Figure 6).

These dimensions were chosen as being descriptive of the size of the bones under investigation and a valid basis for comparison between specimens.

No effort was made to blind the investigator while making measurements of the recovered skulls. However, an operator test was conducted by remeasuring all of the recorded dimensions on 5 randomly selected skulls. These measurements were compared to those initially recorded using the Wilcoxon Ranked Sum test at the 0.05 level of significance.

Analysis of Data

Data obtained from the linear measurements of the skulls was analyzed using the Wilcoxon Ranked Sum test at the 0.05 level of significance. This test was indicated in lieu of a t-test because the resultant sample was too small to provide the necessary true normal values for either the experimental or control group. The Wilcoxon test was better suited for analysis of data from studies having small sample sizes.

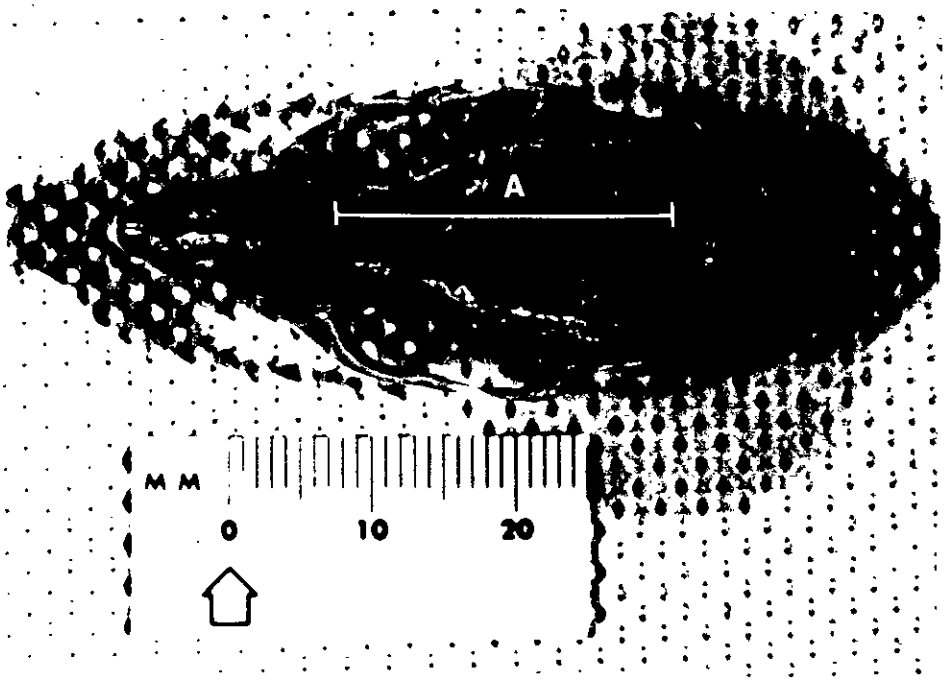


Figure 6. Superior view of the rat skull: A, (L_7), the distance from lambda to the junction of the left and right frontonasal sutures.

Histologic Processing

The recovered skulls were serially dehydrated by immersion in baths of 50%, 70%, 95% and 100% ethyl alcohol for 30 minutes each. The specimens were then immersed in xylene for 15 minutes, followed by a second bath of xylene for 15 minutes. The specimens were then immersed in unpolymerized Bio-Plastic (Ward's Natural Science Establishment Inc., Rochester, New York) for 24 hours, and then in polymerizing Bio-Plastic and cured at 60°C for 48 hours.

Histologic sections were cut at 200 to 300 microns on a high speed precision bone slicer and then stored in distilled water. The sections were thinned to 170-200 microns by hand using wet and dry abrasive paper (#240-A, 0, 2/0, 3/0 and 4/0, Bear Emery Polishing Paper, 7916, Norton Company, Troy, New York). The sections were then placed on a glass slide and secured with a coverslip using UVinert mountant (09505, Hopkins and Williams, Essex England).

RESULTS

Morbidity

Fourteen of the pups survived the initial experimental procedures of composite application and incisor grinding. Of the 6 that died, 5 suffered postoperative complications from the anesthetic and one hemorrhaged during the equilibration of the composite. The pups (6 control and 8 experimental) which survived the initial experimental procedure went on to survive the entire experimental period.

Weight Gain

The pups in both the experimental and control groups exhibited a wide variation in individual weight gain (Table 1), but the differences between the two groups was not statistically significant at the 0.05 level. The difference in weight gain between the two different age groups of pups, which were each housed in a separate cage, was statistically significant at the 0.05 level.

Morphometry of Bone

Values for each of the seven linear dimensions appear in Table 2. The test for operator error appears in Table 3 and suggests that adequate precision was attained by the operator in making his measurements. Some of the

TABLE 1

WEIGHT DATA: INITIAL WEIGHT, FINAL WEIGHT AND WEIGHT GAIN

Animal	Initial Weight (Grams)	Mean (Grams)	S.D. (Grams)	Final Weight (Grams)	Mean (Grams)	S.D. (Grams)	Weight Gain (Grams)	Mean (Grams)	S.D. (Grams)
Control Group									
13	53.6			243.9			190.3		
18	50.4			224.4			174.0		
23	47.5	46.85	4.467	210.0	217.1	16.15	162.5	170.2	12.39
25	42.8			198.6			155.8		
27	42.7			205.6			162.9		
29	44.1			219.8			175.7		
Experimental Group									
11	47.9			213.5			165.6		
15	45.8			232.3			186.5		
19	48.2			227.5			179.3		
22	46.5	44.09	3.308	201.9	197.3	25.49	155.4	153.2	22.68
24	40.9			184.7			143.8		
26	41.0			174.5			133.5		
28	41.1			181.2			140.1		
210	41.3			162.8			121.5		

TABLE 2

MORPHOMETRY OF BONE

Animal	PNS-Incisive Foramen (mm) L_1	PNS-1 (mm) L_2	Mandibular Length (mm) L_3	Mandibular Height (mm) L_4	Mandibular Width (mm) L_5	Maxillary Width (mm) L_6	Calvareal Length (mm) L_7
Control Group							
13	10.70	20.25	18.80	6.65	9.35	8.70	20.65
18	9.65*	20.35	18.52	6.62	9.30	8.55	21.35
23	9.85	20.25	18.60	6.62	9.60	8.25	20.75
25	9.45	19.40	17.90	6.32	9.40	8.60	19.80
27	9.70	19.30	18.52	6.35	9.25	8.35	20.50
29	9.80	19.90	18.70	6.40	9.65	8.00	21.00
Mean	9.90	19.91	18.51	6.49	9.42	8.41	20.68
S.D.	0.473	0.460	0.316	0.152	0.164	0.260	0.522
t_c Value	36	38	58	49	45	56	48
Experimental Group							
11	9.00	19.85	18.15	6.50	9.55	9.00	20.50
15	9.70	20.45	18.88	6.40	9.25	8.40	20.10
19	10.00	20.85	18.42	6.45	9.30	8.15	21.35
22	9.75	20.15	18.37	6,48	*	8.20	21.00
24	9.70	19.60	18.05	6.40	9.75	8.20	21.25
26	6.75*	16.75*	18.15	6.22	*	7.80	20.50
28	9.00	19.15	17.82	6.58	9.10	8.05	20.70
210	6.70*	16.35*	17.38	6.50	9.10	7.95	20.25
Mean	9.52	20.01	18.15	6.44	9.34	8.22	20.71
S.D.	0.422	0.609	0.442	0.107	0.260	0.363	0.456
t_e Value	30	40	47	56	33	49	57
(Range of 0.05 significance level: t_c greater than t_u or t_c less than t_l)							
t_l-t_u	18-42	26-52	29-61	29-61	26-52	29-61	29-61

TABLE 3

OPERATOR ERROR

Animal	PNS-Incisive Foramen (mm) L_1	PNS-1 (mm) L_2	Mandibular Length (mm) L_3	Mandibular Height (mm) L_4	Maxillary Width (mm) L_5	Maxillary Width (mm) L_6	Calvareal Length (mm) L_7
Initial Measurement							
11	9.00	19.85	18.15	6.50	9.55	9.00	20.50
15	9.70	20.45	18.88	6.40	9.25	8.40	20.10
19	10.00	20.85	18.42	6.45	9.30	8.15	21.35
28	9.00	19.15	17.82	6.58	9.10	8.05	20.70
29	9.80	19.90	18.70	6.40	9.65	8.00	21.00
Mean	9.50	20.04	18.39	6.47	9.37	8.32	20.73
S.D.	0.469	0.6465	0.4241	0.0760	0.225	0.410	0.4764
t_i Value	28	29.5	26	23	23.5	23.5	33
Second Measurement							
11	9.15	20.05	18.20	6.50	9.50	8.15	20.65
15	9.75	20.60	18.85	6.30	9.25	8.10	21.85
19	9.80	20.70	18.42	6.35	9.00	8.10	21.55
28	9.10	19.15	17.82	6.42	8.95	7.85	20.30
29	9.70	20.05	18.55	6.45	9.60	8.10	21.40
Mean	9.50	20.11	18.37	6.40	9.26	8.06	21.15
S.D.	0.345	0.6158	0.3862	0.0796	0.290	0.119	0.6490
t_s Value	27	25.5	29	32	31.5	31.5	22
Significant Range: t_i greater than t_u or t_i less than t_l							
t_l-t_u	17-38	17-38	17-38	17-38	17-38	17-38	17-38

specimens presented with skeletal landmarks which were damaged or destroyed during the debridement process. These measurements are marked with an asterisk in Table 2 and were not included in any subsequent calculations. Additionally, since relative growth between the upper and lower jaws was of interest, ratios of lower to upper jaw length, lower to upper jaw width and lower jaw to calvarial length were determined. Calculations concerning the upper jaw involved both the distance from the PNS to the incisive foramen as well as PNS to the interincisal alveolus.

Ratio and measurement values for each group were compared using the Wilcoxon Ranked Sum test at the 0.05 level of confidence and are compiled in Tables 2 and 4. The results show no significant difference between the experimental and control group in upper jaw length (L_1, L_2), mandibular length (L_3), mandibular height (L_4) mandibular width (L_5), maxillary width (L_6) or calvarial length (L_7), nor were there any significant differences in relative jaw size as revealed through comparison of ratios of lower and upper jaw length (L_3:L_1, L_3:L_2), jaw width (L_5:L_6) or calvarial length to lower jaw length (L_7:L_3).

TABLE 4

MORPHOMETRIC RATIOS

Animals	Mandibular Length / Maxillary Length ($L_3:L_1$)	Mandibular Length / Maxillary Length ($L_3:L_2$)	Mandibular Width / Maxillary Width ($L_5:L_6$)	Calvareal Length / Mandibular Length ($L_7:L_3$)
Control Group				
13	1.757	0.9284	1.075	1.098
18	*	0.9101	1.088	1.153
23	1.888	0.9185	1.164	1.116
25	1.894	0.9227	1.093	1.106
27	1.909	0.9596	1.108	1.107
29	1.908	0.9397	1.206	1.123
Mean	1.871	0.9298	1,122	1.117
S.D.	0.06447	0.01763	0.05142	0.01957
t_c Value	27	46	37	30
Experimental Group				
11	2.017	0.9144	1.061	1.129
15	1.946	0.9232	1.101	1.065
19	1.842	0.8835	1.141	1.159
22	1.884	0.9117	1.189	1.143
24	1.861	0.9209	1.130	1.177
26	*	*	*	1.129
28	1.980	0.9305	1.130	1.162
210	*	*	1.145	1.165
Mean	1.922	0.9140	1.128	1.141
S.D.	0.07004	0.01647	0.03959	0.03526
t_e Value	39	32	41	75
(Range of 0.05 significance level: t_c greater than t_u or t_c less than t_l)				
t_l-t_u	18-42	26-52	26-52	29-61

Histology

Technical difficulties with the high speed precision bone slicer precluded obtaining histologic sections from all of the 14 specimens. However, sections were obtained from 2 experimental and 2 control animals. The sections were taken along the sagittal plane through the glenoid fossa and along a plane which passed through the mandibular condyle and incisor. Attention was directed toward attaining sections from similar areas of each bone which would facilitate a qualified comparison of staining patterns.

The sections obtained from the mandibles were similarly complete in their gross appearance, and are assumed to be from nearly the same areas of the mandible as the bone is quite thin and can provide only one such complete section from the entirety of the specimen. The vital dyes were apparent in all of the sections, with good linear staining of the cortical bone in the areas of the alveolus superior to the incisor and the cortex on the inferior border of the corpus.

The section illustrated in Figure 7 is from the incisor alveolus of the control rat. The very sharp lines of stain seen superior to the incisor suggest that bone was actively forming on this area throughout the experiment. The deepest of stain is the yellow color of

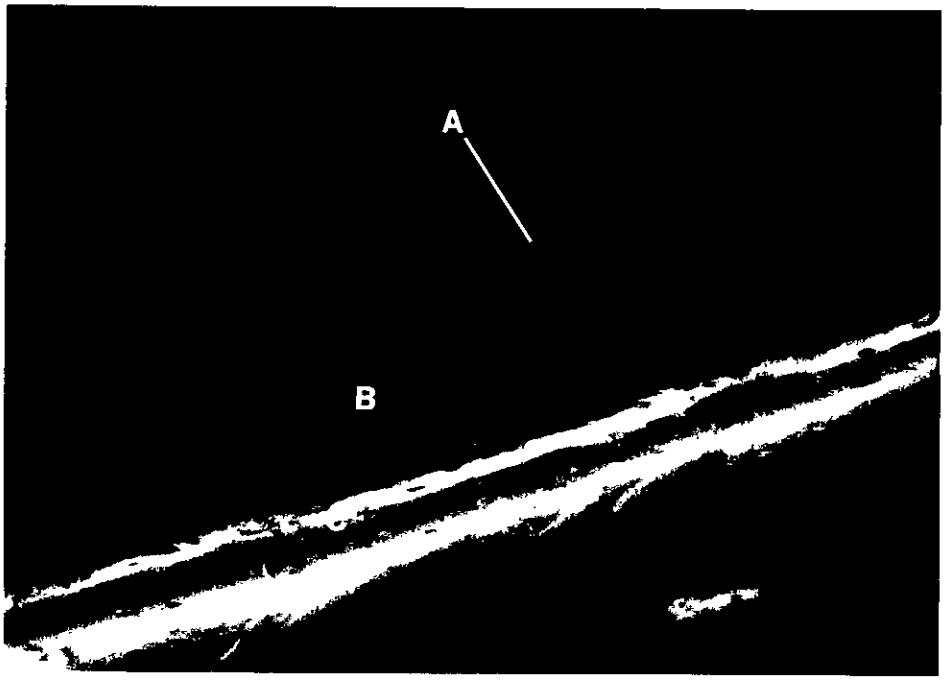


Figure 7. Incisor alveolus from control rat: A, Xylenol Orange. B, Alizarin Complexon. C, DCAF. D, Oxytetracycline.

oxytetracycline. Superficial to this is the green of DCAF, and then the red of Alizarin Complexon and finally the dark orange of Xylenol Orange. The inferior border of the corpus (Figure 8) exhibits a similar linear staining pattern, yet lacks any indication of oxytetracycline and presents DCAF only in the gonial area. The alveolar bone surrounding the posterior teeth contains traces of all stains, but without the continuous linear patterns observed elsewhere. The area of the condyle shows stain within the bone trabeculae, but contains no oxytetracycline stain. The trabecular stain is oriented posterosuperiorly and is comprised of a deep layer of DCAF, a middle layer of Alizarin Complexon and a superficial layer of Xylenol Orange.

The section illustrated in Figure 9 is from the incisor alveolus of an experimental rat. It presents the same linear deposition pattern as seen in the control rat. The inferior border of the corpus (Figure 10) does not contain an extended band of Xylenol Orange, with this particular stain limited to the base of the alveolus. The most remarkable difference between this section and that from the control animal is that the green DCAF stain in the region of the gonial angle presents a much wider band in a nearly triangular pattern. This presents a contrast to the smaller, thinner DCAF band present in the control

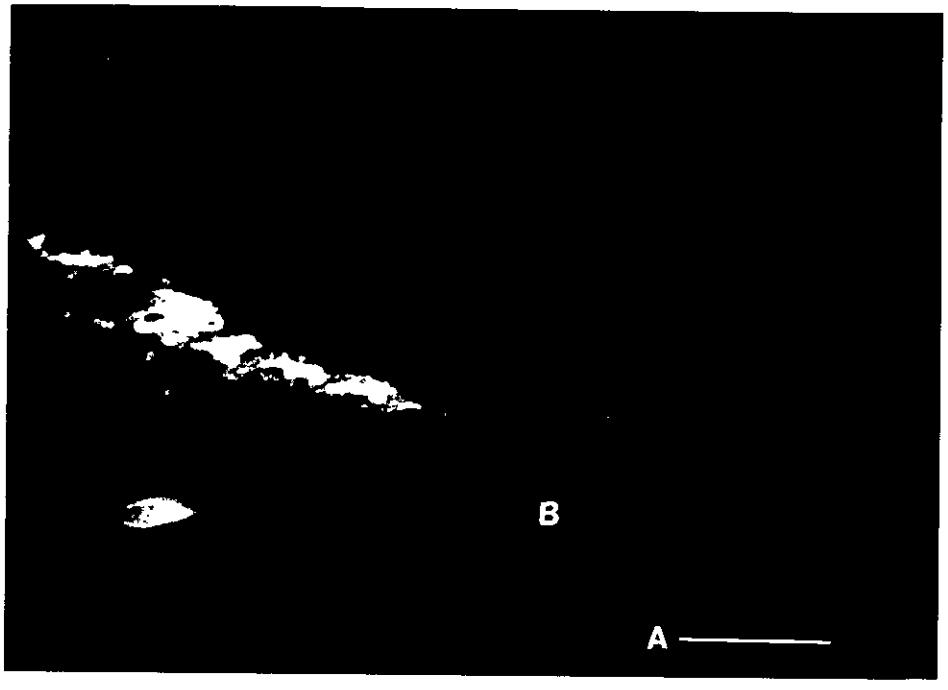


Figure 8. Inferior border of corpus from control rat: A, Xylenol Orange. B, Alizarin Complexon. C, DCAF.

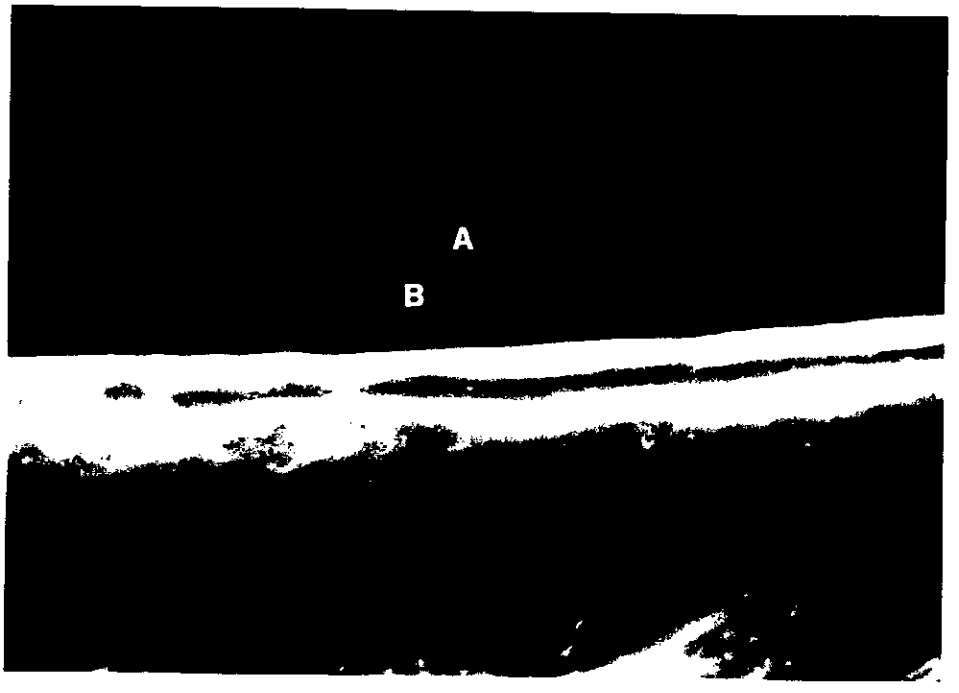


Figure 9. Incisor alveolus from experimental rat: A, Xylenol Orange. B, Alizarin Complexon. C, DCAF. D, Oxytetracycline.

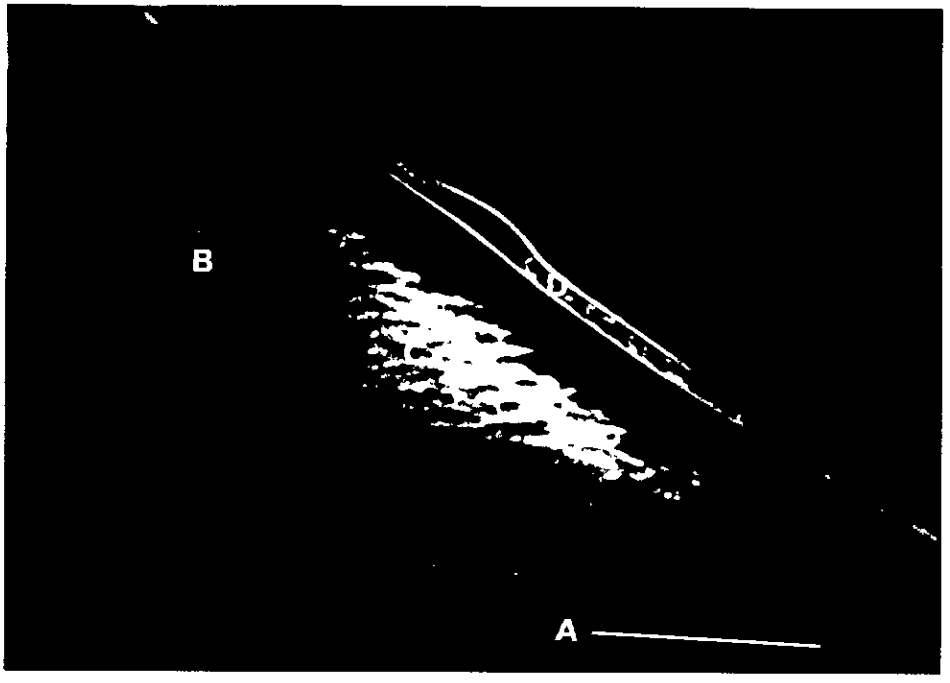


Figure 10. Inferior border of corpus from experimental rat: A, Xylenol Orange. B, Alizarin Complexon. C, DCAF. D, Oxytetracycline.

specimen (Figure 8). The band of Alizarin Complexon extends from the inferior portion of the corpus superiorly through the ramus in a manner which reflects the contour of the posterior border of the ramus. A similar band is absent from the control specimen.

The two sections from the glenoid fossae were remarkably dissimilar. The area to be cut was again very thin, so it is assumed that the two sections were nearly identical. Yet the morphology and staining patterns of the two sections are quite different. The section from the control rat is somewhat rectangular with green DCAF and Alizarin Complexon staining of the trabeculae. A long process extends anteroposterioly from the inferior border of the specimen. The section from the experimental rat is more round in shape and contains localized areas of stain from each of the four stains.

DISCUSSION

The Sprague-Dawley rat was chosen as a model for this study because the investigator desired to utilize the same model used by Petrovic and coworkers in the development of the cybernetic model of mandibular growth (Petrovic, 1974; Lavergne and Petrovic, 1983; Petrovic, 1984; Petrovic and Stutzmann, 1977; Petrovic, et al., 1975). The rat provides an inexpensive model which is easily maintained and matures rapidly. Since the focus of this study was on the growth of the mandible, it was important to select an animal, the mandible of which would grow in a manner similar to the mandible in humans. McDonald (1987) states that the growth and development of the tissues of the mandible in the rat and man proceed in a similar sequential manner.

The experimental period started as early as was possible in the rats' developmental period in that as soon as their posterior teeth had erupted to a level sufficient to provide operable surfaces, the composite was applied. This was done to effectively intervene in the growth process at a time before a pattern of growth was established. Other studies involving mandibular growth in the Sprague-Dawley rat utilized pups ranging in age from 20 days (Petrovic and Stutzmann, 1977) and 28 days (Petrovic et al. 1975) up to 42 days (Awn, et al., 1987)

at the beginning of their respective experimental periods. Since the possibility exists that a pattern of function (and its influence on the surrounding pattern of growth) is established at the onset of intercuspation of the posterior teeth, the timing of the initiation of the experimental period is critical if true internal validity is to be realized. In comparison to the other studies, the pups in this study were treated early enough in their developmental period to allow the desired alteration in their functional and growth patterns to occur.

The movement of the mandible during function is different in the rat from that in the human in that the mandible is protruded a significant distance during incision. Thus, there is a naturally occurring reposturing of the mandible during function, the magnitude of which is not mimicked in humans. Even though the attempt was made to lessen this functional mandibular propulsion by repeatedly sectioning the incisors, the anterior teeth in their entirety could not be completely removed from function because of limits imposed by the dental papilla and the fact that the teeth grew continuously. The sectioned incisors then provided an altered state of function rather than being absent from function. The rats were able to protrude but incised to a lesser degree than would have been possible in the presence of unsectioned incisors.

The observed mandibular growth of the experimental rats in comparison to the control rats does not support the hypothesis that mandibular growth would be augmented in the absence of an intercuspating occlusion. Analysis suggests that no significant absolute or relative differences are demonstrable in growth of the lower or upper jaw in the experimental rats as as compared to those in the control group.

This result calls into question Petrovic's cybernetic model which links maxillary and mandibular growth through confrontation at the occlusal table. Were this true, mandibular growth should have been reduced in comparison to maxillary growth, at least in the anteroposterior dimension. In the absence of an intercuspating occlusion, the cybernetic "messages" for maintaining a "steady-state" occlusion would also be absent, as would the impetus for mandibular reposturing and subsequent compensatory growth. But, congruent growth was seen between upper and lower jaws and confirmed with a comparison of length ratios of upper to lower jaw dimensions in both experimental and control animals. Congruent growth was also seen in the transverse dimension, where no significant differences were seen in comparisons of maxillary width, mandibular width or the ratio of maxillary to mandibular width. The comparison of each linear measurement and ratio indicates

that there were no essential differences in absolute or relative size of the bones in question.

Given the limited sample of histologic sections, the fact that they do not resemble each other and their staining patterns provide little basis for comparison, a comparison between sections from the control and experimental rats is inconclusive.

A synthesis of the results from the morphometric data leads then to the conclusion that few if any significant growth discrepancies exist between rats in the experimental and control groups, and that congruence of growth was exhibited in most if not all of the measured parameters. The results of this study do not support the theory that mandibular growth is regulated through a cybernetic model based on occlusion. The observed result of congruent bimaxillary growth in the absence of a cusped occlusion is contrary to that predicted by such a model. Further discussion of the applicability of hypotheses concerning the modulation of facial growth on a wider scale appears then to be warranted.

Kantomaa, in his studies on growth of the maxilla and mandible (Kantomaa, 1984: Kantomaa and Ronning, 1985) purported that it was not the teeth in occlusal function but rather the tissues surrounding the jaws which guided the growth pattern of the jaws. The 1985 study was

similar to the present study in that it involved measurement of facial growth in rats whose teeth had been ground flat and incisors sectioned. His results were similar to and conclusions concurrent with those of this study. These results also tend not to support the hypothesis of Bakker and Johnston (1985) which states that incisor occlusion may serve to coordinate maxillary and mandibular growth. While it was difficult to evaluate the functional value of the sectioned incisors in the present study, Kantomaa and Ronning (1985) confidently conclude that the cut incisors in the rats in their study effectively removed these teeth from intercuspation, and that the ground and cut teeth in these rats did not adversely affect the overall intermaxillary growth relationship. Such conclusions then imply that if a primary source of growth modulation exists, it is probably not the teeth acting through occlusal function and that a greater possibility exists that more than one source of growth modulation may be accountable for morphologic changes occurring in the mandible.

This concept of multiple sources of growth modulation is consistent with the theory of multiple assurance in which Latham and Scott (1970) stated "there is more than one process involved in growth mechanisms, so that if one does not operate there are other processes available" to

regulate growth. The cuspless occlusal configuration of the experimental rats in this study illustrates this concept in that the removal of the cusps from function did not have a deleterious effect on mandibular growth. It is apparent that there were other processes available which, in the absence of occlusal interdigitation served to modulate facial growth in a harmonious fashion. As stated by Enlow (1982) in regard to this theory,

> The processes and mechanisms that function to carry out growth are virtually always multifactorial. Should any one determinant of the growth process become inoperative (as by experimental deletion of an anatomic part), other morphologic components in some instances have the capacity to 'compensate'. That is, they can provide an alternative means to achieve more or less the same developmental and functional result, although perhaps with some degree of anatomic distortion.

This theory then implies that the facial growth patterns exhibited by the experimental rats were ones characterized by not only the absence of an intercuspating occlusion but also by other morphologic components which acted in an altered fashion to compensate for the cuspless occlusion. Analysis of the results of this study may not be conclusive as to the role of occlusion in facial growth but will imply that there are other components beyond the occlusion which play a role in the regulation of facial growth and which, in the altered state found in the experimental rats, had the capacity to adjust and

compensate for the lack of an intercuspating occlusion and guide the jaws through harmonic patterns of growth. However, such conclusions are acceptable because a similar altered state is present in patients undergoing certain forms of orthodontic therapy, and it is the description of this state that was the purpose of this study.

Research on such regulation from a wider scope of sources was published by Moss, most notably in his studies which include the concept of the capsular matrix. The basic postulates of the functional cranial analysis are (Moss and Salentijn, 1969):

1. Operationally, the head is a region within which certain functions occur.
2. Every function is completely carried out by a functional cranial component. Each such component, in turn, is composed of two parts:
   a. a functional matrix which actually carries out the function, and
   b. its skeletal unit whose biomechanical role it is to protect and/or support its specific functional matrix

A single bone may consist of a number of skeletal units which are then termed microskeletal units. The mandible is one such bone which is composed of many contiguous microskeletal units. The alveolar bone surrounding the teeth is a microskeletal unit of the mandible, and the teeth are its functional matrix. It is important to note that to a variable extent, contiguous microskeletal units are independent of each other. This

point is relevant to this study in that the teeth (a functional matrix) in their altered state of function may result only in an alteration of their own microskeletal unit (the alveolus) and lack a more global influence on the morphogenesis of the mandible as a whole.

Moss and Salentijn (1969) further describe two different types of functional matrices: a periosteal type best exemplified by the temporalis muscle acting on the coronoid process as its skeletal unit, and a capsular type, which in the case of the orofacial region is the oronasopharyngeal functioning spaces. The primary function of the orofacial capsular matrix is maintenance of a patent airway via a dynamic musculoskeletal postural balance which is termed the "airway-maintenance mechanism". They then go on to state:

> Mandibular growth (as well as neurocranial growth) is seen now to be a combination of the morphologic effects of both capsular and periosteal matrices. The capsular matrix growth causes an expansion of the capsule as a whole. The enclosed and embedded macroskeletal unit (the 'mandible as a whole'), accordingly, is passively and secondarily translated in space to successively new positions. In normal conditions the periosteal matrices related to the constituent mandibular microskeletal units also respond to this volumetric expansion. Such an alteration in their spatial position inevitably causes them to grow; that is, causes changes in their functional demands. These now call forth direct alterations in the size and shape of their microskeletal units. The sum of translation plus changes in form comprises the totality of mandibular growth.

Thus, it is the growth of the orofacial matrices that furnishes the primary morphogenic forces for facial skull growth (Moss and Rankow, 1968).

SUMMARY AND CONCLUSIONS

This study focused on growth of the rat mandible in the absence of an intercuspating occlusion. Fourteen male Sprague-Dawley rat pups (6 control and 8 experimental) were used to evaluate the differences in mandibular growth patterns between rats possessing an intercuspating occlusion and those having a flat plane occlusal scheme.

At twenty-two days of age, the maxillary posterior teeth of pups in the experimental group were covered with composite and then ground flat to provide a cuspless, flat plane occlusal scheme at the original vertical dimension of occlusion. The incisors of rats in both the experimental and control groups were sectioned to alter their functional state. The rats were sacrificed at forty-three days of age. Their skulls were debrided and morphometric measurements were taken from the upper and lower jaws.

A synthesis of the results from the morphometric data led to the conclusion that few if any significant growth discrepancies existed between rats in the experimental and control groups, and that congruence of growth was exhibited in most if not all of the measured parameters. The results of this study did not support the theory that mandibular growth is regulated through a cybernetic model

based on occlusion, and the observed patterns of growth were contrary to that predicted by such a model.

A final analysis, guided by hypotheses which purport regulation of facial growth on a wider scale, led to the conclusion that the role of occlusion in the modulation of mandibular growth is one of a component part in a larger whole a rather than a principle governing factor and that within the limits of this study, intercuspation per se does not appear to provide the primary guiding influence on mandibular growth.

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