1965

A Gross and Histologic Study of the Changes Occuring in Young Macaca Rhesus Monkeys as a Result of Intracapsular, Subcondylar Fracture of the Mandible

Stanley James Kaczala
Loyola University Chicago

A GROSS AND HISTOLOGIC STUDY OF THE CHANGES OCCURING IN YOUNG MACACA RHESUS MONKEYS AS A RESULT OF INTRACAPSULAR, SUBCONDYLAR FRACTURE OF THE MANDIBLE

by

STANLEY J. KACZALA

A Thesis Submitted to the Faculty of the Graduate School of Loyola University in Partial Fulfillment of the Requirements for the Degree of Master of Science

JUNE

1965

LIFE

Stanley James Kaczala was born in Chicago, Illinois, January 23, 1939.

From 1956 to 1959 he attended the Lake Shore Campus of Loyola University, Chicago, Illinois, in the pre-dental curriculum. In September of 1959 he began his dental education at Loyola University School of Dentistry and received the degree of Doctor of Dental Surgery in June of 1963. In September of the same year he began a two year graduate program at Loyola University leading to a Master of Science Degree in Oral Biology. In March of 1963 he received an appointment as a Resident in Oral Surgery at Cook County Hospital, Chicago, Illinois.

ACKNOWLEDGEMENTS

I am most grateful to Dr. Nicholas Choukas, Chairman of the Graduate Oral Surgery Department, whose interest and guidance has made the completion of this research possible.

To Dr. Harry Sicher, Professor Emeritus of Anatomy and Histology, whose teachings and writings have been a significant contribution to my education, and who has now so generously consented to be a member of my advisory board.

To Dr. John O'Malley, Chairman of the Histology Department, with whom I have spent much time in discussion of this research, and whose suggestions were most constructive.

To Mrs. Prapoulenas, Laboratory technician, for the preparation of the histologic material.

TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

The hyaline cartilage in the mandibular condyle has long been regarded as the most significant growth center of the mandible. This growth cartilage differs from that of the articular and epiphyseal plate cartilage of long bones in that it is covered by a thick layer of dense connective tissue. It is this layer of dense connective tissue which allows appositional growth of the mandibular cartilage whereas, in the articular and epiphyseal plate cartilage of long bones growth is accomplished in an interstitial manner.

The purpose of this thesis is to investigate the changes occuring in young Macaca rhesus monkeys as a result of intracapsular, subcondylar fracture of the mandible. The reactions of the hard and soft tissues of the temporomandibular joint were intensively studied microscopically, radiographically, and by gross dissection.

CHAPTER II

REVIEW OF THE LITERATURE

In 1952, Stuteville and Jarabak unilaterally resected the condyle in a monkey, without detaching the lateral pterygoid muscle, and immediately replaced it into its pre-surgical position by opening the capsule and reducing the fracture by means of a Vitallium plate and screws. At sacrifice, six months later, an osteologic examination revealed: a) healing at the site of fracture, b) partial covering of the Vitallium plate by an overgrowth of bone, c) growth in the head of the condyle, forcing the Vitallium plate downward onto the ramus, d) bone remodeling in both the condyle and neck, e) no evidence of ankylosis, f) no indication of gross bony changes in the articular fossa of the temporal bone, g) no open-bite or evidence of malocclusion.

In 1959, Hendrix, Sanders, and Green unilaterally fractured the condyles of two dogs. The condyle was completely removed from the capsule and a hole was drilled through the inferior portion of the head and the superior portion of the neck. The condyle was then replaced into its pre-surgical position and fixed by means of a trans-osseous stainless steel

wire which was placed first through the neck of the condyle, inferior to the fracture site, and then through the hole in the condyle superior to the fracture site. Elastic traction was then applied to intra-oral arch bars to maintain firm median occlusal position.

The animals were sacrificed three months later and a dissection of both right and left temporomandibular joints revealed a relatively normal range of motion, and a viable condyle above the healed fracture site with a smooth, glistening, articular surface. A microscopic study of only the articular surfaces showed the articular surface of the unoperated side to be composed of typical fibrocartilage, with a matrix of homogenous laminated intercellular material having irregular nuclei interspersed in a linear or tandem fashion. Occasional zones showed increased cellularity with an aura of hyaline cartilage. The articular surface of the operated side demonstrated fibrocartilage, with some zones of dense collagenous tissue, scattered with fibroblasts, which was suggestive of scarring. Cartilage similar to that of hyaline was found adjacent to the bone.

Walker, in 1960, reported on a study of mandibular condylar fracture dislocations in nine young Macaca **rhesus**

monkeys. By means of a submandibular (Risdon) approach he proceeded, with a number 700 dental bur, to surgically fracture, unilaterally and bilaterally, the neck of the condyles and then displaced the condyles in a medial and anterior direction. Three of the unilateral fractures were reduced by means of trans-osseous fixation; in the others no form of treatment was instituted. In one of the animals the condyle was completely excised from all viable attachments, removed, then repositioned and reduced by trans-osseous wiring. In all animals the masseter muscle was secured in its normal position by suturing its covering fascia to the periosteum of the angle and inferior border of the mandible. Except in one animal, no intermaxillary fixation was applied. Modified antero-posterior radiographs of the temporomandibular joints were taken preoperatively, immediately postoperatively, and at sacrifice. At sacrifice, sixteen and one half to twenty months later, the soft tissue was removed from the skulls and they were prepared for osteologic study.

He found: a) that each operated side demonstrated a relatively normal, functional, growing condyle, b) the dental occlusion remained unchanged with no mandibular deviation or open-bite, c) no loss of vertical height of the mandible,

measuring from the highest tip of the condyle to the horizontal plane of the inferior border, on the operated side as compared with the unoperated side or control animals, d) higher reattachment of the masseter muscle, except in the immobilized animal, with a lipping medially and inward of the inferior portion and angle of the mandible, due to the unopposed action of the medial pterygoid muscle, e) what were evaluated as somewhat insignificant growth changes, the most noteworthy of which was a decrease in the antero-posterior width of the ramus on the operated side.

In a succeeding study, using four young Macaca rhesus monkeys, Walker unilaterally fractured, by means of a pre-auricular approach, the condyles and again displaced them in a medial and anterior direction. All the animals jaws were immobilized by intermaxillary fixation for two weeks. Histologic specimens of the condyles of animals which were sacrificed at one, two and three months following surgery showed: a) active bone resorption of the displaced condyles coincidental with b) profuse metaplastic cartilage acting as the primary cellular repair tissue of the callus, in the early stages, and c) increased bone repair activity. As the length of time increased following surgery, excessive bone production

occured on the medial surface of the ramus "serving as a scaffold in the reformation of the new condyle."[1] This "scaffolding" is later resorbed once the condyle is reformed. In one animal sacrificed a year after surgery there was found a relatively normal, functional, condyle in an upright position within the glenoid fossa. Histologic sections of the condyle demonstrated cartilagenous growth similar to that found in any normal condyle. "The cartilage was apparently active in pursuing its inherent proclivity of endochondral ossification."[2] He concluded "the condylar area possesses a noteworthy propensity to reconstitute its epiphyseal cartilage and be about its normal activities following fracture dislocation."[3]

In 1961, Heurlin[7] studied the skeletal changes following fracture dislocation of the mandibular condyle in four adult Macaca rhesus monkeys. Two of the monkeys were subjected to experimental unilateral fractures while the remaining two were subjected to bilateral fractures. Through a pre-auricular approach the condyle was visualized and fractured by means of a bi-bevel bone bur. The condyle was then dislocated out of the glenoid fossa and wired to the medial surface of the ramus. No intra-oral fixation was applied. Antero-posterior and right and left cephalometric radiographs were taken

preoperatively, postoperatively, six months following surgery, and at sacrifice eleven to twelve months later. All the soft tissues were removed from the skulls except those of the temporomandibular joint and lateral pterygoid muscle. Osteometric findings were recorded, followed by hemisection of the skulls and lateral head radiographs of each half. He found on the operated sides: a) no apparent facial nerve damage, b) decrease in facial height, c) shift of basal bone towards the affected side, d) an unchanged occlusion in the unilateral animals, e) open-bite in the bilateral animals, the severity of which decreased with time, f) reduction in the height of the ramus, g) an elevated coronoid process, h) a disruption in the trabecular pattern, i) an increase in the antegonial notch.

In examining the temporomandibular joint of the operated sides he found no evidence of ankylosis. The condylar fragments had fused to the ramus in all animals except one in which it fused to the lateral pterygoid plate. In addition, there was a flattening of the articular eminence and a more shallow glenoid fossa. Heurlin concluded, "although mandibular growth does not cease entirely, the pattern of growth is changed so that development takes place by apposition and

resorption under the influence of functional stress."[4]

CHAPTER III

MATERIALS AND METHODS

Eight, young, Macaca rhesus monkeys, seven males and one female, were obtained from the Shamrock Animal Farm in New York state. Their estimated age, based upon weight, hand length, crown-rump length, and dentition ranged from eight to fourteen months. The average weight of the animals was 2.16 kilograms. Their diet consisted of various fresh fruits and vegetables, fortified with vitamins, and dry monkey biscuits. The animals were divided into four groups of two, three pairs of which were subjected to surgical fractures while the fourth pair was used for control. One animal in each group, discounting the two control animals, was subjected to unilateral, intracapsular, subcondylar fracture of the mandible while to other was subjected to the same type of fracture bilaterally. No attempt at reduction or fixation of these was made. The experimental period, following surgical fracture, varied for each pair, being sixty, one hundred and twenty, and one hundred and eighty days. The control monkeys were sacrificed at one hundred and twenty, and one hundred and eighty days.

The animals were removed from their regular cages by means

of a squeeze cage. While still in the squeeze cage they were weighed, and the dosage of anesthetic agent to be employed was calculated. Using a 25 gauge needle, Pentobarbital Sodium U.S.P. (Nembutal-Abbot) was administered via an intravenous route (saphenous vein) in a dosage of 64 mgm./2.27 Kg. (1 gr./ 5 lbs.) of body weight. Antero-posterior and right and left cephalometric radiographs were then taken using a cephalometric head holder, with Kodak (Rochester, N.Y.) Medical X-Ray film in a Kodak 8x10 cassette with a double intensifying screen. The target-film distance was 39 inches with an exposure time of 0.75 seconds at 115 kilovolt-peak and 15 milliamperes. Weight, sex, crown-rump length (highest convexity of the skull to the base of the tail), and hand length (distal of the third finger to the proximal of the hypothenar eminence), were recorded along with a description of the dentition, facial symmetry, and median occlusal position. Using a metric caliper intra-oral measurements of the maxillary and mandibular inter-canine distances were also recorded.

Opthalmic Butyn Sulfate 2% and Metaphen 1:3000 (Abbot) was induced into the eyes of the animal to prevent dessication. With a 25 gauge needle an intravenous infusion of 5% dextrose/ water was established (saphenous vein) to replace lost fluids

and to provide a convenient route for the administration of more anesthetic or other drugs should conditions warrant. The animal was then shaved, scrubbed, and draped. Under strict aseptic technique a pre-auricular approach was employed to gain exposure of the condylar area. With a number 15 Bard-Parker blade a vertical skin incision over the head of the condyle was made. By means of blunt dissection the capsule of the joint was exposed. A longitudinal incision, parallel to the fibers, was then made through the lateral aspect of the capsule and the capsule was reflected. Using a number 700 tapered fissure bur in a dental handpiece, with warmed normal saline running, the surgical fracture was produced just above the inferior portion of the capsule. The fractured condyle, with the lateral pterygoid muscle still attached, was then medially rotated so as to assume a position approximately sixty degrees on the vertical plane and to position the articular surface of the condyle to face somewhat laterally. The masseter muscle and the subcutaneous tissues were closed with 000 plain gut suture, while the skin was closed with 000 black silk suture followed by several applications of plastic spray bandage (Rezifilm-Squibb). To minimize the possibility of postoperative infection 600,000 units of Benzathine

Penicillin G (Bicillin L-A —Wyeth) and 400,000 units of Procaine Penicillin G with 0.5 Gm. of Streptomycin Sulfate (Wycillin S-M —Wyeth) were administered intramuscularly (gluteal muscle).

Antero-posterior and right and left cephalometric radiographs were taken immediately postoperatively. The animal was then returned to the regular housing cage and for ten days postoperatively was kept on a soft diet consisting of various fresh fruits and vegetables, fortified with vitamins, and monkey biscuits soaked in water. Daily examination of all animals was made and notes of significant findings were recorded.

At sixty day intervals, antero-posterior and right and left cephalometric radiographs were taken. In addition, the weight, crown-rump length, hand length, and intra-oral measurements were again recorded as was a description of the dentition, facial symmetry, and median occlusal position.

At sacrifice the animals were intravenously administered a lethal dose of Nembutal, and then were perfused with a solution of 10% buffered formalin via the right and left common carotid arteries to obtain immediate fixation of the entire head. In addition to the reapplication of the afore mentioned

methods of study, a dissection and description, along with a photographic record of findings, of the temporomandibular joints and surrounding structures was made.

Both right and left condyles were removed for histologic study from the following animals: six month unilateral right (6UR), four month unilateral right (4UR), four month bilateral (4B), and two month unilateral left (2UL). The two month bilateral (2B) animal had both right and left condyles removed with the articular disc attached. Block sections of both right and left temporomandibular joints were removed from the six month bilateral (6B) animal and from the four month control (4C) and six month control (6C) animals. These tissue specimens were kept in 10% buffered formalin for 48-72 hours to insure fixation. The specimens were then removed and washed in running water for three to four hours before being placed in decalcifying solution composed of sodium citrate (25%) and formic acid (75%). The specimens were washed again in running water for eight hours and then dehydrated by placing them in three successive baths of seventy-five percent alcohol for thirty minutes each, followed by three baths in ninety-five percent alcohol for thirty minutes each, and a thirty minute bath in absolute alcohol (100%). Following this the specimens

were placed in three xylene baths for ten minutes each. They were then removed and introduced into liquid paraffin (55°C) in a vacuum oven for one and one-half hours, and then imbedded in a paraffin block (60°C-tissue mat-Fischer Co.).

Central, para-central and peripheral sections of each specimen, measuring eight to ten microns, were cut along the frontal plane and placed on slides for staining. The sections were deparaffinized in xylene, washed in one hundred percent, ninety-five percent, and seventy-five percent alcohol and then placed in distilled water for fifteen minutes. After staining with hemotoxylin they were washed in distilled water, followed by a fifteen minute wash in tap water. Next the sections were placed in acid alcohol, followed by a wash in distilled water and then tap water. They were then placed in seventy-five percent alcohol, followed by ninety-five percent alcohol, and stained with eosin. After three baths in ninety-five percent alcohol, one in one hundred percent alcohol and two in xylene, cover slips were applied with Permount (Fischer Co.).

CHAPTER IV

FINDINGS

All of the animals survived the experimental surgery and their recovery was uneventful. Upon periodic visual examination none of the animals showed evidence of facial nerve damage or postoperative infection. Throughout the experimental period their masticatory function and range of mandibular movement remained essentially normal, except during the immediate postoperative period, of four to five days, when swelling attendant to surgical fracture was present. No gross discrepancies of facial growth or symmetry were discernible. Somatic growth proceeded in a normal fashion with all animals showing a continual increase in crown-rump and hand length. Every animal showed a progressive increase in the inter-canine distance of both the maxillary and mandibular dental arches (Figure 1). A loss of incisal relation occured in two animals. Animal 2B demonstrated an anterior open-bite measuring 1 mm. at sacrifice (60 days) while animal 6B developed an anterior open-bite measuring 1 mm. at sixty days, 1.3 mm. at one hundred and twenty days, and increasing to 1.8 mm. at sacrifice (180 days). The median occlusal position of the remaining animals was unchanged.

Dissection of the temporomandibular joint at sacrifice revealed the joint capsules of all operated sides to be thicker and more extensive in size than the capsules of the unoperated sides or of the control animals (Figures 3,4). No evidence of ankylosis of the condyle or gross changes in the articular fossa or eminence were observed. The superior and inferior compartments of the joint were easily exposed and examined and the articular disc appeared normal in position and morphology. In all operated animals the mandible in the area of fracture was approximately two to three times as thick medio-laterally as that of the unoperated sides or of the control animals (Figure 5). On all operated sides there was continuity of bone at the site of fracture except in animal 2B. Animal 2UL presented an enlarged condyle on the operated side with an antero-posterior width of 7.9 mm. as compared to 4.5 mm. on the unoperated side. It measured 9.5 mm. medio-laterally as opposed to a medio-lateral width of 9.9 mm. on the unoperated side (Figures 2,6,7,8,9,10). In animal 2B both the right and left condyles were also enlarged.

On the left side of animal 2B the condyle was medially rotated approximately thirty-five degrees. Soft tissue was present in the fracture site and the condyle was slightly mobile

(Figure 11). In addition, a depression in the center of the articular surface of the condyle was evident. The antero-posterior width of the condyle was 9.9 mm. with a medio-lateral width of 9 mm.. The right condyle (Figures 12,13) was found to be located in a medially tilted position (approximately 55°). Its capsule was more extensive in size than that of the left side and the neck of the condyle at the fracture site was much thicker medio-laterally than that of the contralateral condyle. The antero-posterior width of the condyle was 6.2 mm. and its medio-lateral width was 10 mm.. Above the fracture site, in which soft tissue was present, the condyle was extremely mobile (Figure 14).

Radiographically there was a medio-lateral widening of the mandible at all sites of experimental fracture which persisted up to the time of sacrifice. The condyles of all operated sides except the right side of animal 2B, which was tilted medially, assumed a vertical position in the temporomandibular joint by sixty days (Figure 15).

In the operated animals special care was employed in the removal of specimens for histologic study to insure inclusion of the fracture site. By means of vertical measurements it was ascertained that these specimens, when mounted on slides

for histologic study, contained the site of fracture. Histologic study of the unoperated sides and control animals revealed a layer of dense, fibrous, connective tissue covering the condyle, evenly spaced with fusiform fibroblasts, some of which almost, but not quite, reach the free surface. The cells ranged in shape from bluntly stellate to thin fusiform. The cytoplasm could not be seen and the nucleoli were not visible due to the dark staining of the nuclei. All of the collagenous fibers on the free surface were directed antero-posteriorly, whereas the deeper fibers formed a basket weave pattern parallel to the free surface. At the junction of the dense, fibrous, connective tissue and the hyaline cartilage the two tissues blend together with no definite demarcation. This junction was occupied by a cell rich layer of rounded and fusiform mononuclear cells and a pale staining ground substance with thin collagenous fibers. The cytoplasm of these cells is scanty and the nucleus is coarsely granular with a small distinct nucleoli. The nucleus is twice the size of the nucleus of the cells in the dense, fibrous, connective tissue layer. This intermediate layer is one-half to two-thirds as thick as the dense, fibrous, connective tissue covering the condyle. Beneath this is the cartilagenous layer which is about twice

as thick as the dense, fibrous, connective tissue layer. The hyaline cartilage is eosinophilic where it blends with the cell rich intermediate or transitional layer. It becomes basophilic as the hyaline ground becomes abundant. Not including the transitional zone, the average number of cells in this area, which is analogous to a teritory of cells in an epiphysis, is five. Moving away from the transitional zone the nucleus of the cartilage cells becomes hydropic and more eosinophilic. The cytoplasm increases and takes on a vesiculated appearance, with the cytoplasm between the vesicles appearing basophilic. Farther down, the cytoplasm of the cartilage cells is filled with larger vesicles and the nuclei are undergoing karryorhexis or karryolysis. The total size of the cell increases due to an accumulation of fluid which in turn results in a thinning of the ground substance. Chondroclasts and mononuclear phagocytes can be found entering the calcified cartilage were it borders upon the metaphysis.

The metaphysis is represented by a zone of variable thickness which was about twenty to twenty-five times as thick as the hyaline cartilage. It is characterized by coarse, fibrillar, immature bone which was often laid down around irregular spicules of calcified cartilage. Islands of calcified

cartilage demonstrated thick seams of osteoid tissue covered by a layer of osteoblasts. Osteoclastic activity was also present. The marrow contained delicate, loose, connective tissue with evidence of hemopoetic cells, but in some animals it was not typically stuffed with cells of the granulocytic series. (Figure 16)

The fracture sites of all animals were healed except in animal 2B. In this animal a bilateral pseudoarthrosis developed. On the medial surface of the left side in animal 2B, the cells of the transitional zone lipped over the thin edge of hyaline cartilage, entered the periosteum, and continued downward to a point where fibrous proliferation of the cells of the capsule occured. These cells give rise to fibrocartilage at the site of beginning impingement, on the medial surface, of the proximal (condylar) and distal (mandibular) fracture segments. Moving centrally, the fractured surface of the proximal segment is covered with almost typical hyaline cartilage, as is the distal segment in most areas. Beneath the cartilage of the distal segment there is metaphysis formation with growth taking place. Interposed between these cartilagenous areas covering the fractured surfaces of each segment was a layer of moderately vascular, dense, fibrous, connective tissue. The loose

connective tissue surrounding the mature capillaries were cell rich and contained large basophilic mononuclear cells and ~~polymorphe~~multinucleated giant cells. In areas where the fracture segments are in close proximity they are separated only by a large island of hyaline cartilage, with no evidence of intervening dense, fibrous, connective tissue. Extending into this island of cartilage was a developing joint cavity lined with fibrocartilage. Some of the hyaline cartilage cells showed irregular territory formation and degenerative changes directed towards the bone thus establishing a new proliferative zone on the proximal (condylar) fracture segment. The bearing surface across the defect was not uniform. The main bearing point appeared to be an abutment of non-vital bone on the surface of the distal (mandibular) fragment and the cartilagenous surface of the proximal (condylar) segment. Osteoclastic activity was evident in the marrow spaces of both segments. (Figure 17).

On the medial surface of the right side the proximal (condylar) and distal (mandibular) fracture surfaces are covered with almost typical hyaline cartilage, and are separated by dense, fibrous, connective tissue which is filled with blood vessels and capillaries. Beneath the cartilage of the

distal (mandibular) segment there is metaphysis formation with growth taking place. Moving laterally, necrotic bone, which is covered with fibrocartilage, is found on the distal (mandibular) segment. In the marrow spaces of both segments evidence of osteoclastic activity and undermining resorption was present (Figure 18).

On the operated side of the two month unilateral specimen a portion of the hyaline cartilage of the condyle was inadvertently displaced into the area of metaphysis (Figures 19, 20).

In examining the specimens removed from the other experimentally operated animals no dissimilarities were found when compared with the unoperated sides or control animals. All condyles showed active endochondral bone formation.

CHAPTER V

DISCUSSION

In this investigation, the gross and histologic changes occuring as a result of intracapsular, subcondylar fracture of the mandible were studied. The temporomandibular area of the Macaca rhesus monkey differs from that of humans in that this animal has a shorter condylar neck, a shallower glenoid fossa, a less prominent eminence, and a larger postglenoid process.

After surgical fracture the animals were returned to their regular cages. They were kept on a soft diet for ten days and were examined several times daily for two weeks. Upon reduction of the postoperative swelling their masticatory function and range of mandibular movement seemed essentially normal. At no time was there evidence of facial nerve damage or postoperative infection.

At two months following surgery the antero-posterior radiographs showed a medio-lateral widening of the condylar neck at all sites of fracture. This medio-lateral widening was still visible at sacrifice, and was in actuality a bony callus. With time this widening would have diminished as a

result of continual bone remodeling resorption. The antero-posterior and right and left cephalometric radiographs taken at sixty days showed all fractured condyles to be in their pre-surgical position with the exception of the right side of animal 2B (two month bilateral fracture). This condyle was tilted medially approximately fifty-five degrees.

A change in incisal relation occured in animals 2B (two month bilateral fracture) and 6B (six month bilateral fracture). At sixty days both animals demonstrated an anterior open-bite of 1 mm.. In animal 6B the open-bite increased to 1.3 mm. at one hundred and twenty days and 1.8 mm. at one hundred and eighty days. This progressive increase in the anterior open-bite occurs only in the early stages following such injury, for Heurlin showed, in his one year study, that the severity of open-bite decreases with time. This changing of incisal relation is postulated as being due to several interrelated factors. Due to discontinuity of the mandible following fracture, the elevator muscles rotate the mandible on the distal molars. This results in an open-bite which increases in magnitude from the posterior teeth to the anterior teeth. The teeth that are out of occlusion eventually super-erupt, thereby decreasing the severity of the open-bite.

Dissection of the temporomandibular joint at sacrifice revealed the joint capsules of all operated sides to be fibrotic and more extensive in size than the capsules of the unoperated sides or control animals. This was probably due to the trauma associated with surgical fracture. In this type of fracture the capsule plays an important role in the healing of the fractured condyle, in that it tends to maintain the condyle in its pre-surgical position.

The right and left condyles of animal 2B (two month bilateral fracture) and the left condyle of animal 2 UL (two month left unilateral fracture) were enlarged as compared to those of the unoperated sides or control animals. This occured as a response to displacement of the condyle within the temporomandibular joint after union of the fractured segments had occured. This union may be bony as in animal 2UL (two month left unilateral fracture) or of a pseudoarthrotic type as in animal 2B (two month bilateral fracture). Reconstruction of the condyle occurs in an attempt to maintain the condyle in its proper position in the glenoid fossa. In the four and six month specimens the condyles were of normal, almost identical, size and morphology, indicating that remodeling of the condyle will occur until it has assumed a normal

position in the glenoid fossa.

In animal 2B (two month bilateral fracture) the left condyle was medially rotated approximately thirty-five degrees and the right condyle was tilted medially approximately fifty-five degrees. Soft tissue was visually evident in both fracture sites and both condyles were mobile above the fracture sites. Histologic study revealed the formation of a bilateral pseudoarthrosis. The proximal and distal fracture surfaces of both right and left sides were covered in part with hyaline cartilage. Interposed, in most areas, was a layer of dense, irregular, connective tissue. This pseudoarthrosis was thought to be due to failure of the condyles to become properly repositioned because of interposing soft tissue between the fracture surfaces. In histologic examination of the remaining specimens no dissimilarities were found between the operated sides, unoperated sides, or control animals. All condyles showed active endochondral bone formation.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary:

Three pairs of young Macaca rhesus monkeys were subjected to surgical, intracapsular, subcondylar fracture of the mandible. No attempt at reduction or fixation of any of these fractures was made. One animal in each pair was subjected to a unilateral fracture while the other was subjected to a bilateral fracture. One pair of animals was sacrificed at two months, another pair at four months, and the third pair at six months. In addition, two animals used for control were sacrificed at four and six months. Antero-posterior and right and left cephalometric radiographs were taken preoperatively, immediately postoperatively, at two month intervals, and at sacrifice. A dissection of both right and left temporomandibular joints was made at sacrifice and specimens were removed for histologic study.

After the postoperative swelling had subsided, the masticatory function and range of mandibular movement of all animals seemed essentially normal. The two and six month bilateral fracture animals showed a loss of incisal relation

which progressively increased in the six month specimen. The occlusion of the remaining animals was unchanged.

The capsules of all operated sides were fibrotic and more extensive in size than were the capsules of the unoperated sides or control animals. At two months, enlarged condyles were found on the left side of an animal sustaining left subcondylar fracture and on both sides of an animal sustaining bilateral subcondylar fracture.

All animals showed a persistent medio-lateral widening of the mandible at all sites of fracture. All fractures healed with the exception of the right and left sides of the two month bilateral fracture animal. This animal developed a bilateral pseudoarthrosis.

All condyles were active in endochondral bone formation.

Conclusions:

From this investigation it was found that:

All intracapsular, subcondylar fractures of the mandible in the Macaca rhesus monkey heal without fixation or reduction when the fractured segments are relatively well aligned.

A medio-lateral widening occurs at all healing sites of intracapsular, subcondylar fracture of the mandible.

Endochondral bone formation persists in all condyles involved in intracapsular, subcondylar fracture of the mandible.

BIBLIOGRAPHY

Baume, L.J.: Postnatal Growth of the Mandible in Macaca mulatta, Journal of Dental Research, 30:502, August, 1951.

Baume, L.J. and Derichsweiler, H.: Is the Condylar Growth Center Responsive to Orthodontic Therapy? Oral Surgery, Oral Medicine, and Oral Pathology, 14:347, March, 1961.

Choukas, N.C. and Sicher, H.: Structure of the Temporomandibular Joint, Oral Surgery, Oral Medicine, and Oral Pathology, 13:1203, October, 1960.

Gisley, D.B. and Wilson, S.G.: Correlation of Skeletal Growth and Epiphyseal Ossification with Age of Monkeys, Annals of New York Academy of Science, 85:800-802, May, 1960.

Hartman, C.G.: The Anatomy of the Rhesus Monkey, Baltimore, Williams and Wilkins Co., 1933.

Hendrix, J.H., Sanders, S.G. and Green, B.: Open Reduction of the Mandibular Condyle, Plastic and Reconstructive Surgery, 23:283-287, March, 1959.

Herzberg, F. and Sarnat, B.G.: Radiographic Changes in the Bony Trabecular Pattern in the Mandible of Growing Macaca Rhesus Monkeys Following Condylar Resection, Anatomical Record, 144:129-34, October, 1962.

Heurlin, R.J.: Skeletal Changes Following Fracture Dislocation of the Mandibular Condyle in the Adult Rhesus Monkey, Master's Thesis, Northwestern University, 1961.

Jarabak, J.R.: Subcondylar Fracture of the Mandible: Research and Treatment, American Journal of Orthodontics, 40:729-55, 1954.

Jarabak, J.R. and Stuteville, O.H.: Bilateral Mandibular Condylar Resection, Journal of Dental Research, 31:509-10, 1952.

Kendrick, G.S. and Cameron, J.A.: Observation on the Growth of the Macaca Rhesus Monkey Skull, Journal of Dental Research, 38:741, 1959.

Laesson L.E.: Mandibular Positioning. The Effect of Pressure on the Joint Capsule, Acta Neurologica Scandinavica, 40:131-43, 1964.

Lanfranchi, R.P.: Surgical Reconstruction of the Mandible Following Condylectomy in the Rhesus Monkey, M.S.D. Thesis, Northwestern University, 1955.

Robinson, E.R., Stuteville, O.H. and Gans, B.J.: The Gross Anatomy of the Temporomandibular Joint of Young Macaca Rhesus Monkeys Following Unilateral Replacement of the Mandibular Condyle with Autogenous Third Metatarsal Bones, Oral Surgery, Oral Medicine, and Oral Pathology, 16:1120, September, 1963.

Sarnat, B.G.: Facial and Neurocranial Growth after Removal of the Mandibular Condyle in the Macaca Rhesus Monkey, American Journal of Surgery, 94:19, 1957.

Sarnat, B.G. and Engel, M.B.: A Serial Study of Mandibular Growth after Removal ofthe Condyle in the Macaca Rhesus Monkey, Plastic and Reconstructive Surgery, 7:364-380, 1951.

Schwartz, D.J.: Morphology of the Head and Neck of the Macaque Monkey: The Muscles of Mastication and the Mandibular Division of the Trigeminal Nerve, Journal of Dental Research, 42:1222-33, September-October, 1963.

Shore, N.A.: The Interpretation of Temporomandibular Roentgenograms, Oral Surgery, 13:341-50, March, 1960.

Sicher, H.: Oral Anatomy, St. Louis, C.V. Mosby Co., 1952.

Stuteville, O.H. and Jarabak, J.R.: Condylar Plating for the Reduction of Condylar Fracture, Journal of Dental Research, 31:515, August, 1952.

Tinoco, A.A.: Study of the Effects Produced on Facial Growth by the Removal of the Condylar Growth Center in Rhesus Monkeys, Master's Thesis, Northwestern University, 1962.

Tomek, S.: Postoperative Growth of the Lower Jaw after Removal of the Condyles in Macaca Rhesus Monkeys, Dental Abstract, 4:32, 1959.

Walker, R.V.: Traumatic Mandibular Condylar Fracture Dislocations, American Journal of Surgery, 100:850-63, December, 1961.

Weinmann, J.P. and Sicher, H.: Bone and Bones, St. Louis, C.V. Mosby Co., 1955.

FOOTNOTES

[1] R.V. Walker: Traumatic Mandibular Condylar Fracture Dislocations, American Journal of Surgery, 100:850-63, p. 861, December, 1961.

[2] Ibid., p. 860.

[3] Ibid., p. 860.

[4] R. J. Heurlin: Skeletal Changes Following Fracture Dislocation of the Mandibular Condyle in the Adult Rhesus Monkey, Master's Thesis, Northwestern University, p. 52, 1961.

APPENDIX

A. CHARTS

		0 Day	60 Days	120 Days	180 Days
Crown-rump length in cm.	6UR	32.0	33.4	35.2	36.8
	6B	30.7	31.3	32.6	33.2
	4B	32.0	33.2	35.7	
	4UR	31.3	33.8	34.5	
	2B	30.5	31.7		
	2UL	30.0	30.9		
	C6	30.5	30.9	31.4	31.7
	C4	31.2	31.7	32.1	
Hand Length in cm.	6UR	7.45	8.20	9.50	9.90
	6B	8.20	8.40	8.80	9.60
	4B	7.80	8.90	9.90	
	4UR	8.10	8.30	8.90	
	2B	7.40	7.70		
	2UL	7.90	8.10		
	C6	7.30	7.80	8.30	8.90
	C4	7.60	8.10	8.70	
Maxillary Inter-Canine Distance in cm.	6UR	2.30	2.40	2.45	2.53
	6B	1.76	2.30	2.35	2.38
	4B	2.30	2.40	2.43	
	4UR	2.30	2.35	2.39	
	2B	2.13	2.16		
	2UL	2.20	2.40		
	C6	2.40	2.50	2.54	2.59
	C4	2.35	2.39	2.42	
Mandibular Inter-Canine Distance in cm.	6UR	1.55	1.70	1.78	1.81
	6B	1.65	1.68	1.72	1.75
	4B	1.79	1.82	1.86	
	4UR	1.65	1.70	1.74	
	2B	1.50	1.70		
	2UL	1.60	1.73		
	C6	1.58	1.70	1.73	1.79
	C4	1.64	1.70	1.72	

FIGURE 1

Antero-Posterior width of the condyle in cm.; at sacrifice

6UR	R	11.0
	L	10.5
6B	R	7.50
	L	7.10
4B	R	6.80
	L	6.80
4UR	R	7.00
	L	7.00
2B	R	6.20
	L	9.90
2UL	R	4.50
	L	7.90
C6	R	7.60
	L	7.40
C4	R	7.00
	L	7.10

Medio-lateral width of the condyle in cm.; at sacrifice

6UR	R	10.0
	L	10.0
6B	R	10.5
	L	10.5
4B	R	10.5
	L	10.1
4UR	R	10.0
	L	10.0
2B	R	10.0
	L	9.00
2UL	R	9.50
	L	9.90
C6	R	10.0
	L	9.80
C4	R	10.0
	L	10.0

FIGURE 2

FIGURE 3

Photograph showing the joint capsule of the unoperated side of the unilateral six month specimen.

FIGURE 4

Photograph showing the enlarged joint capsule of the operated side of the unilateral six month specimen.

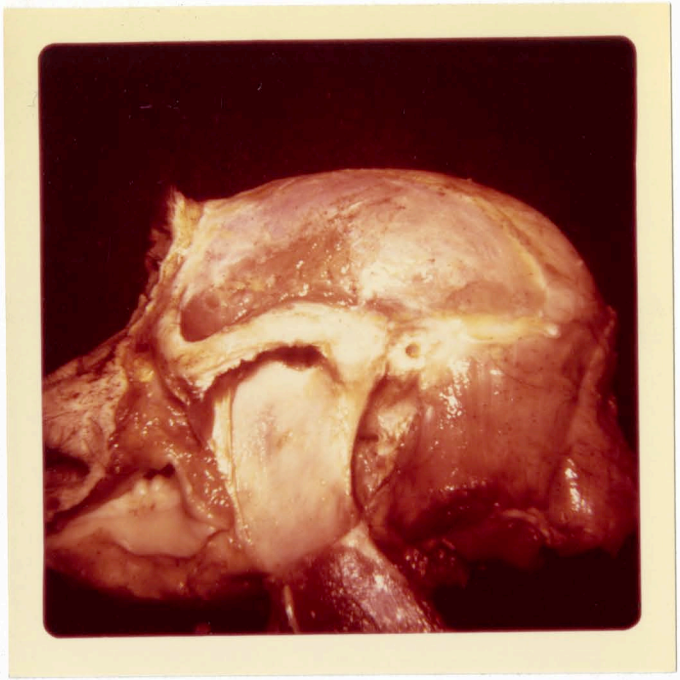


FIGURE 3

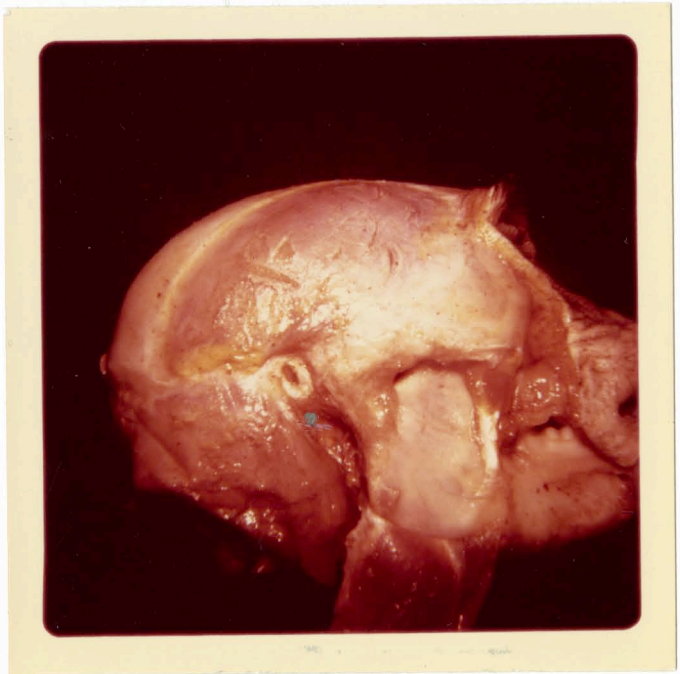


FIGURE 4

FIGURE 5

Photograph (postero-inferior view) of the medio-lateral widening of the right condylar neck of the unilateral six month specimen.

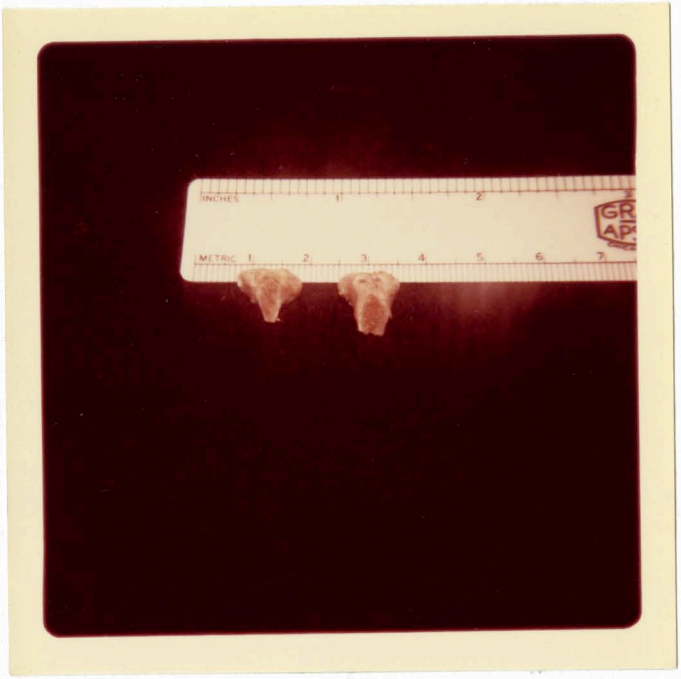


FIGURE 5

FIGURE 6

Photograph showing the unoperated condyle of the unilateral two month specimen.

FIGURE 7

Photograph showing the enlarged condyle on the operated side of the two month unilateral specimen.

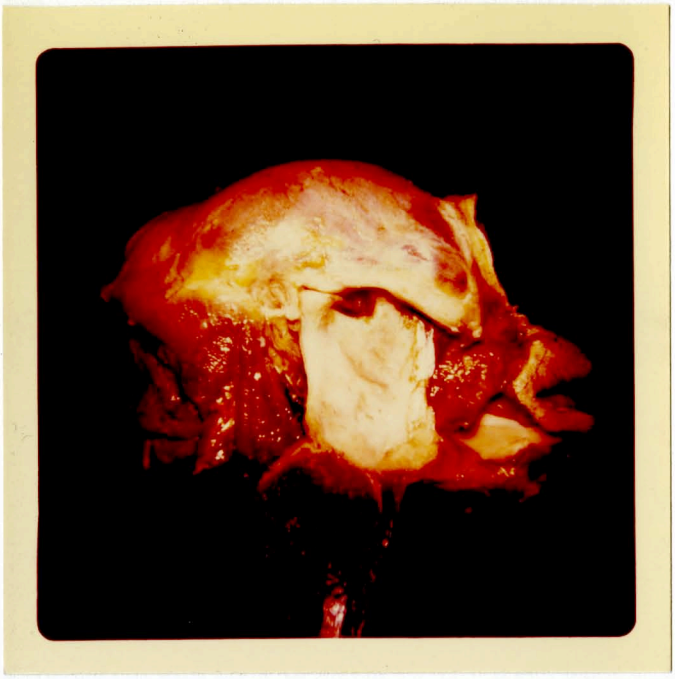


FIGURE 6

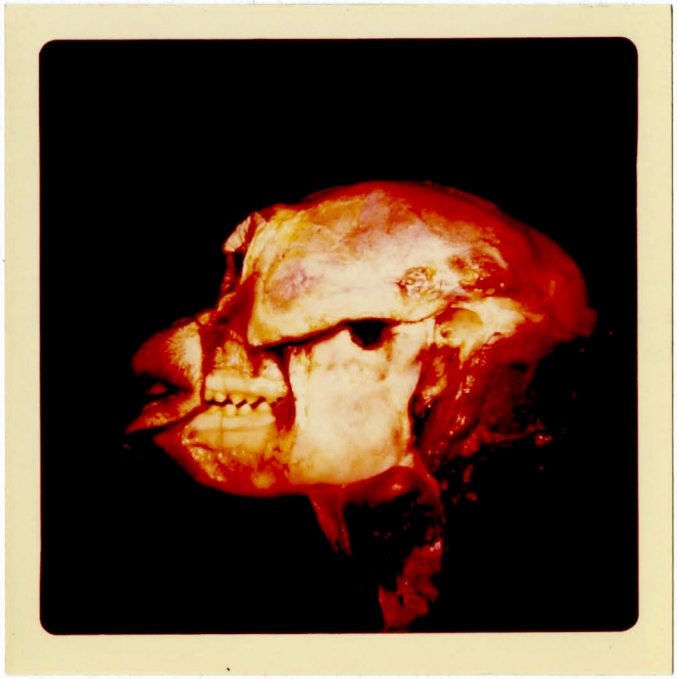


FIGURE 7

FIGURE 8

Photograph (superior view) of enlarged condyle of unilateral two month specimen.

FIGURE 9

Photograph (anterior view) of enlarged condyle of unilateral two month specimen.

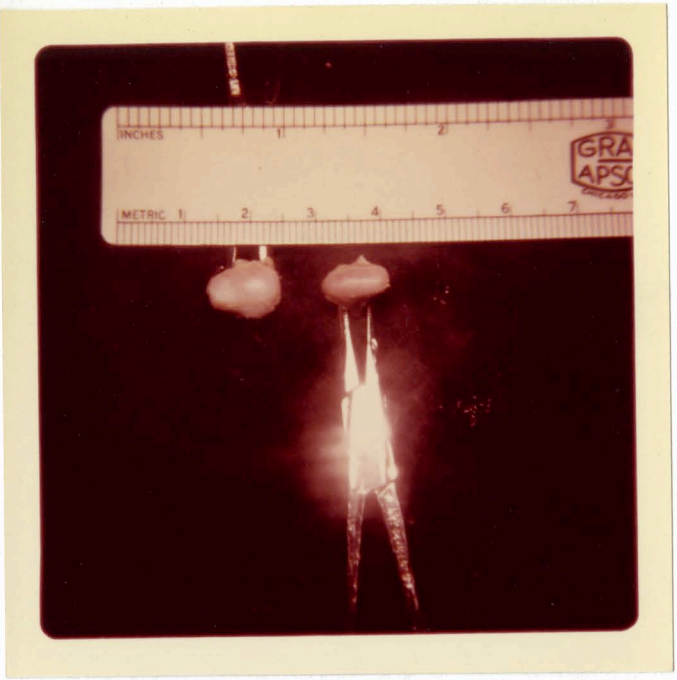


FIGURE 8

FIGURE 9

FIGURE 10

Photograph (postero-inferior view) of enlarged condyle of unilateral two month specimen.

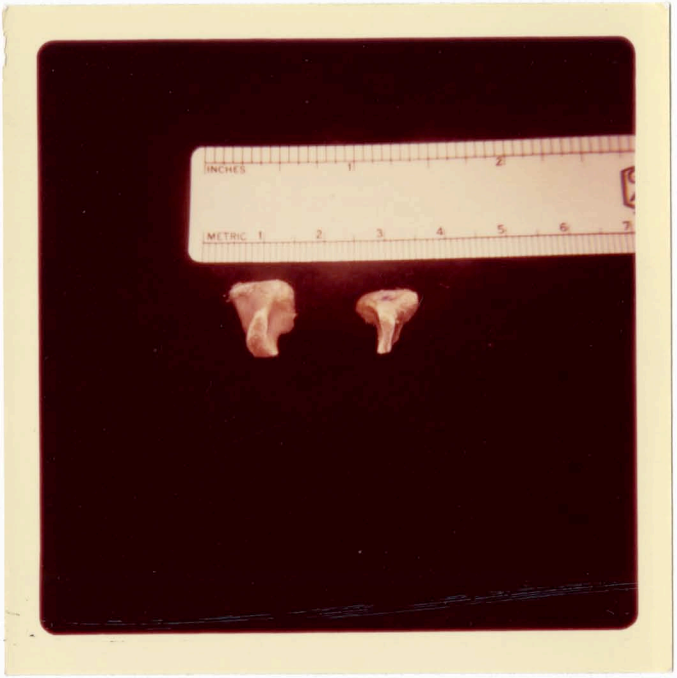


FIGURE 10

FIGURE 11

Photograph showing left condyle involved in bilateral pseudoarthrosis of two month specimen.

FIGURE 12

Photograph (anterior view) showing condyles involved in bilateral pseudoarthrosis of two month specimen.

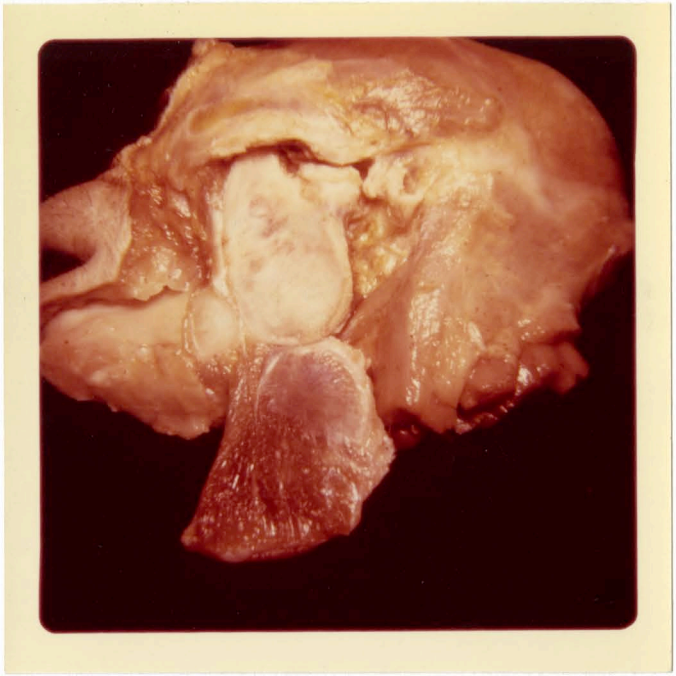


FIGURE 11

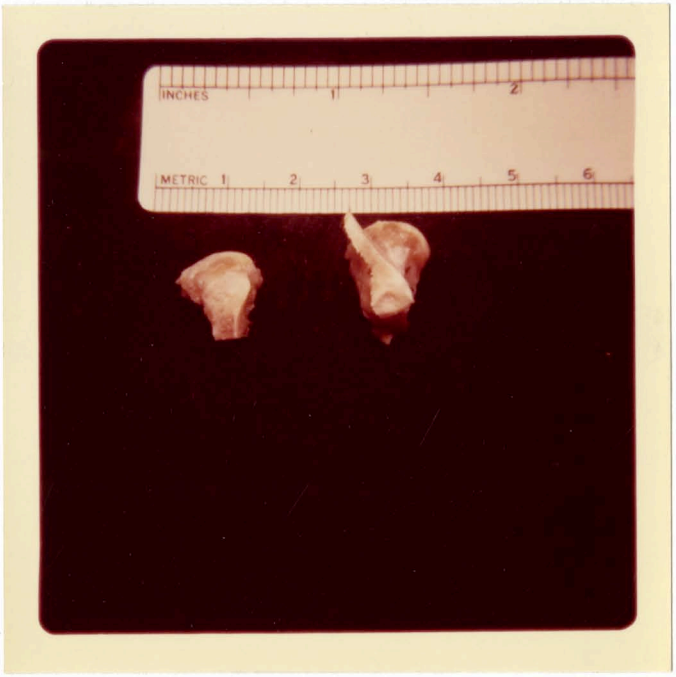


FIGURE 12

FIGURE 13

Photograph (posterior view) showing condyles involved in bilateral pseudoarthrosis of two month specimen.

FIGURE 14

Photograph showing right condyle involved in bilateral pseudoarthrosis of two month specimen.

FIGURE 13

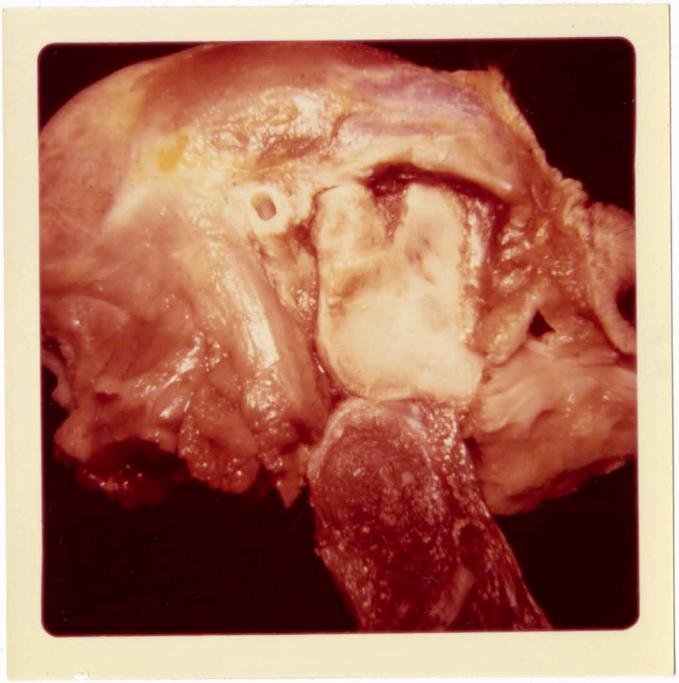


FIGURE 14

FIGURE 15

Radiograph (antero-posterior view) showing the medio-lateral widening of the condylar neck in the unilateral six month specimen.

C. PHOTOGRAPH OF RADIOGRAPH

FIGURE 15

FIGURE 16

Photomicrograph X25 showing the hyaline cartilage of and the dense, fibrous connective tissue covering the articular surface of the condyle in the six month control animal.

D. PHOTOMICROGRAPHS

FIGURE 16

FIGURE 17

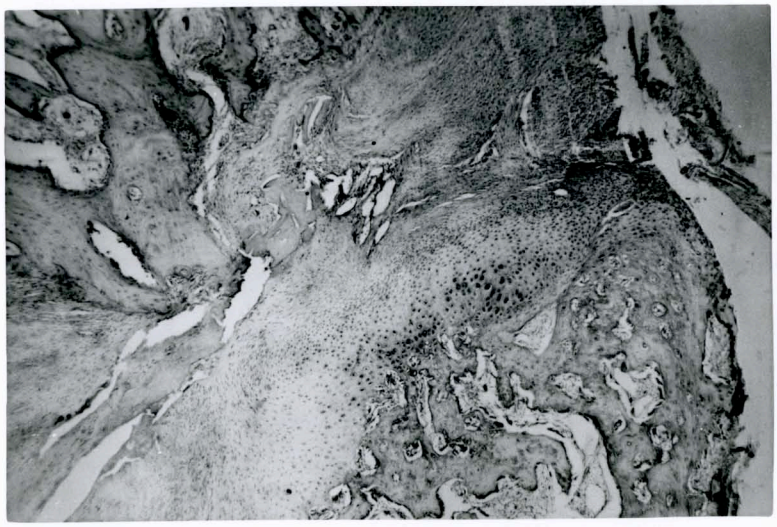
Photomicrograph X32 showing the medial portion of the left pseudoarthrosis in the bilateral two month specimen.

FIGURE 18

Photomicrograph X32 showing the medial portion of the right pseudoarthrosis in the bilateral two month specimen.

F.82

FIGURE 17



F.81

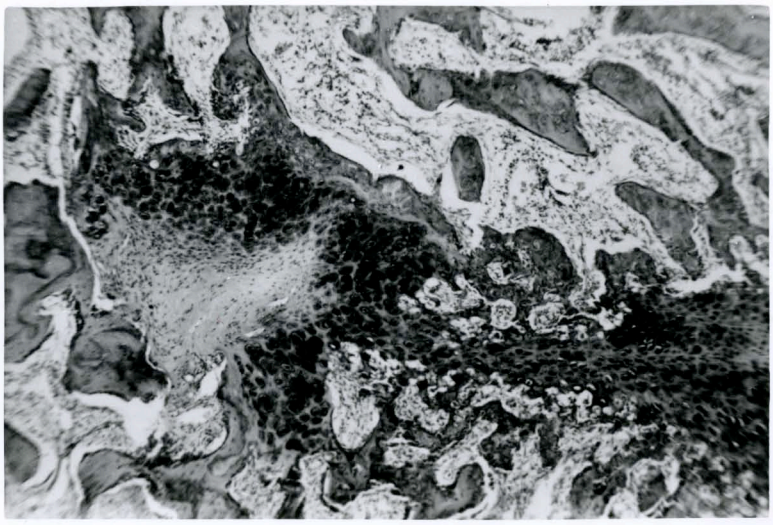
FIGURE 18

FIGURE 19

Photomicrograph X32 showing hyaline cartilage displaced into the area of metaphysis on the fractured side of the unilateral two month specimen.

FIGURE 20

Photomicrograph X100 showing the terminal portion of the hyaline cartilage displaced into the area of metaphysis on the fractured side of the unilateral two month specimen.



F183

FIGURE 19

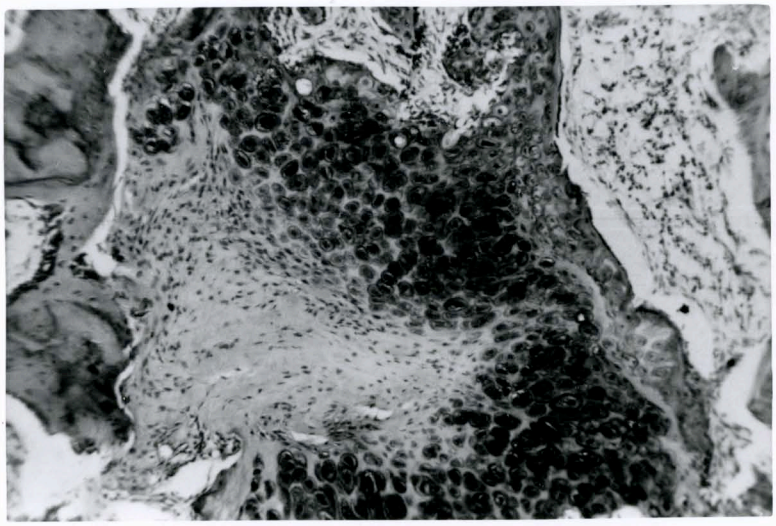


FIGURE 20

APPROVAL SHEET

The Thesis submitted by Stanley James Kaczala has been read and approved by three members of the faculty of the Graduate School.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

Date 5/17/65

Nicholas C. Choukas, D.D.S., M.S.
Signature of Adviser

Nicholas C. Choukas, D.D.S., M.S.