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# Changes in Tension of the Masseter and Digastricus Muscles of a Decerebrate Cat When Force Stimuli Are Applied to Teeth

by

Wesley H. Ardoin

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, 1967

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## ACKNOWLEDGMENTS

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I am grateful to my wife, Patty, who has always shown unsurpassed patience and understanding. It is only through her encouragement that I was able to attain this level in my education.

## TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS.--Continued

# LIST OF TABLES

# CHAPTER I

## INTRODUCTION AND STATEMENT OF THE PROBLEM

Muscles causing mandibular movements respond to force stimuli applied to teeth. The object of this research is to determine the reflex response and relationship of certain antagonistic muscles associated with mastication. Changes in muscle tension evoked by proprioceptive and painful stimuli will be studied. The decerebrate preparation allows one to study the reflex activity in an animal in which control from the higher brain centers has been eliminated.

The decerebrate preparation was first described by Sherrington at the close of the nineteenth century. Since this time many theories have been given in an attempt to explain the phenomenon of decerebrate rigidity.

## CHAPTER II

## REVIEW OF THE LITERATURE

### A. SURGICAL PROBLEMS AND TECHNIQUES:

Sherrington (1898) removed the cerebral hemispheres of a monkey surgically. The carotid arteries were ligated to reduce intracranial hemorrhage. The anesthetics employed were chloroform and ether.

In 1909 the surgical procedure for decerebration of the cat was described by Sherrington in greater detail. Chloroform and ether were employed. The cranium was exposed by partial eversion of one temporalis muscle. A trephine hole was made in the skull and enlarged with bone forceps. A thread loop was placed around each carotid artery and a cannula inserted into the trachea. The carotid arteries were temporarily occluded and the vertebral arteries were compressed just below the transverse process of the atlas vertebra. The midbrain was then transected with a blunt knife.

Weed (1917) described the direction of the cut necessary to decerebrate the cat:

> The line of the bony tentorium is followed toward the base of the

> skull, so that the resultant section slopes from above downwards and forwards, including more cephalic structures in the basal portion than in the tegmental regions.

Sherrington (1909) noted that breathing difficulties and hemmorhage were two major problems in obtaining the decerebrate preparation. He employed a tracheal cannula for disturbances in respiration.

In 1921 Macleod studying the respiration of the decerebrate cat noted that most of the animals in respiratory distress responded remarkably well to oxygen administration. A catheter inserted into the trachea to its bifurcation provided the best results.

Bazett and Penfield (1922) found that the frequency of failures due to cessation of respiration was reduced by keeping the animal in deep anesthesia during decerebration. Injections of 0.5 mg. of atropine was found to be helpful in reducing mucous formation.

In 1962 Plum and McNealy observed that pulmonary air embolism induced during Sherringtonian decerebration caused hyperpenea, anoxemia and often failure of the cat to demonstrate typical postural responses. They suggested to avoid air embolism the head should be kept at or below the level of the hindquarter during surgery, the bone edges should be carefully removed and sealed with wax and the anesthesia should be of sufficient concentration to prevent gasping.

B. DECEREBRATION AND ITS EFFECTS UPON SKELETAL MUSCLE:

Sherrington noted that upon removal of the cerebral hemispheres of a monkey the extensor muscles of the extremities displayed great contraction. In 1898 while seeking to determine the relationship of antagonistic muscles he observed that when one muscle group exhibited contraction the antagonistic muscle group was inhibited. Following removal of the cerebral hemispheres the neck became rigidly extended with the head retracted and the chin thrown upward.

Sherrington (1909) reported that the extensor muscles in the decerebrate animal are:

> ...dependent upon the proprioceptive arc of the muscle itself, and all other spinal afferents than those of that arc are inessential to them.

Pollock and Davis (1931) differed from Sherrington in that they state deafferentation does not abolish rigidity of the limbs of the decerebrate preparation. They found that:

> Decerebrate rigidity is due to a summation of reflex activities of which the stretch reflex represents but a small part.

Matthews (1958) in an attempt to resolve this dispute suggested that the problem could be explained by the difference in methods of decerebration.

Szentagothai (1948) reported that the mesencephalic tract of the trigeminal was the only central pathway of the cranial nerves where monosynaptic reflex areas exist. Two-neuron reflex arcs were observed for the masseter and temporalis muscles. Direct inhibitory collateral fibers connect some stretch afferents of these muscles to motoneurons of respective antagonists.

Linsley, Schreiner and Magoun (1949) studied electromyographs of decerebrate cats with relation to spasticity. One of their more important contributions was a list and diagram of the facilitory and supressor systems of the cat brain. They also determined that the spastic state is maintained by facilitory influx to the spinal cord from the remaining brain.

Bertioff (1914) found that the spasticity may be influenced by the position of the neck in relation to the body and the position of the labyrinth in space. The extensor tone increased when the mandible pointed upward and decreased when the mandible was directed downward. Bertioff termed these reactions "labyrinth reflexes". He also stated that the neck should not be twisted during experimentation. This increases the tone of the extensors on the side to which the head is turned and inhibits the muscles of the opposite side. Extensor tone may be altered if the head is bent ventrally or dorsally. Beritoff introduced the term "neck reflexes" to describe these reactions.

Weed in 1917 while studying the decerebrate cat noted that the results of decerebration may also be affected by the age of the animal. No rigidity could be observed in the majority of the kittens employed. The rigidity seemed to be present only in the older less active kittens. He suggested (1914) waiting ninety minutes after decerebration before proceeding with experimentation in order to obtain a constant state of rigidity.

Girvin (1966) attempted to explain the many theories found in the literature in relation to the mechanism of rigidity following decerebration. He differentiates between "gamma rigidity", afferent impulses from the muscle spindle, and "alpha rigidity" due to direct efferent drive.

C. FORCE STIMULI APPLIED TO TEETH AND THE RESPONSE OF MASTICATORY MUSCLES:

Pfaffman (1939) measured afferent impulses following mechanical pressure applied to the teeth of cats by use of the von Frey bristles. These force-producing mechanisms were a series of calibrated bristles that bent at certain values. He found that the threshold for the canine teeth of the adult cat was from 2 to 3 grams.

In 1962 Kruger applied pressure and taps to the teeth of the cat and measured the response in the sensory trigeminal complex. Fast adapting and slow adapting neurons were observed upon stimulation of canine teeth of the decerebrate animal.

The fast adapting neurons excited by touch on the labial surface were very sensitive and responded with a short burst of impulses regardless of stimulus duration. The neurons elicited by sharp taps responded with only one impulse.

The slow adapting neurons due to touch stimulation commonly displayed a rapid acceleration of impulse discharge and then maintained a somewhat slower rate until the stimulus was removed.

Loenstein and Rathkamp (1955) found that thresholds increase significantly from the anterior to the posterior teeth of the maxilla and the mandible. The average proprioceptive threshold for human teeth was 2.535 grams. Ness (1954) using rabbit teeth found the threshold value was from one to two grams. In 1966 Kizior and Cuozzo found that the threshold for the mandibular canine tooth of the adult cat was four grams. These investigators obtained threshold values by measuring the change in electrical potentials on the afferent side of the reflex. Kizior and Cuozzo also determined that pain threshold was reached at 1700 grams of incisally applied force upon the canine tooth. The incisally applied forces within the long axis of the tooth gave greater changes in electrical potential of the inferior alveolar nerve than any other direction.

Corbin and Harrison (1946) found that action potentials from the mesencephalic root of the trigeminal nerve were elicited due to force applied to the teeth and palatal gingiva of the cat. The canine teeth were the most responsive of the oral structures stimulated.

Sherrington (1917) stated that decerebration causes a steady reflex postural activity of the antigravity muscles, and the jaws of the animal maintain a closed position. When mechanical stimuli (of undetermined magnitudes) were applied to the gums bordering the teeth and to the anterior portion of the hard palate, jaw opening resulted. The jaw returned to its previous closed posture immediately following removal of the stimulus. Pressure on the crown of a tooth often evoked this response.

The mandible was split at the symphysis and a stimulus was applied to the gums of one side. The reflex was found to be practically unilateral on the side of the stimulus and contraction of the digastric muscle became especially evident when it was detached from the mandible. A series of repeated stimulations resulted in masticatory movements.

Sherrington speculated that when an animal receives a bolus and has voluntarily closed the jaw a stimulus is produced which tends to reflexly open the jaw. The phenomenon of rebound results in closure, and the masticatory cycle is produced. He found that the jaws of the decerebrate cat would open and close as long as a bolus remained between the teeth.

In 1918 Miller and Sherrington induced reflex swallowing by mechanically stimulating the dorsum of the tongue, the soft palate and the posterior wall of the pharynx.

Kawamura _et al_. in 1964 detached the muscles from the mandible of decerebrate cats. The mandible was moved mechanically and the electrical activity was measured in the mesencephalic root and motor nucleus of the trigeminal nerve. Kawamura stated:

> The results indicate that not only the muscle proprioceptive mechanisms but the proprioception from the temporomandibular joint might also strongly participate to control the muscle activities of the jaw.

Carlsoo (1956) determined electromyographically that the elevators of the mandible are mechanical antagonists of the digastric muscle during both elevation and depression of the human jaw. The activity of the digastric muscle increased during jaw opening and reached its maximum at the fully opened position. Recordable activity of the elevator muscles disappeared during mandibular opening when the teeth were no longer in occlusal contact. A gradual decrease in digastric activity was observed upon closure and was accompanied by an increase in activity of the elevator muscles.

Hyman (1942) described the action of the masseter muscle of the cat as an elevator of the mandible in common with the temporal muscle. The action of the digastric was defined as a depressor of the lower jaw.

Kawamura *et al*. in 1953 observed that during decerebration of the cat the electrical activities of the geniohyoid, mylohyoid and digastric muscles were remarkably strong; however, the activity of the masseter and temporalis muscles was weak. In regard to this finding Kawamura concluded that the potential action of a muscle and its tonus do not always coincide.

In 1958 he found that the electrical activity of the masseter increased greatly following light stretching of the muscle, but no change in electromyographic readings of the suprahyoid muscles was noted. Reflex jaw opening and closing occurred when a greater stretch was applied to the masseter muscle. Kawamura stated in a discussion of the mesencephalic nucleus:

> The sensitivity of the jaw muscles to stretch is due to a release phenomenon of the mesencephalic trigeminal nucleus; therefore, complete destruction of this nucleus abolishes the spastic state of the jaw closing muscles because the impulses from the proprioceptors in the jaw muscles were interrupted in transmission to the motor nucleus of the fifth cranial nerve.

Corbin and Harrison (1940) attempting to determine the function of the mesencephalic root of the trigeminal nerve observed that primary proprioceptive impulses from the muscles of mastication and pressure impulses from the teeth are transmitted through this nucleus. These impulses transverse the fibers which constitute the afferent portion of the masticatory reflex arcs and thereby coordinate and control chewing movements.

These investigators in 1942 used decerebrate cats and applied light taps on the canine teeth. Jaw movements were elicited as a result of the force stimuli. They type of movement in any one animal was rather constant, but responses from several animals were about equally divided between jaw opening and jaw closing. Jaw opening was also the result of electrical stimuli applied to the gingiva, teeth and palate.

In 1959 Kawamura et al. reported that following stretch of the masseter muscle electrical activity could be found in the motor nucleus as well as the mesencephalic root of the fifth nerve. These centers were accelerated simultaneously but that of the hypoglossal was inhibited reciprocally.

Rioch and Lambert (1934) seeking to determine the afferent path for the jaw-jerk reported that a twitch of the masseter muscle was noted following a sharp tap on the first molar tooth. Muscular stretch caused this response. Severing the afferent root of the trigeminal nerve abolished the rigidity.

# CHAPTER III

# METHODS AND MATERIALS

## Introduction

Eleven adult cats were used in this study. The surgery involved can be divided into two categories. Exposure of the trachea, common carotid arteries, external jugular vein and the muscles under consideration was performed first. The second division of surgery was the decerebration of the animal.

The physiologic experimentation was concerned with the quantitative and qualitative reflex responses of certain antagonistic masticatory muscles induced by force stimuli applied to the canine teeth.

The force stimuli were delivered by two different instruments. One operated on a torque force system and the other depended on hydraulic pressure.

## Preparation for Surgery

Ether was initially administrated by the open cone technique. The animal was placed in a supine position and secured to the surgery board. The head and neck were shaved. A tracheotomy was performed after the animal had reached the appropriate surgical plane of anesthesia.

Surgery and Anesthesia

A 7 cm. midline incision was made on the ventral aspect of the cat's neck from the sternum just caudal to the mandibular symphysis. The trachea was exposed and a transverse incision made between the tracheal rings about 2 cm. inferior to the thyroid cartilage. This incision allowed for the insertion of a tracheal cannula which was ligated in place.

Anesthesia was administered through the cannula by the use of an open system. Compressed air was directed into the anesthetic bottle with only enough pressure to cause movement of the vapors in the desired direction. A valve mounted on the anesthetic bottle allowed the desired quantity of anesthesia to flow via a rubber tube into the trachea. A glass "Y" was employed approximately 5 cm. from the cannula. Its base led into the cannula. The rubber tube from the anesthetic bottle was connected to one of its inlets. Another tube was connected to the second inlet. Oxygen or compressed air could be forced through this tube in order to ventilate the animal artificially. A small hole was cut in this tube just as it connected to the glass "Y". Air flowed directly into the lungs when this hole was blocked by the operator's finger. The animal was permitted to exhale when the finger was released.

A regulating mechanism was devised to avoid forcing an excessive amount of pressure into the lungs. The base of a glass "T" was connected by a rubber tube to the compressed air source used for artificial respiration. The other side was connected to the glass "Y" previously described. The oxygen or compressed air would force the column of water out of the glass tube and bubble over if the pressure in the system surpassed 20 cm. of water. A double hole stopper permitted stabilization of the glass "T" and allowed an exit for excessive gaseous pressure (Figure 1).

The common carotid arteries and one external jugular vein were exposed and a thread loop placed around them for future identification.

The skin, fascia and platysma muscle overlying the masseter and digastric on one side were reflected. The origin of the superficial and deep portions of the masseter muscle was freed from the anterior two-thirds of the zygomatic arch by use of a periosteal elevator. A needle with extra strong nylon thread was inserted into the muscle at its free end. The nylon thread afforded the means of connecting the

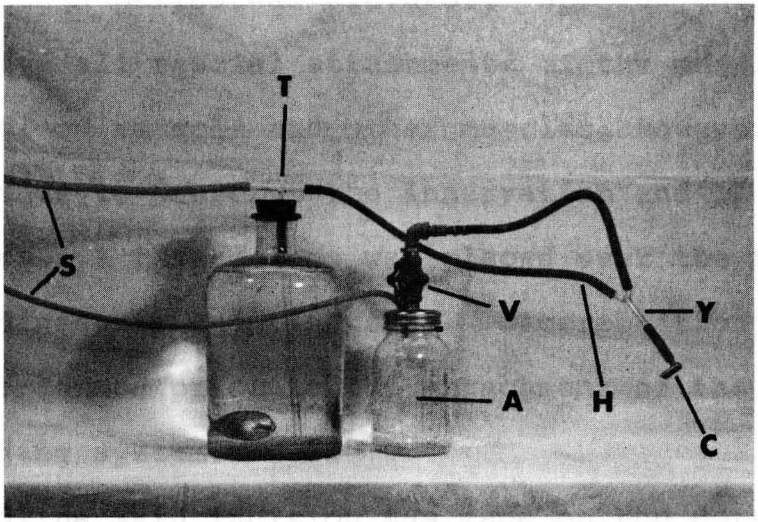


FIGURE 1

SYSTEM FOR ANESTHESIA ADMINISTRATION

A = Anesthesia Bottle
C = Tracheal Cannula
H = Hole in Tubing
S = Compressed Air Sources
T = 20 cm. Glass "T"
V = Anesthesia Regulating Valve
Y = Glass "Y"

muscles to the recording system at a later time.

The insertion of the digastric to the mandible was also freed with a periosteal elevator. Special care was taken to remove all fascial attachments of the muscle to surrounding blood vessels and other muscles; however, every attempt was made to preserve the innervation and blood supply of the muscles. A thread loop was placed over the freed portion of the digastric and tightened. Decerebration of the animal was performed prior to the attachment of the muscles to the recording system.

A midline skin incision was made on the dorsal aspect of the skull to gain access to the cerebral hemispheres. It extended just caudal to the external occipital protuberence rostrally for approximately eight cm. A three cm. incision was made bilaterally from the caudal end of the initial incision along the superior nuchal line. The skin was reflected and the underlying muscles were dissected from the skull.

The common carotid arteries were temporarily occluded by rubber tipped arterial clamps thus reducing the blood flow to the head. Manual pressure was applied with fingers between the atlas and axis vertebrae to occlude the vertebral arteries. The hindquarter was kept at or above the head during the following surgical procedure to avoid air embolism.

An electric moto-tool with a large round steel bur was employed for initial penetration of the cranium. The point of penetration was made in the parietal bone one cm. lateral to the lambda. This site was made as close to the superior sagittal crest as possible while avoiding injury to the superior sagittal sinus. Care was taken not to penetrate the dura mater and damage the brain tissue. Small pieces of bone were removed with rougeurs thus enlarging the incision. Bone wax was placed over the exposed dipole to prevent hemorrhage and air embolism. The site was extended across the midline of the skull for access in making the section necessary for decerebration.

The sectioning of the midbrain was performed in two steps. A blunt, thin-bladed spatula having a width of 2.5 cm. was employed. The bony tentorium was used as a guide for the proper direction of the section. The spatula was guided ventrally and rostrally by the slope of the tentorium. Immediately before reaching the base of the skull the spatula was removed. The section was then completed by crushing the remaining brain tissue with a straight hemostat. This procedure reduced the possibility of excessive hemorrhage caused by severing the blood vessels at the base of the skull.

The cerebral hemispheres were removed and nonabsorbent cotton placed in the cavity. The cotton provided a slight opposing pressure to reduce hemorrhage without absorbing blood.

The exposed muscles were kept moist with Tyrode's solution at a temperature of 37 degrees centigrade. This temperature was maintained by a heat lamp and constantly checked with a thermometer. Tyrode's solution is an electrolyte composed of 0.8 gram of sodium chloride; 0.2 gram of potassium chloride; 0.2 gram of calcium chloride; 1.0 gram of sodium bicarbonate; 0.1 gram of magnesium chloride; 0.05 gram dibasic sodium phosphate; and distilled water q.s. 1 liter. Glucose in the quantity of 0.1 gram was added to every 100 ml. of solution just prior to using.

Dextran (Gentran) 6% in normal saline was administered through the previously exposed external jugular vein by a 10 cu. cm. syringe with an 18 gauge needle. Gentran is manufactured by Baxter Laboratories, Inc. of Morton Grove, Illinois. Each 100 ml. contains 6.0 grams of Dextran (specifically prepared glucose polysaccharide) and 0.9 gram of sodium chloride. This solution maintained plasma volume, blood pressure and consequently aided in restoring circulatory dynamics to normal. Eight to twenty cu. cm. were administered depending upon the amount of blood loss during surgery.

An electric heating pad was placed under the preparation to maintain a normal body temperature. Two 250 watt infrared bulbs also provided heat and better vision.

Immobilization of the Preparation

The animal was placed in a supine position on a specially constructed platform having a stereotaxic device mounted at one end. This permitted stabilization of the jaws and head. Immobilization of the preparation is a necessity for accurate results.

The poly-vinyl chloride platform was 28 in. x 12 in. x 1/2 in. The stereotaxic portion was mounted on a 5 in. x 5 in. base attached to one 12 in. side of the platform. It consists of four slotted vertical posts through which 1/2 in. metal bars could be placed. A threaded metal rod was inserted through each vertical post nearest the main platform. Concave wooden yokes were attached to the threaded bars. These yokes when properly adjusted just caudal to the base of the skull prevented movement of the animal in a caudal direction. The yokes could also be adjusted to raise or lower the neck. A single threaded metal bar was placed through both of the remaining slotted posts. The mandible of the cat was then firmly ligated to the bar. The mandible could be raised or lowered as desired since this bar was adjustable in a vertical direction. The base of the snout rested on a specially contoured wooden block which was permanently secured to the stereotaxic base. The preparation was adjusted in the head holding device so that the maxillary canines were directly over the wooden snout support.

Two 1/4 in. metal screws which were three in. long were placed through the stereotaxic base near the contoured wooden block and in line with the four vertical posts. These screws could be moved in an anterior or posterior direction since the base was slotted to accept the screw. The heads of the screws were countersunk allowing the stereotaxic device and platform to lie flat. The vertical three in. screws were used to adjust a horizontal "U" shaped aluminum bar in a vertical direction. The metal bar was placed over the cat's posterior teeth and adjusted downward by wing nuts to secure the snout against the wooden block thus immobilizing the maxilla (Figure 2).

## Recording System

The physiograph is a precision measurement and recording system used for physiological experimentation. It consists of three separate recording channels mounted in a metal frame assembly. The instrument and all of its accessories are manufactured by the E & M Instrument Company of Houston, Texas.

This system was used to provide simultaneous recordings of masseter and digastric muscle movements. One channel was used for each muscle. These recording channels consisted of a transducer, amplifier, pen motor and recording paper.

A transducer is a device which converts one form of energy into another form of energy. The transducers used in this study were myographs. A myograph with a maximum range of 0-500 grams was attached to the masseter muscle. The leaf spring displacement was 0.005 mm./gram, and the maximum sensitivity was 5 grams/cm. or physiograph pen deflection. The myograph employed for digastric readings had a maximum range of 0-30 grams. Its spring displacement was 0.08 mm./gram, and its maximum sensitivity was 0.5 grams/cm. (Figure 3).

Muscle movement is transmitted to the myograph leaf spring by a loop of thread attached to the muscle. This instrument operates on a photoelectric principle. As the leaf spring is moved the shutter varies the amount of light

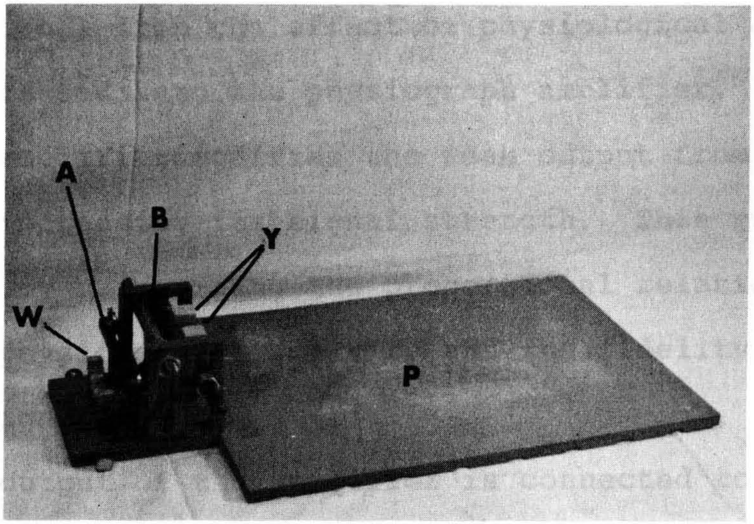


FIGURE 2

VINYL PLATFORM AND STEREOTAXIC MOUNT

A = Palatal Stabilizing Bar
B = Bar for Mandibular Ligation
P = Platform
W = Wooden Snout Support
Y = Concave Yokes

reaching the photo-tube; therefore, the output to the channel amplifier is in turn modified. The myograph creates an electrical signal from the effect of physiological activity. This signal is fed into the physiograph amplifier.

The amplifier modifies the weak output from the myograph by increasing its signal strength. This must be accomplished by maintaining the proportional relationship between the physiological activity and the fidelity of the electrical signal.

The output of the amplifier is connected to the pen motor. Upon receiving the electrical signals from the amplifier, the motor drives the direct-inking recording pen. The excursions of the pen across the moving recording paper are proportional to the physiological activity, and a permanent record of the movement of the muscles is obtained (Figure 4).

One cm./sec. was selected for the paper speed during this experiment. The paper control unit provided time signals every one, five, thirty or sixty seconds which are recorded as momentary downward deflections of the time-event channel pen. This pen deflects upward when activated by a panel-mounted event-marker switch.

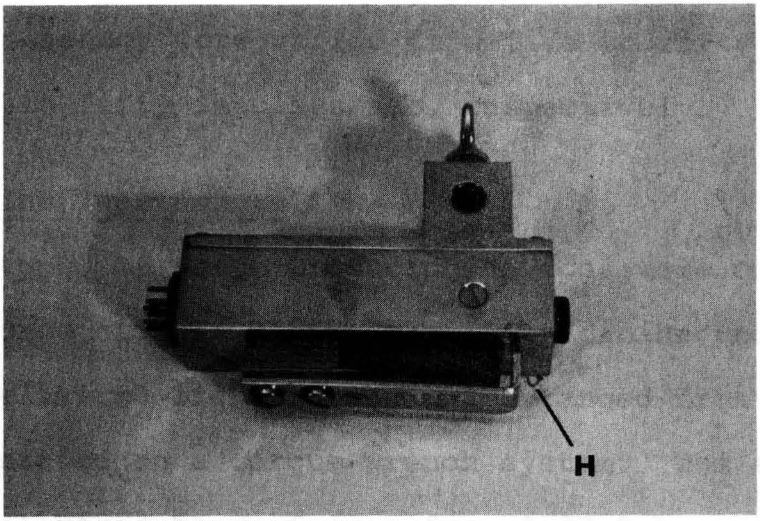


**FIGURE 3**

**MYOGRAPH**

**H = Leaf Spring Hook for Muscle Attachment**

Electrical stimuli were applied to the palatal gingiva and pulp of the maxillary canine tooth. The electrical output and frequency were varied from five to fifty volts and from two to fifty impulses/sec. respectively.

<u>Force Producing Instruments</u>

Two types of force producing devices were employed to deliver force stimuli to the maxillary canine teeth. One device delivered light forces which ranged from 0-1500 grams and operated on a torque wrench system. The second instrument delivered heavy forces from 0-27.8 kg. and operated on a hydraulic principle. All forces were delivered along the long axis of the tooth.

1. Force Producing Device-Torque Wrench System:

This instrument was designed and constructed by the P.A. Sturtevant Company of Addison, Illinois. It has two major components: The torque wrench with its adapter and the structure on which it is mounted. The direction of the force can be altered as desired.

The torque wrench is calibrated so the resistance to torque can be measured. Its major components are the drive square, beam, scale, handle and pointer (Figures 5 & 6).

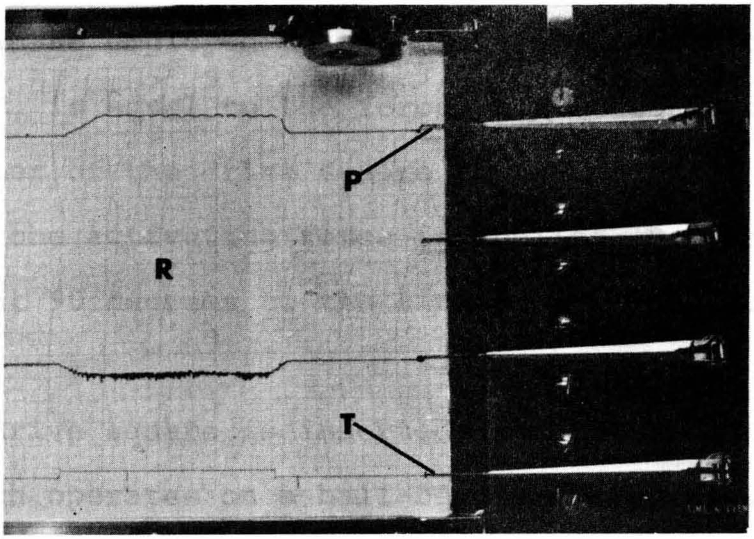


FIGURE 4

RECORDING PENS AND PAPER

P = Direct-Inking Recording Pen
R = Recording Paper
T = Time-Event Channel Pen

The beam is the activating element. It is flexed when force is applied to the handle. The Torque Law, T = F X D, can be employed to calculate the amount of torque. The torque, T, is equal to the force, F, times the distance from the center of the drive square to the point on the handle where the activating force is applied, D. The distance is measured at 90 degrees to the direction of the pulling force.

The drive square is inserted into the drive shaft assembly which operates on a ball-bearing principle. This produces a practically frictionless movement. The opposite end of the drive shaft assembly is screwed onto a rotating lever arm. A pointer for force application is fixed on the lever arm 12 in. from the center of the drive shaft.

A balancing counter-weight was placed on the opposite end of the lever arm. The relationship of the pointer to the long axis of the tooth determined the angle at which the force was directed.

The torque wrench employed was calibrated from 0-1500 grams in fifty gram increments. These readings represent the amount of force applied to the tooth.

The equation T = F X D may be rewritten as F = T/D. This force is transferred to the tooth through the pointer.

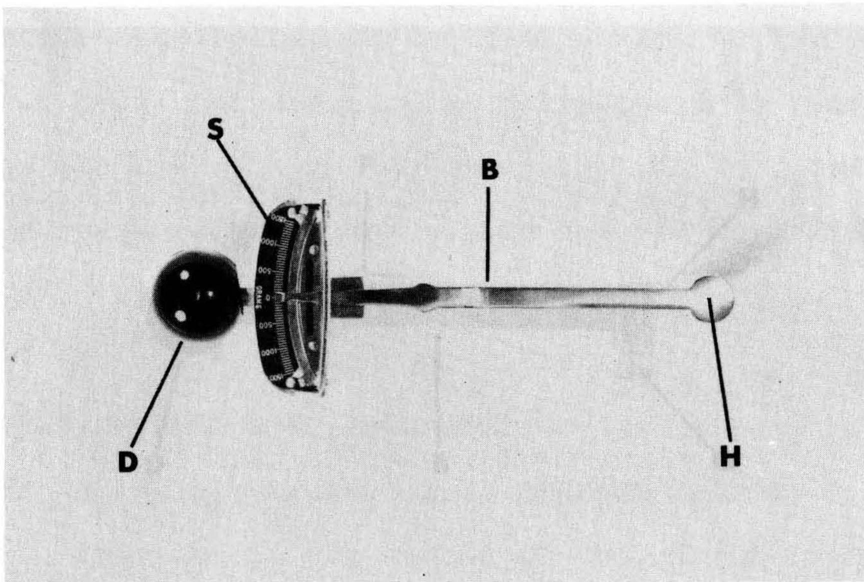


FIGURE 5

TORQUE WRENCH WITH LABELLED COMPONENTS

B = Beam
D = Handle
H = Head
S = Scale

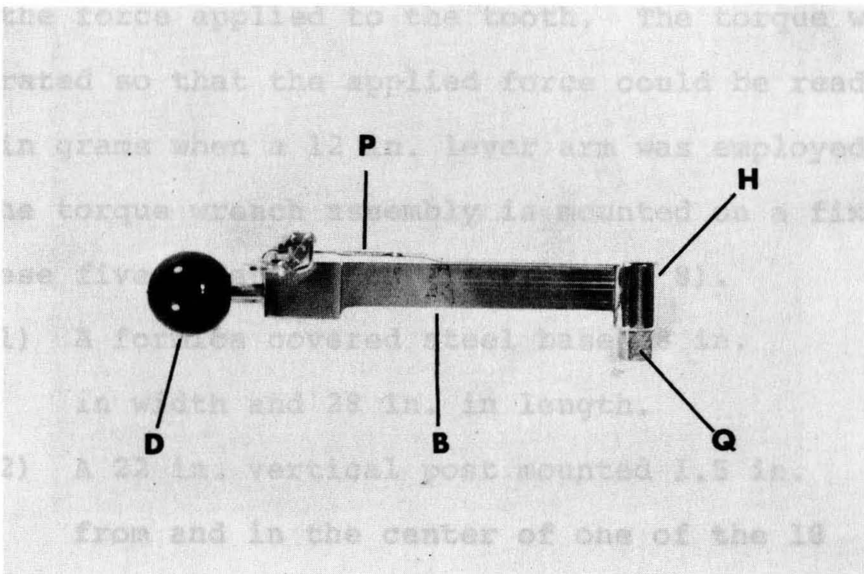


FIGURE 6

TORQUE WRENCH WITH LABELLED COMPONENTS

B = Beam
D = Handle
H = Head
P = Pointer
Q = Drive Square

The force also varies with the length of the lever arm. The 12 in. lever arm may be considered a constant when calculating the force applied to the tooth. The torque wrench was calibrated so that the applied force could be read directly in grams when a 12 in. lever arm was employed.

The torque wrench assembly is mounted on a fixture having these five constituents (Figures 7 & 8).

(1) A formica covered steel base 18 in. in width and 28 in. in length.

(2) A 22 in. vertical post mounted 1.5 in. from and in the center of one of the 18 in. sides.

(3) A 20 in. horizontal extension arm adjustable in both horizontal and vertical planes.

(4) A vertical assembly holding arm at the opposite end of the horizontal extension arm. This holding arm supports the torque wrench assembly.

(5) A drive shaft assembly suspended from the vertical holding arm by a ball and socket joint. This type of joint aids in the versatility of directing the

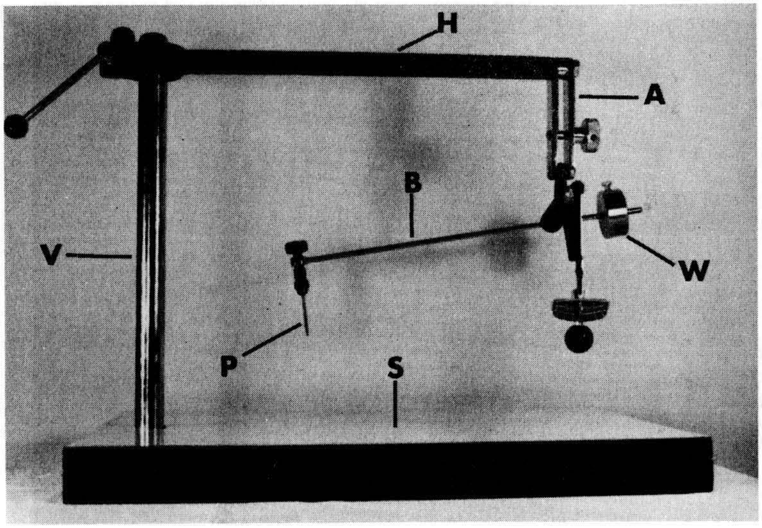


FIGURE 7

TORQUE FORCE PRODUCING INSTRUMENT

A = Vertical Assembly Holding Arm
B = Balancing Arm
H = Horizontal Extension Arm
P = Adjustable Pointer
S = Steel Base
V = Vertical Post
W = Counter-Weight

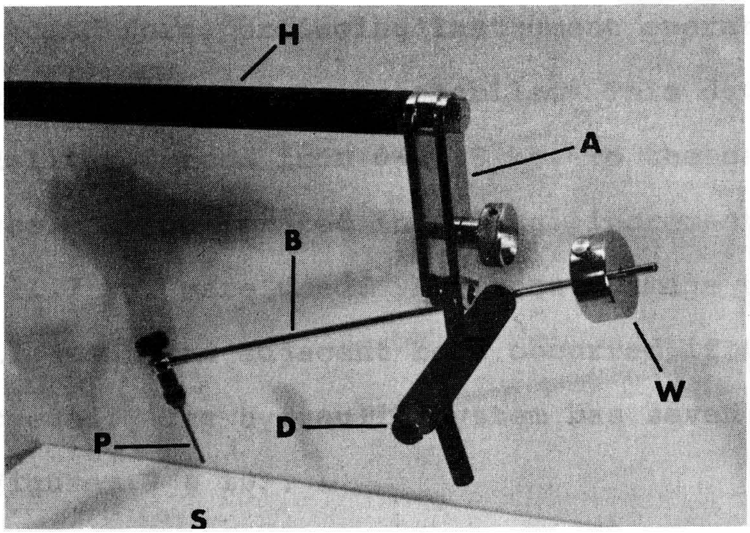


FIGURE 8

TORQUE FORCE PRODUCING INSTRUMENT

A = Vertical Assembly Holding Arm
B = Balancing Arm
D = Drive Shaft Assembly
H = Horizontal Extension Arm
P = Adjustable Pointer
S = Steel Base
W = Counter-Weight

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force which is produced.

2. Force Producing Instrument-Hydraulic Principle

The second force producing instrument operates on the hydraulic braking system of an automobile. This device is designed to deliver forces from 0-27.8 kg. to the canine tooth. Its scale is calibrated in 0.9 kg. increments. Only forces up to 21.7 kg. were used. Permanent damage to the periodontal ligament and adjacent bone occurred if this force was exceeded. The hydraulic system has seven major components (Figures 9 & 10).

(1) Brake pedal and mounting fixture

(2) Master brake cylinder

(3) Junction box and steel tubes

(4) Fluid pressure gauge

(5) Bleeder valve

(6) Wheel cylinder and tooth stimulating rod

(7) Brake fluid

The brake pedal and master cylinder were mounted on a 1 in. x 8 in. x 20 in. wooden board. A 1/4 in. steel tube led from the master cylinder to the junction box. A fluid gauge manufactured by the United States Gauge Company was inserted into the junction box. This gauge was calibrated in lbs./in.$^2$ from 0 to 60. Also leading from the

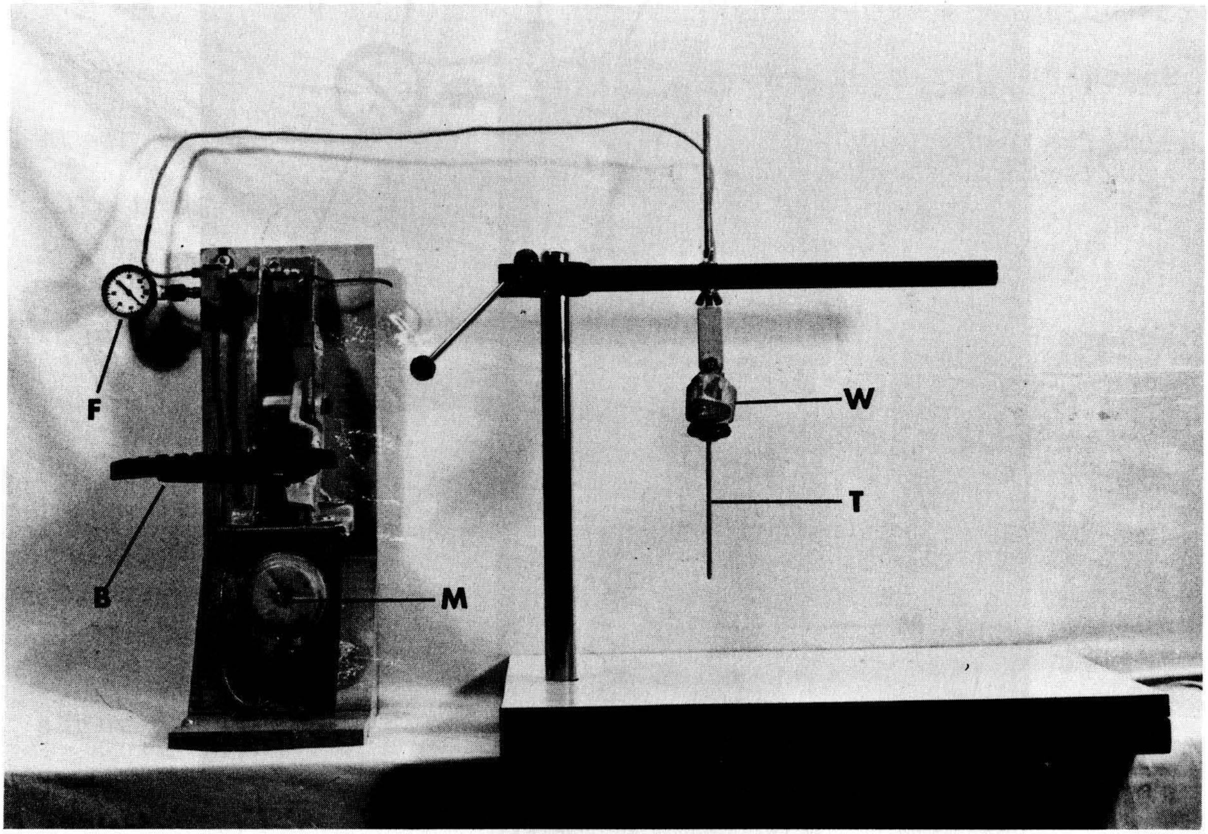



FIGURE 9

HYDRAULIC FORCE PRODUCING INSTRUMENT

B = Brake Pedal
F = Fluid Gauge
M = Master Cylinder
T = Tooth Stimulating Rod
W = Wheel Cylinder

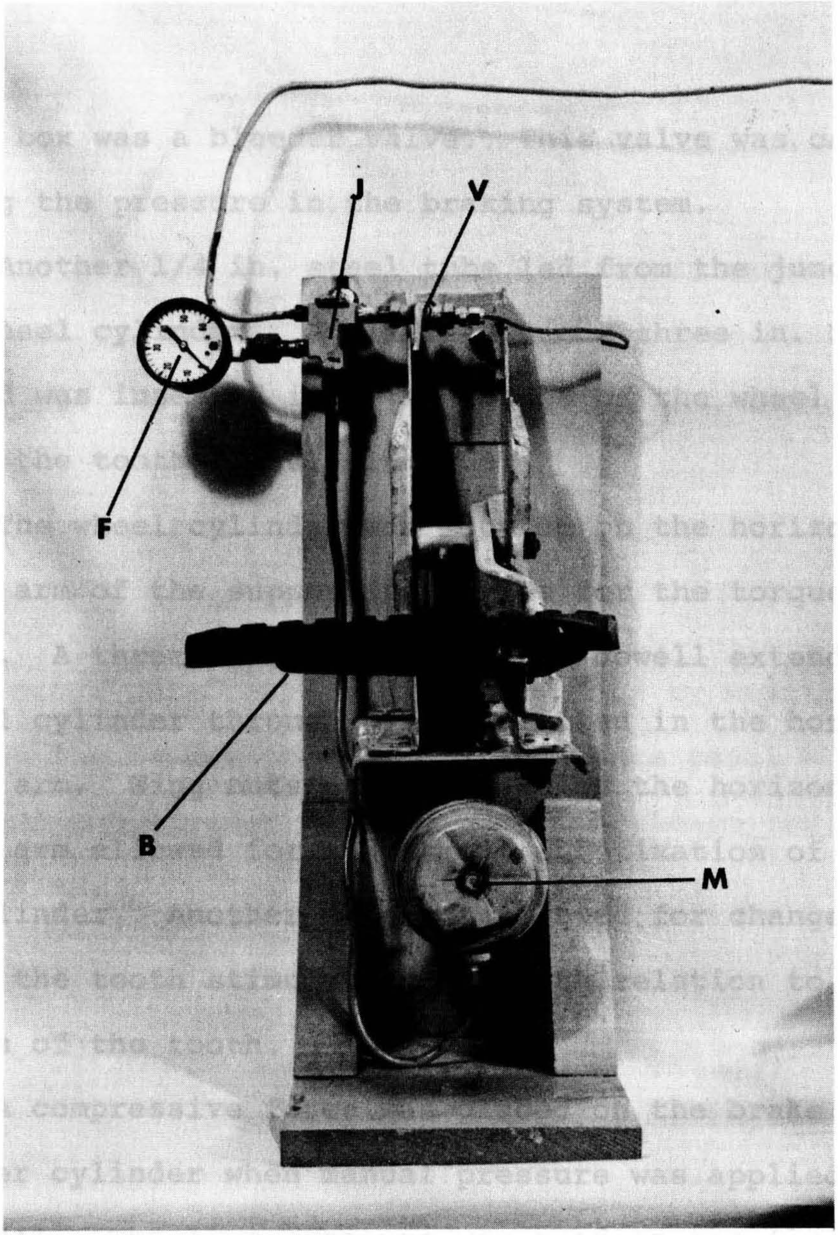



FIGURE 10

HYDRAULIC FORCE PRODUCING INSTRUMENT

B = Brake Pedal
F = Fluid Gauge
J = Junction Box
M = Master Cylinder
V = Bleeder Valve

junction box was a bleeder valve. This valve was capable of releasing the pressure in the braking system.

Another 1/4 in. steel tube led from the junction box to the wheel cylinder. A six in. long x three in. diameter steel rod was inserted into the piston of the wheel cylinder. This was the tooth stimulating rod.

The wheel cylinder was mounted on the horizontal rotating arm of the supporting device for the torque wrench assembly. A threaded 1/4 in. diameter dowell extended from the wheel cylinder through a hole drilled in the horizontal rotating arm. Wing nuts above and below the horizontal rotating arm allowed for adjustment and fixation of the wheel cylinder. Another wing nut allowed for change in the angle of the tooth stimulating rod with relation to the long axis of the tooth.

A compressive force was placed on the brake fluid by the master cylinder when manual pressure was applied to the brake pedal. The line pressure was read on the fluid gauge in lbs./in.$^2$. This pressure was equal throughout the system and was therefore the pressure applied to the wheel cylinder piston which had a cross sectional area of 1 in.$^2$. The force applied to the tooth was determined by the formula:

$$P = F/A$$

or: $F = P \times A$

F = Force applied to the tooth (lbs.)

P = Line pressure (lbs./in.$^2$)

A = Area of piston (1 in.$^2$)

$$F = \frac{\text{lbs.} \times 1\ \cancel{\text{in}}.^2}{\cancel{\text{in}}.^2}$$

or: F = lbs.

Pounds were converted to kilograms by multiplying by 0.454. The manual pressure on the brake pedal must be removed and the bleeder valve opened to release the pressure in the system.

## CHAPTER IV

## FINDINGS

Rigidity of the preparation was noted approximately ten minutes after the removal of the cerebral hemispheres. Resistance to jaw opening was observed first. This increased resistance to opening following decerebration as compared to the slight resistance of the animal under general anesthesia was very pronounced.

A snap closing and opening of the mandible occurred if great effort was exerted to open the jaw wide. The forelegs became rigid, the spine arched and lastly the hindlegs were rigid and the tail erect.

Breathing was irregular in many instances and artificial respiration was administered. The response of the preparation was good to both compressed air and oxygen. A significant amount of hemorrhage occurred during decerebration. The most common causes were the penetration of the skull and the sectioning of the midbrain. The administration of a plasma expander helped to maintain the animal in a functional condition.

Relaxation of the digastric occurred when stretch was applied to the masseter muscle (Figure 11). Conversely, stretch applied to the digastric resulted in relaxation of the masseter (Figure 12).

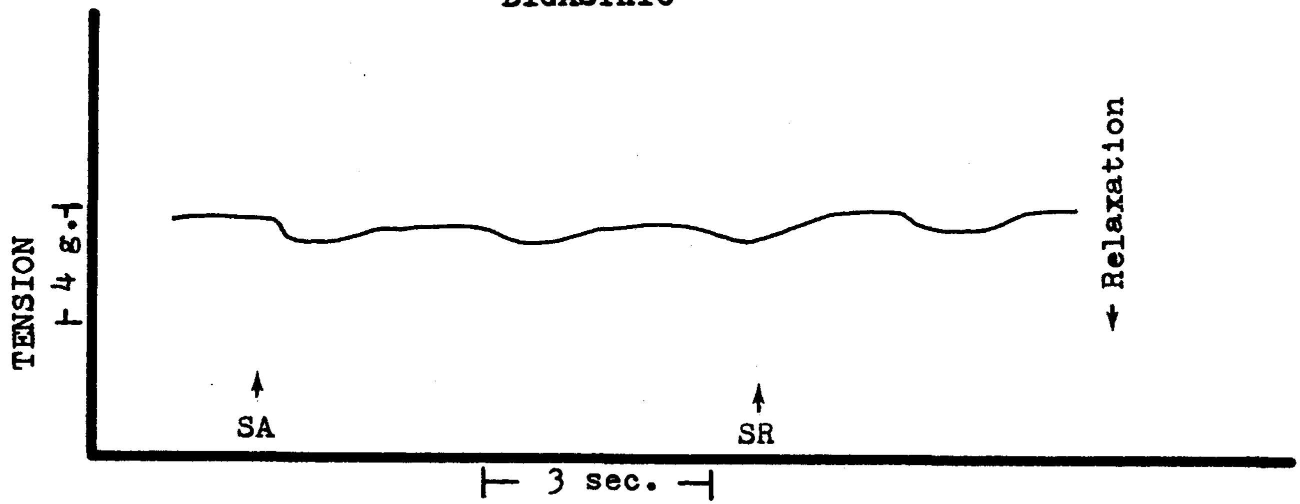
"Light forces" were delivered by the torque wrench apparatus which had a range of 0-1500 grams of applied force. The hydraulic stimulator delivered the "high magnitude forces" and had a range of 2-60 lbs. (907-27,216 grams).

Contraction of the masseter was observed in all instances when light forces were applied to the maxillary canine tooth. The force necessary to produce a stimulus of sufficient magnitude to cause a noticeable contraction of the masseter ranged from 75-300 grams. The mean threshold force for this proprioceptive reflex was 155 grams as determined from the average of five preparations (Figure 13).

No definite ratio exists between the increment of increased force and the resulting increase in masseter contraction. However, an increase in force stimuli generally resulted in an increase in muscle tension. This phenomenon is readily demonstrated during contraction of the masseter in every animal. The amount of muscle tension increase between 300 and 400 grams of applied force for cat number 101 (Table I) was 0.6 grams. There is an increase of 5.13 grams between 1200 and 1300 grams of applied force in the

Cat Number 107

DIGASTRIC

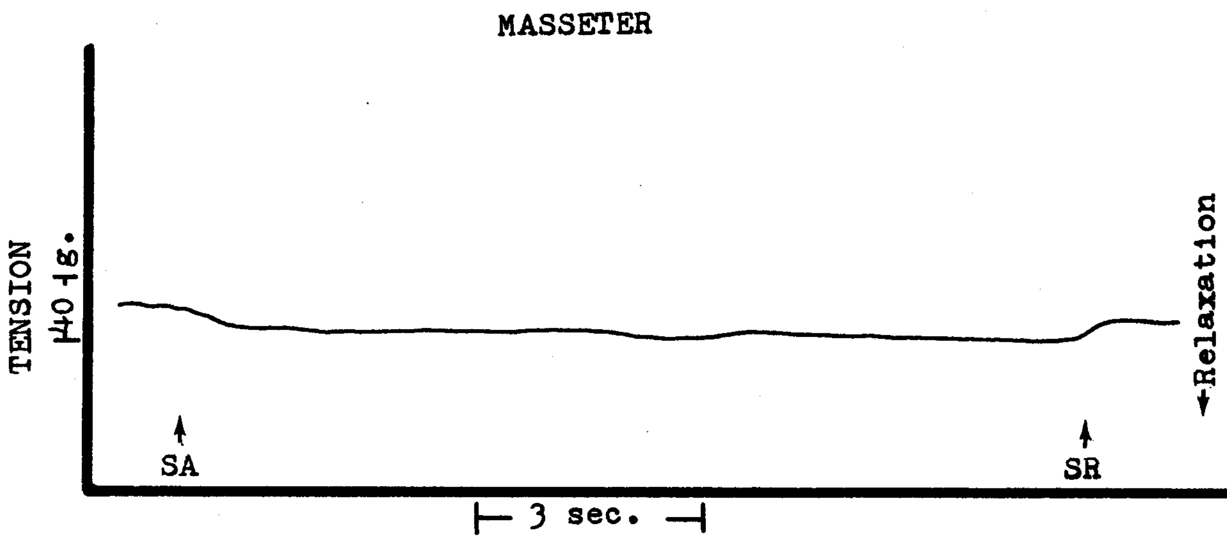



SA = Stretch Applied
SR = Stretch Removed

STRETCH APPLIED TO THE MASSETER
NOTE DIGASTRIC RELAXATION

Figure 11

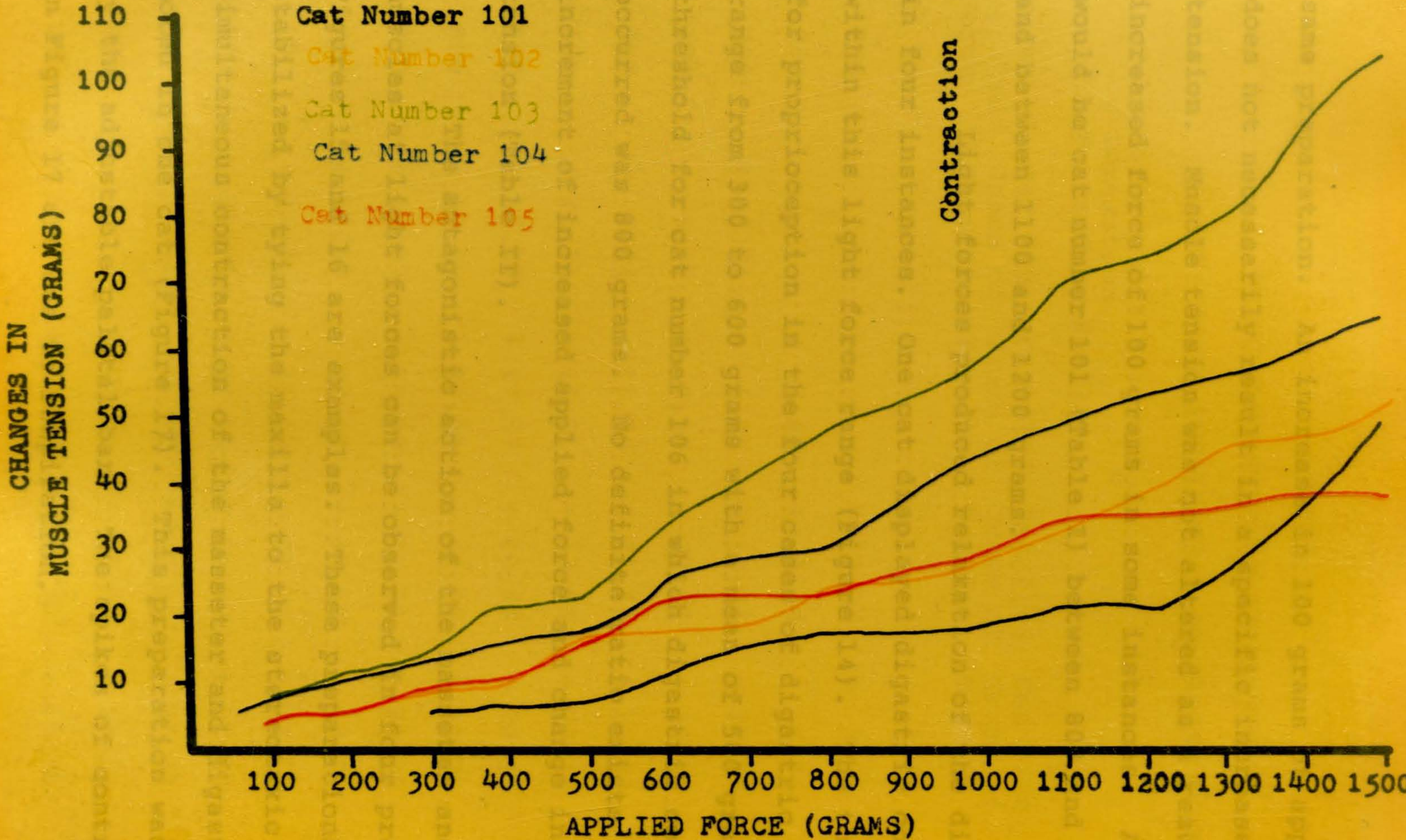
Cat Number 107




SA = Stretch Applied
SR = Stretch Removed

STRETCH APPLIED TO THE DIGASTRIC
NOTE MASSETER RELAXATION

Figure 12




MASSETER MUSCLE

Figure 13

same preparation. An increase in 100 grams of applied force does not necessarily result in a specific increase in muscle tension. Muscle tension was not altered as a result of increased force of 100 grams in some instances. An example would be cat number 101 (Table I) between 800 and 900 grams and between 1100 and 1200 grams.

Light forces produced relaxation of the digastric in four instances. One cat displayed digastric contraction within this light force range (Figure 14). The threshold for proprioception in the four cases of digastric relaxation range from 300 to 600 grams with a mean of 500 grams. The threshold for cat number 106 in which digastric contraction occurred was 800 grams. No definite ratio exists between any increment of increased applied force and change in muscle tension (Table II).

The antagonistic action of the masseter and digastric muscles at light forces can be observed in four preparations. Figures 15 and 16 are examples. These preparations were stabilized by tying the maxilla to the stereotaxic board. Simultaneous contraction of the masseter and digastric was noted in one cat (Figure 17). This preparation was stabilized by the adjustable palatal bar. The spikes of contraction in Figure 17 are due to respiration.

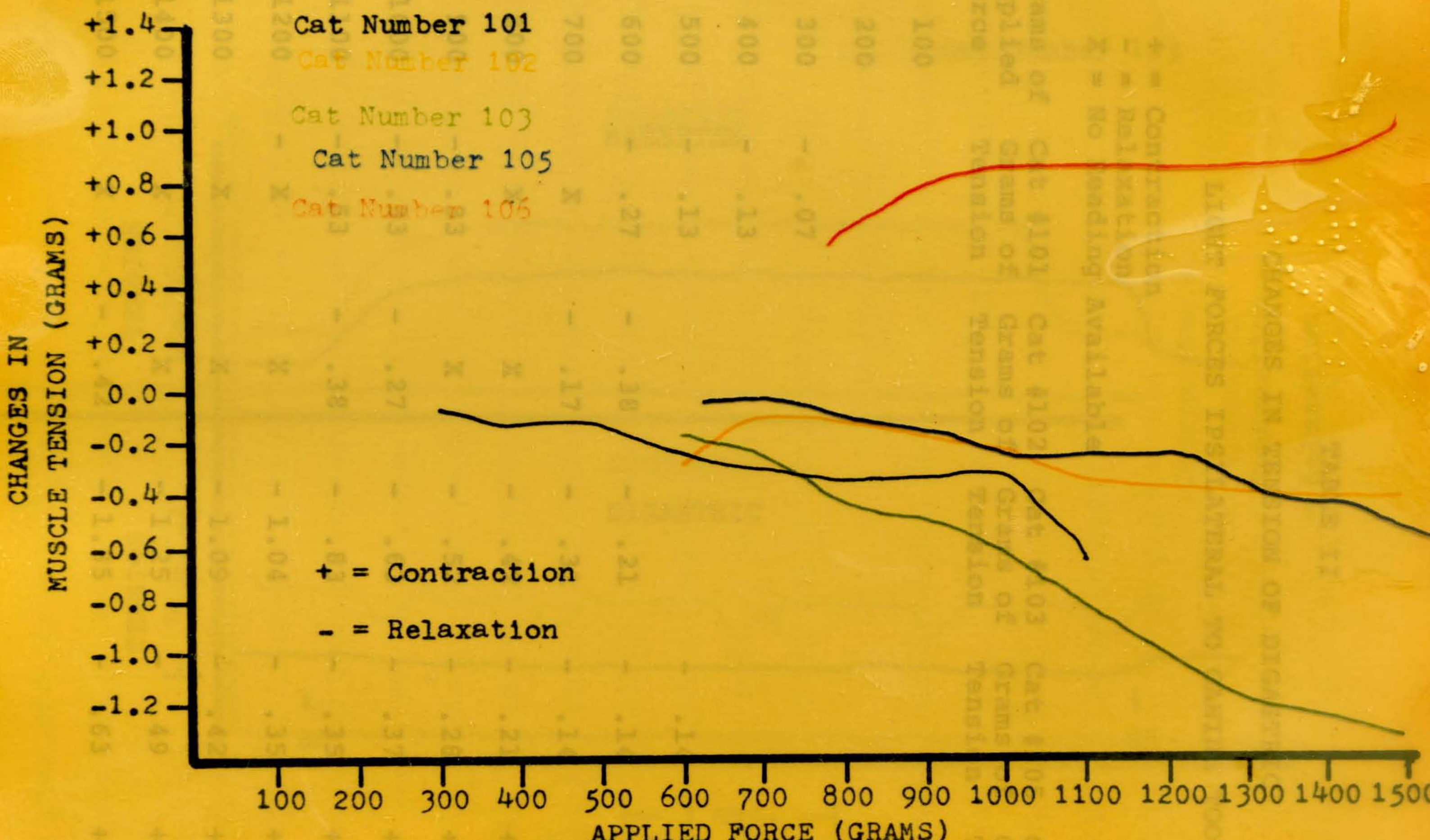
TABLE I

CHANGES IN TENSION OF MASSETER

LIGHT FORCES IPSILATERAL TO CANINE TOOTH

+ = Contraction
- = Rexaxation
X = No Reading Available

| Grams of Applied Force | Cat #101 Grams of Tension | Cat #102 Grams of Tension | Cat #103 Grams of Tension | Cat #104 Grams of Tension | Cat #106 Grams of Tension |
|---|---|---|---|---|---|
| 75 | | | | + 1.56 | |
| 100 | | | + 5.25 | + 3.75 | + 3.00 |
| 200 | | + 3.65 | + 9.38 | + 6.56 | + 6.00 |
| 300 | + 5.81 | + 6.86 | + 12.75 | + 10.25 | + 7.75 |
| 400 | + 6.41 | + 8.57 | + 20.25 | + 13.33 | + 10.50 |
| 500 | + 6.84 | + 15.60 | + 21.75 | + 15.00 | + 14.25 |
| 600 | + 11.11 | + 16.71 | + 33.00 | + 23.14 | + 22.50 |
| 700 | + 15.38 | + 17.57 | + 40.50 | + 26.88 | + 22.50 |
| 800 | + 17.09 | + 24.00 | + 48.00 | + 28.75 | + 22.75 |
| 900 | + 17.09 | + 24.90 | + 52.50 | + 36.25 | + 24.50 |
| 1000 | + 18.00 | + 27.42 | + 58.50 | + 42.86 | + 28.00 |
| 1100 | + 20.51 | + 33.42 | + 70.50 | + 48.13 | + 33.75 |
| 1200 | + 20.51 | + 39.42 | + 75.00 | + 51.88 | + 35.25 |
| 1300 | + 25.64 | + 45.42 | + 81.00 | + 55.63 | + 36.75 |
| 1400 | X | + 47.10 | + 97.50 | + 58.75 | + 40.75 |
| 1500 | + 48.20 | + 52.70 | +106.50 | + 65.00 | + 40.75 |




DIGASTRIC MUSCLE

Figure 14

TABLE II

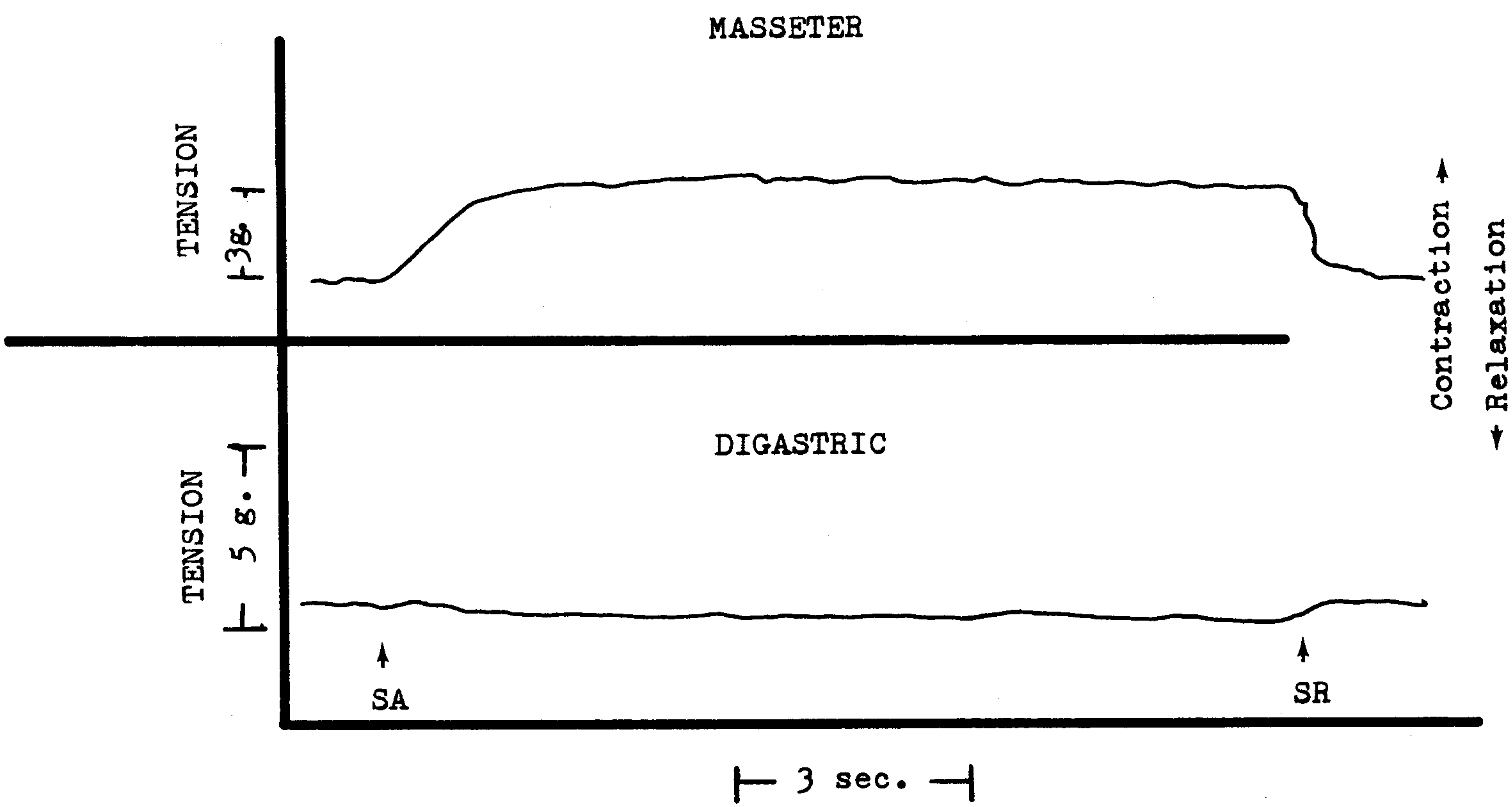
CHANGES IN TENSION OF DIGASTRIC

LIGHT FORCES IPSILATERAL TO CANINE TOOTH

+ = Contraction
- = Relaxation
X = No Reading Available

| Grams of Applied Force | Cat #101 Grams of Tension | Cat #102 Grams of Tension | Cat #103 Grams of Tension | Cat #105 Grams of Tension | Cat #106 Grams of Tension |
|---|---|---|---|---|---|
| 100 | | | | | |
| 200 | | | | | |
| 300 | - .07 | | | | |
| 400 | - .13 | | | | |
| 500 | - .13 | | | - .14 | |
| 600 | - .27 | - .38 | - .21 | - .14 | |
| 700 | X | - .17 | - .31 | - .14 | |
| 800 | X | X | - .42 | - .21 | + .46 |
| 900 | - .33 | X | - .52 | - .28 | + .67 |
| 1000 | - .33 | - .27 | - .63 | - .37 | + .75 |
| 1100 | - .53 | - .38 | - .83 | - .35 | + .75 |
| 1200 | - X | X | - 1.04 | - .35 | + .75 |
| 1300 | X | X | - 1.09 | - .42 | + .75 |
| 1400 | X | X | - 1.25 | - .49 | + .79 |
| 1500 | X | - .42 | - 1.35 | - .63 | + .92 |

Cat Number 103

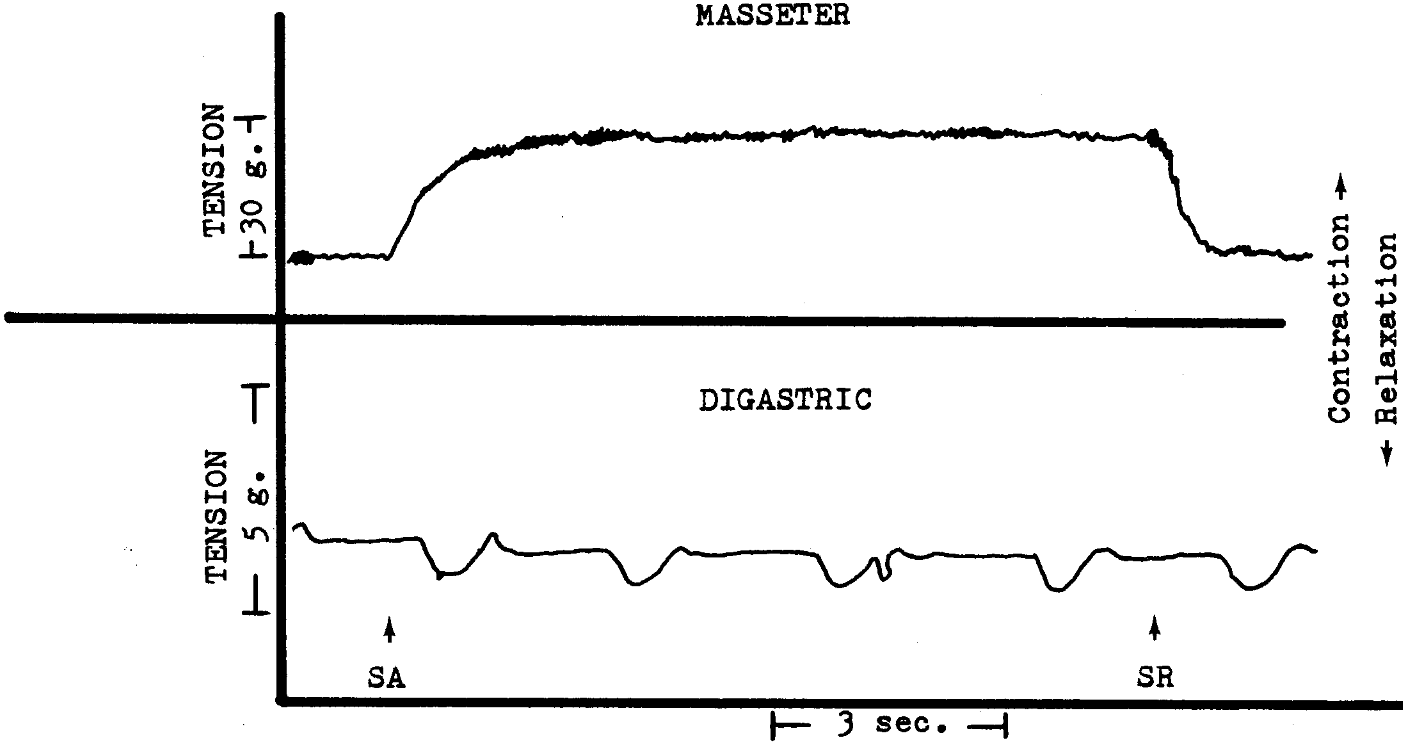



SA = Stimulus Applied
SR = Stimulus Removed

700 g. FORCE STIMULUS
NOTE RECIPROCAL ACTION

Figure 15

Cat Number 102




SA = Stimulus Applied
SR = Stimulus Removed

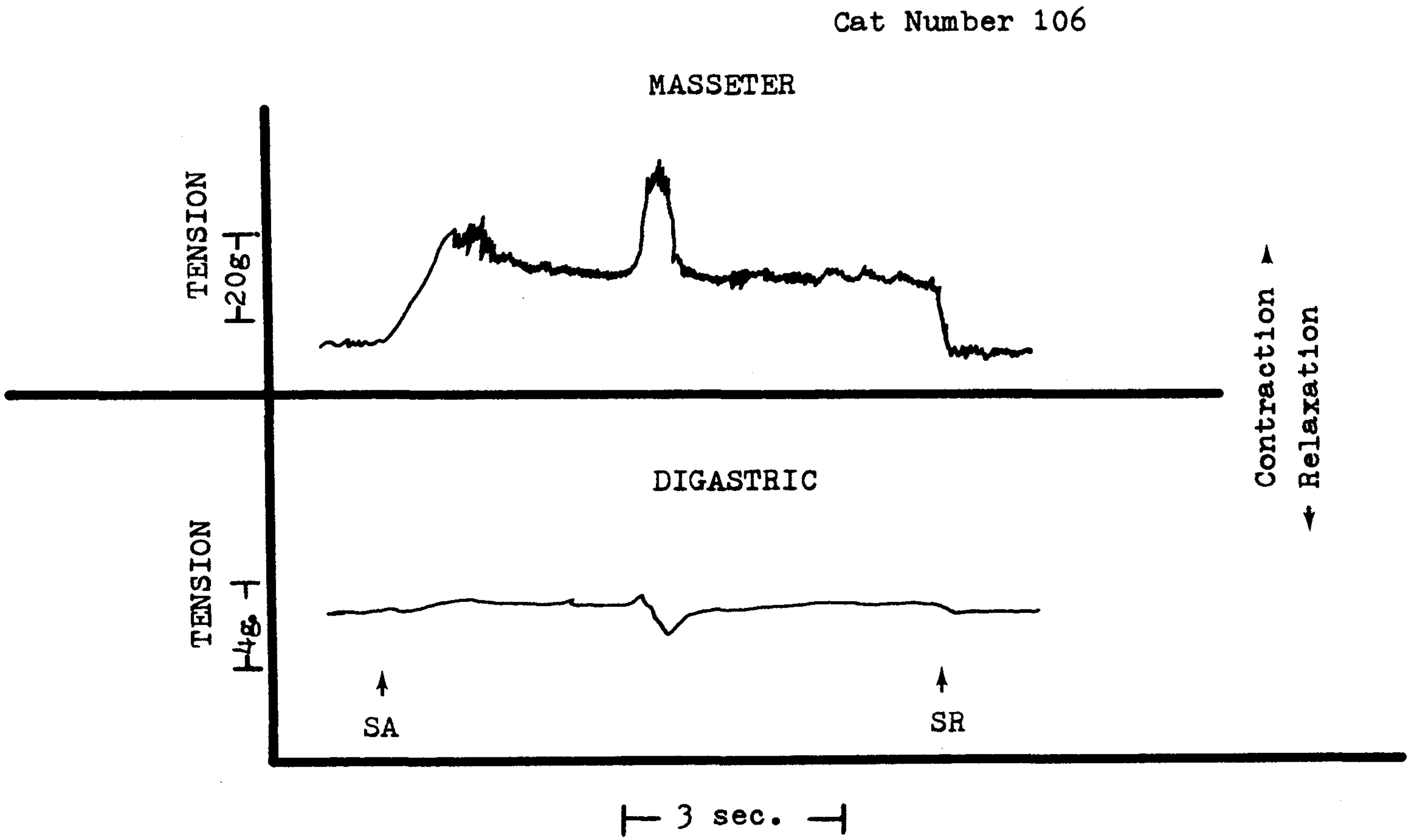
1000 g. FORCE STIMULUS
NOTE RECIPROCAL ACTION

Figure 16

Relaxation of the masseter and contraction of the digastric throughout the application of heavy force stimuli occurred in only one instance (Figure 18). A simultaneous contraction of the two muscles was noted in the other preparations. Occasionally, an initial masseter relaxation followed by a secondary contraction of that muscle above base tension was evident (Figure 19). A delayed masseter contraction was noted in many instances where the initial relaxation was not obtained.

Electrical stimulation of the palatal gingiva on the ipsilateral side also resulted in some instances in an initial masseter relaxation followed by contraction (Figures 20 & 21). The spikes of the digastric in Figure 21 are a result of increased respiratory depth and rate. Such a change in respiration is indicative of pain. These results were obtained within a range of 25 to 50 volts at a frequency of 25 impulses/sec. The initial masseter relaxation was not evident in all instances; however, delayed masseter contraction was again frequently observed. Simultaneous contraction of both muscles occurred especially between 50 and 100 volts at 25 impulses/sec.

A continuous reciprocal action of the masseter and digastric occurred at 17.5 volts and 25 impulses/sec. The

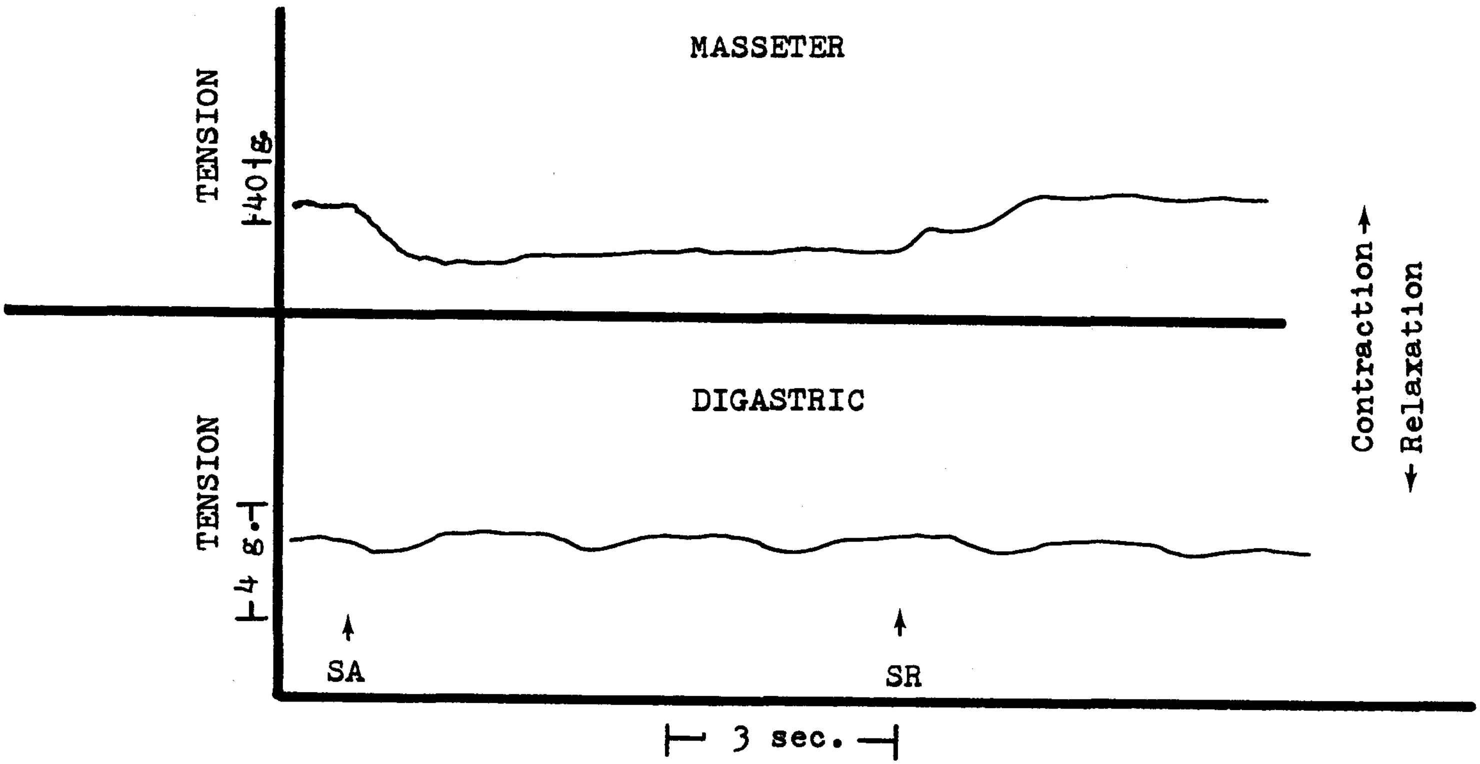



SA = Stimulus Applied
SR = Stimulus Removed

1000 g. FORCE STIMULUS
NOTE MUSCLES CONTRACTING SIMULTANEOUSLY

Figure 17

Cat Number 107

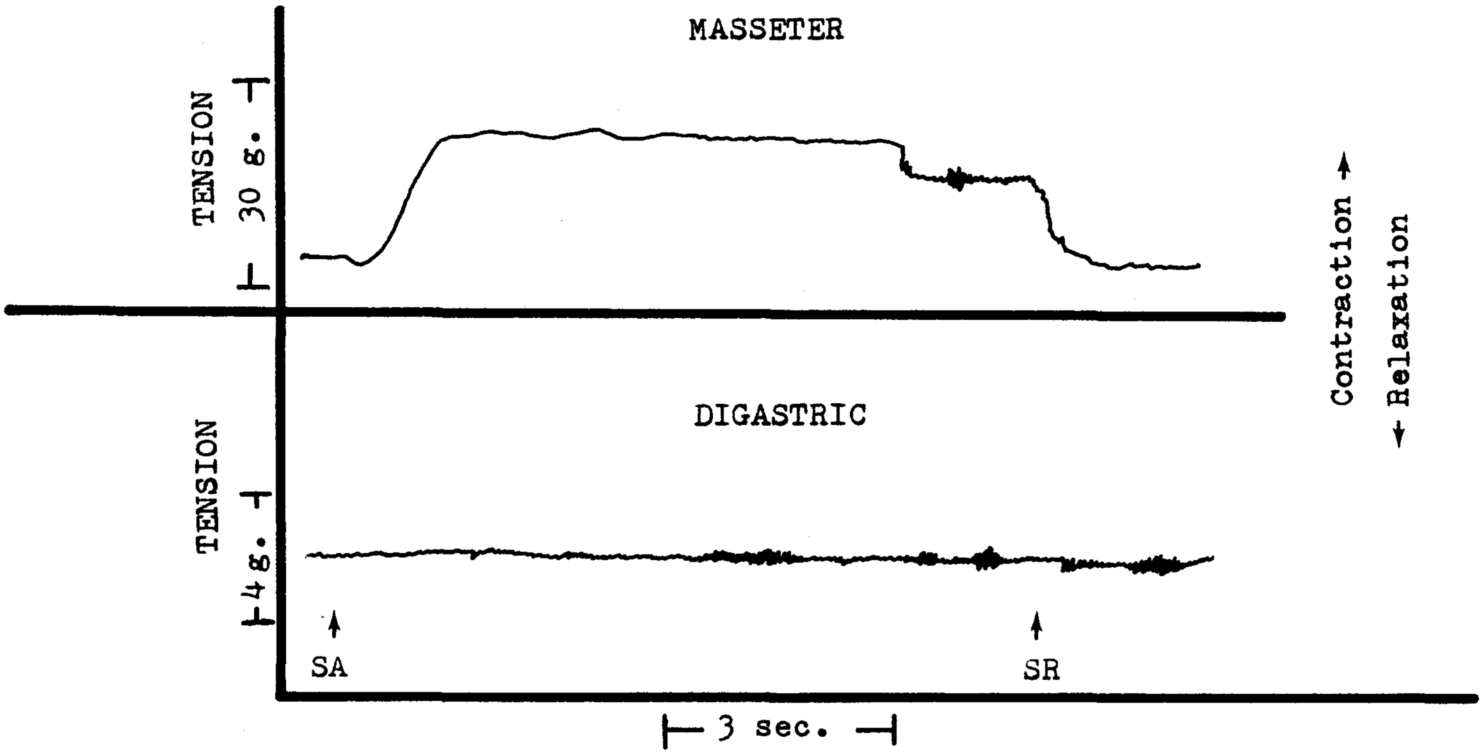



SA = Stimulus Applied
SR = Stimulus Removed

13,608 g. (30 lbs.) FORCE STIMULUS
NOTE RECIPROCAL ACTION

Figure 18

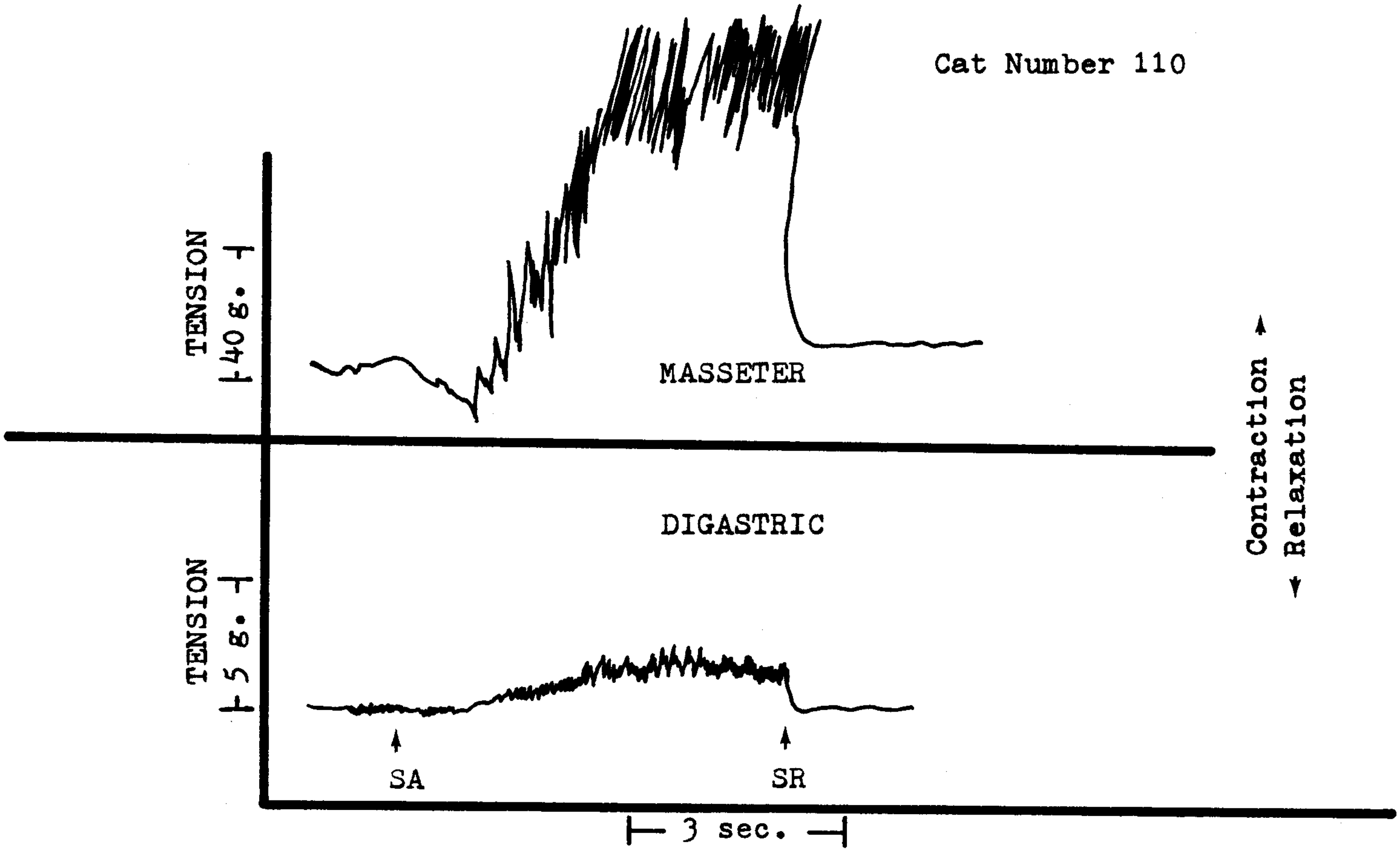
Cat Number 108




SA = Stimulus Applied
SR = Stimulus Removed

13,608 g. (30 lbs.) FORCE STIMULUS
PAIN: NOTE INITIAL MASSETER RELAXATION & SECONDARY CONTRACTION

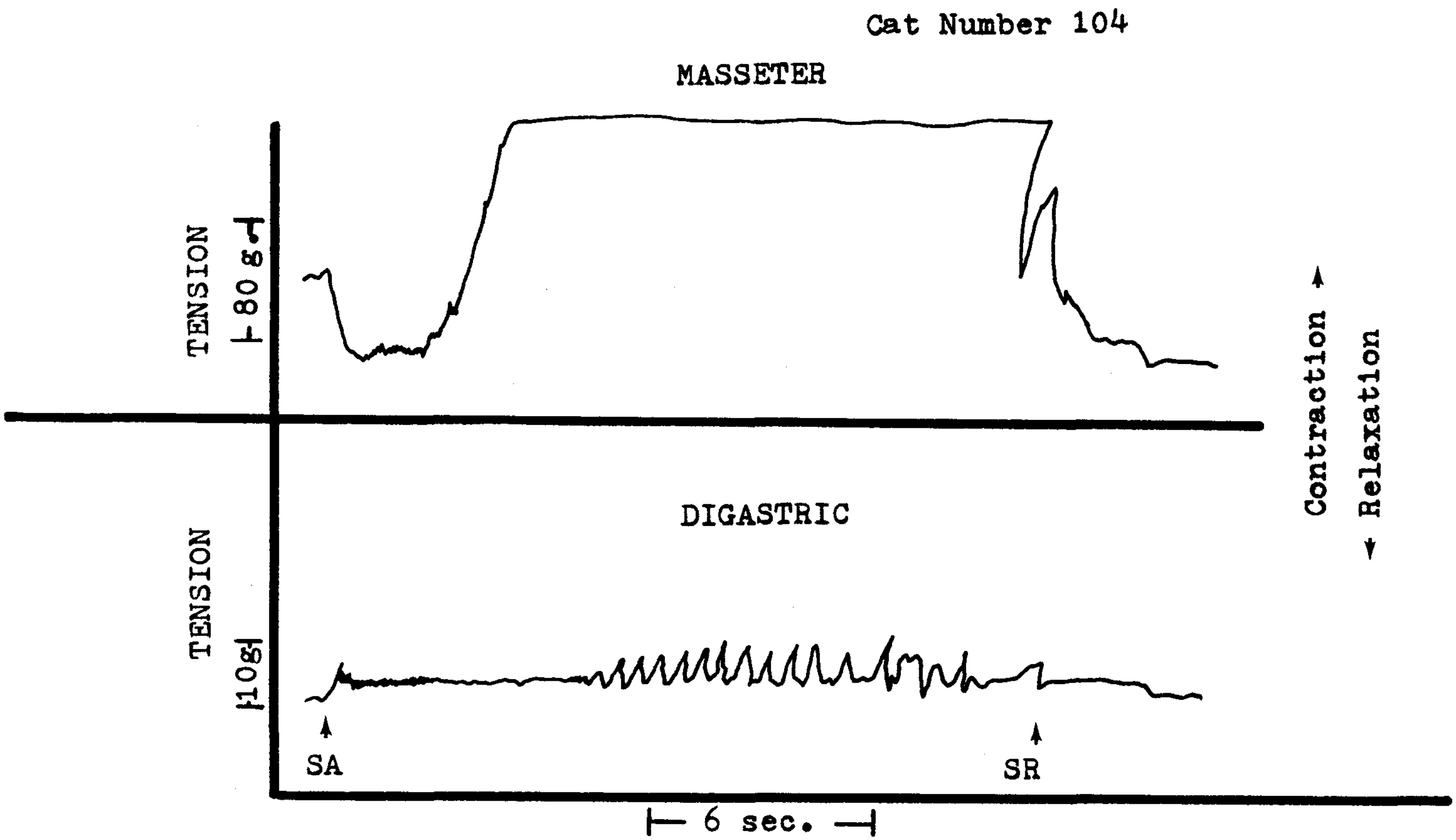
Figure 19




SA = Stimulus Applied
SR = Stimulus Removed

25 volts & 25 impulses/sec.
PAIN: NOTE INITIAL MASSETER RELAXATION & SECONDARY CONTRACTION

Figure 20



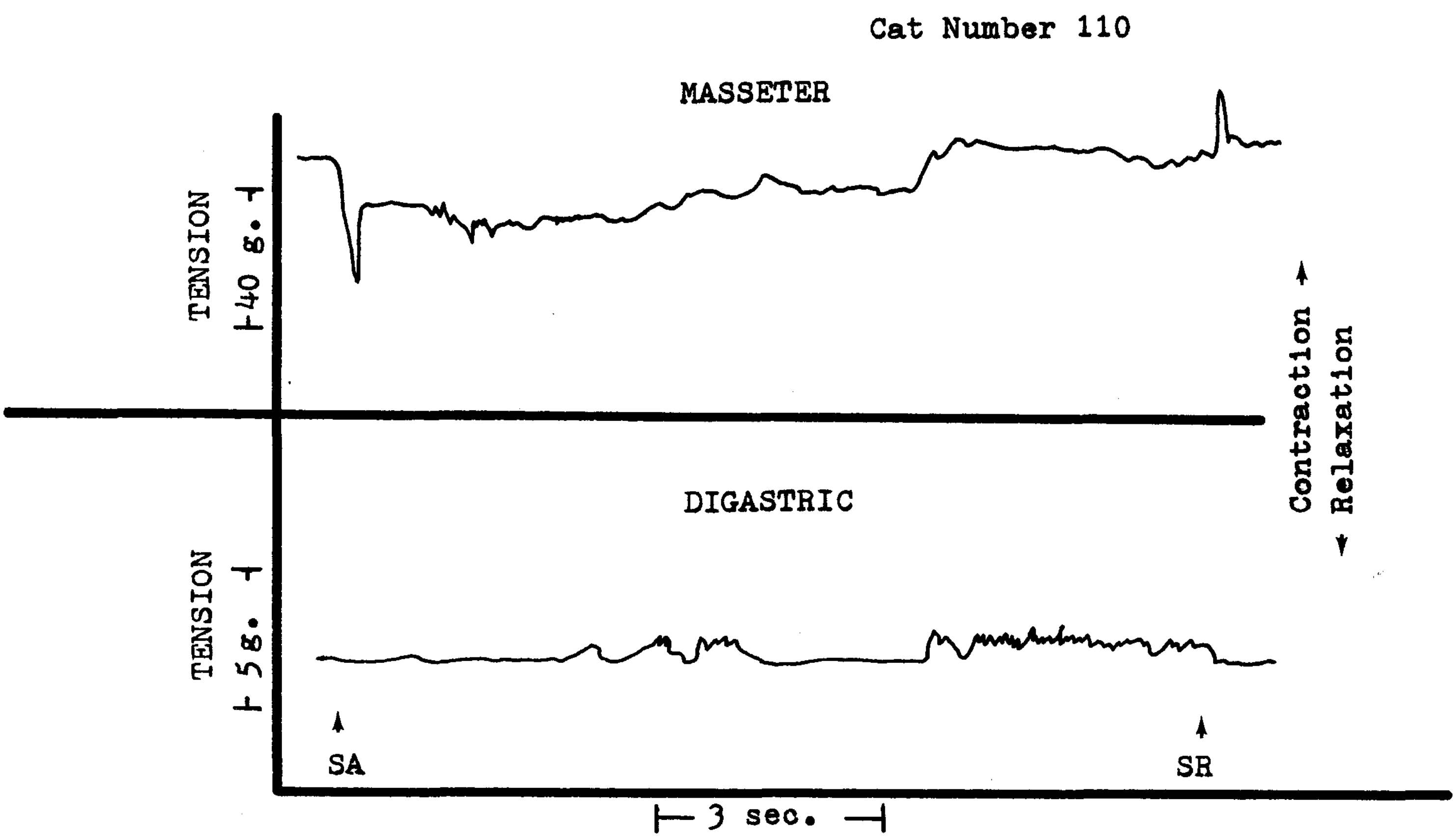

SA = Stimulus Applied
SR = Stimulus Removed

50 volts & 25 impulses/sec.
PAIN: NOTE INITIAL MASSETER RELAXATION & SECONDARY CONTRACTION

Figure 21

masseter relaxed and the digastric displayed contraction (Figure 22).

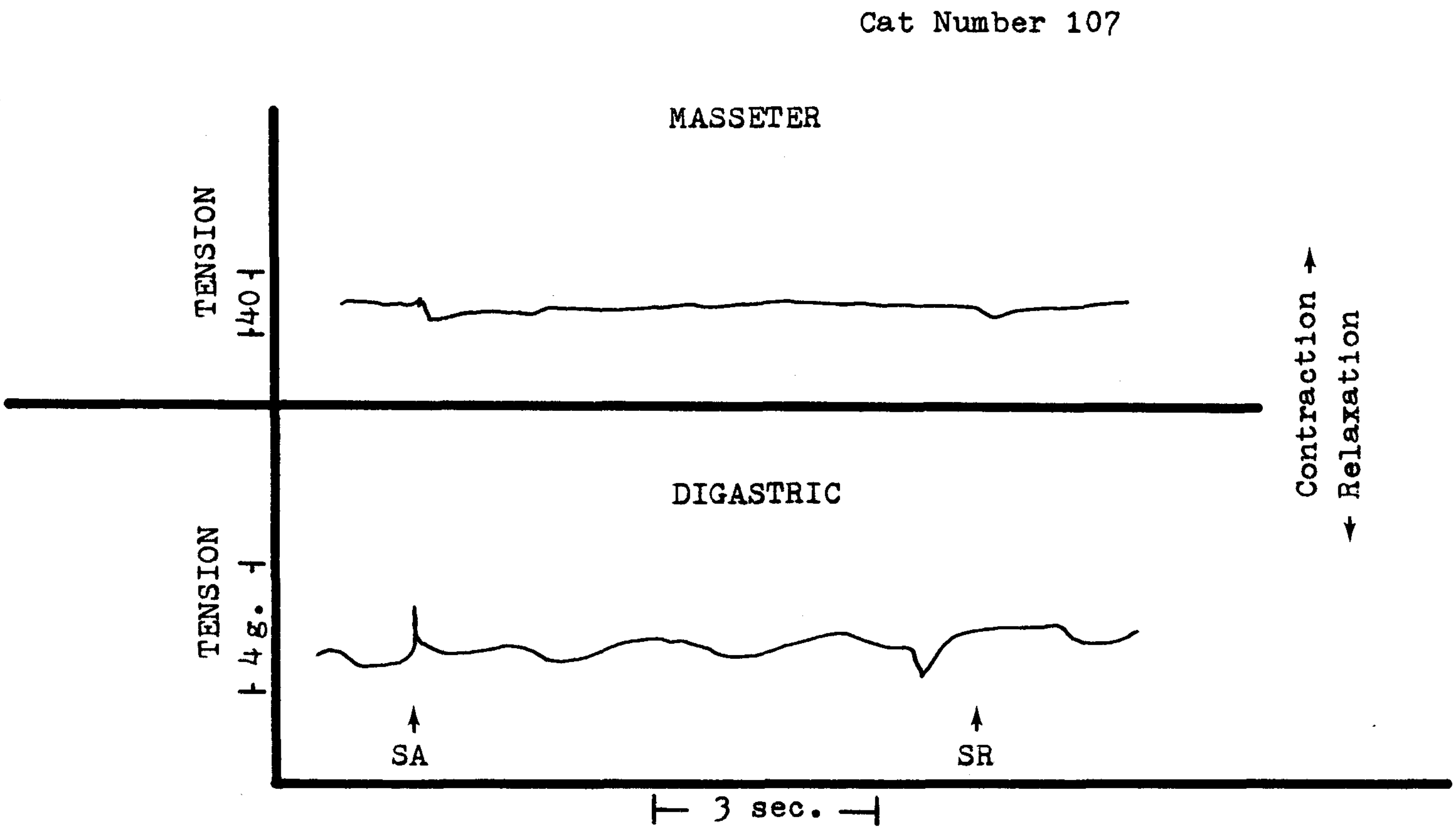
The maxillary canine tooth was severed even with the gingiva so that both a mechanical and electrical stimulus could be applied to the pulp. The mechanical stimuli caused an initial contraction of the digastric and relaxation of masseter followed by a return to the original tension (Figure 23). One electrode was allowed to remain in the pulp canal and another applied to the exposed dentin. The masseter showed very little change in this case (stimulus of ten volts and two impulses/sec.). The digastric displayed contraction spikes every one-half second. See Figure 24. Masseter relaxation occurred when the frequency was increased to 50 impulses/sec. and the electrical potential retained at ten volts (Figure 25). A high initial spike of digastric contraction followed by a return toward base tension was noted.




SA = Stimulus Applied
SR = Stimulus Removed

17.5 volts & 25 impulses/sec.
PAIN: NOTE MASSETER RELAXATION AND DIGASTRIC CONTRACTION

Figure 22

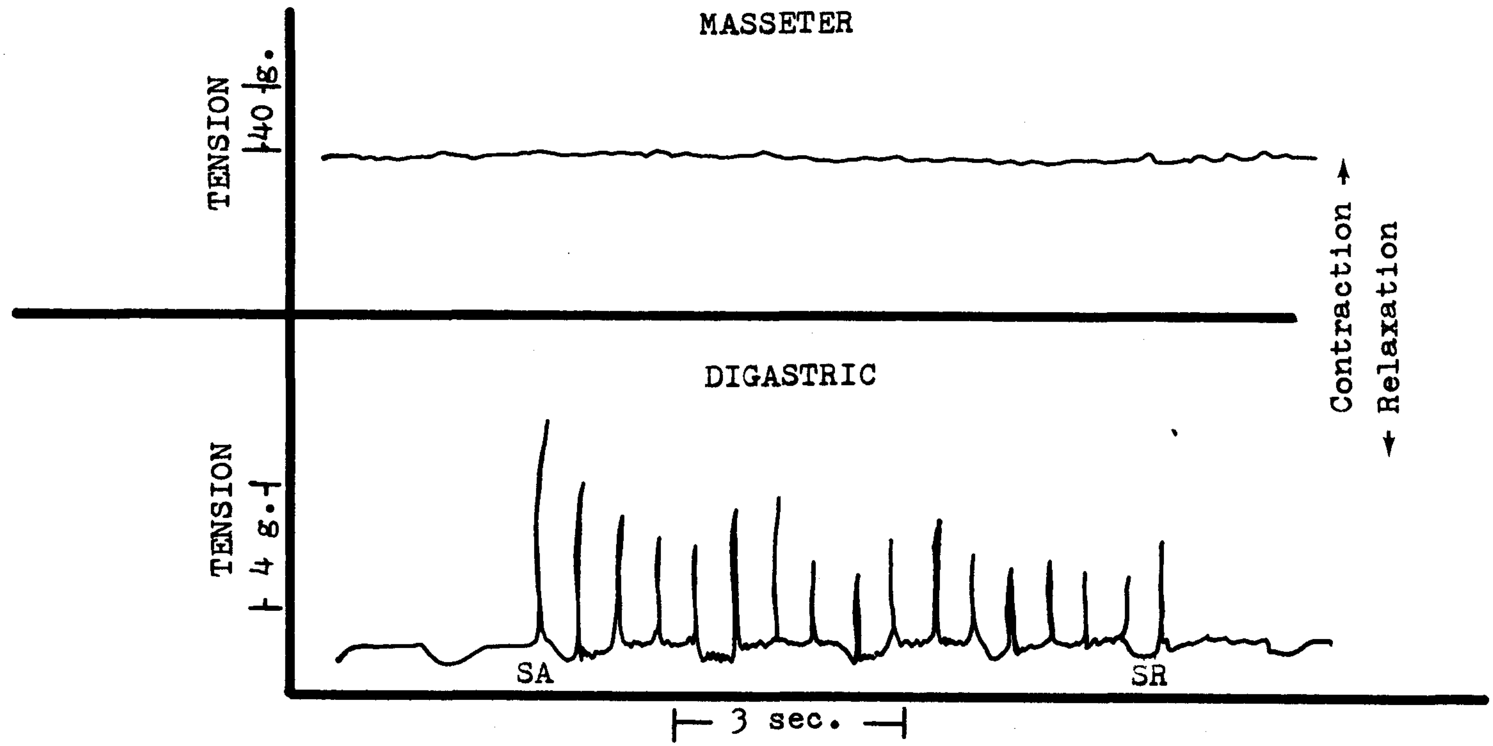



SA = Stimulus Applied
SR = Stimulus Removed

MECHANICAL PULP STIMULUS

Figure 23

Cat Number 107

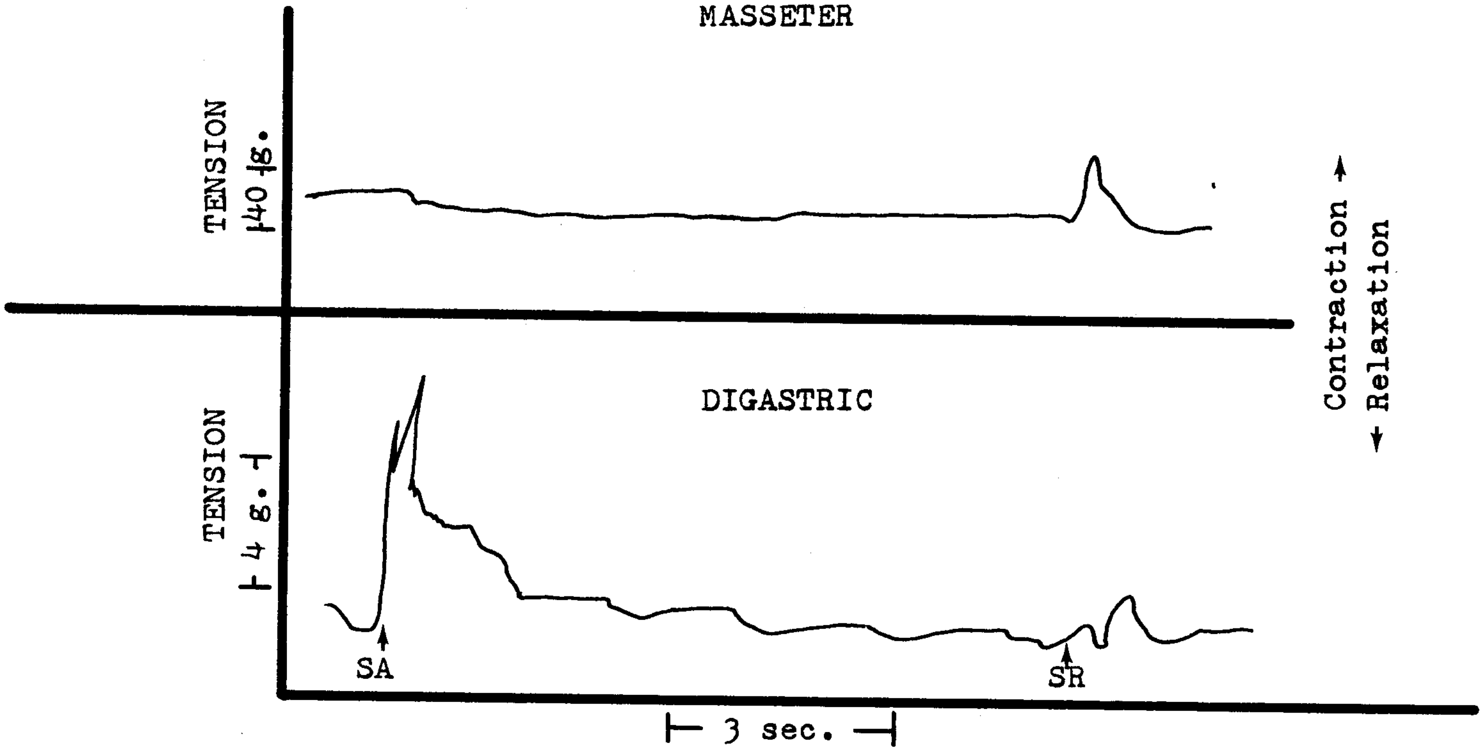



SA = Stimulus Applied
SR = Stimulus Removed

10 volts & 2 impulses/sec.
ELECTRICAL PULP STIMULATION

Figure 24

Cat Number 107




SA = Stimulus Applied
SR = Stimulus Removed

10 volts & 50 impulses/sec.
ELECTRICAL PULP STIMULATION

Figure 25

# CHAPTER V

## DISCUSSION

The phenomenon of decerebrate rigidity depends upon the dominance of the myotatic reflex. This monosynaptic reflex is initiated by a specialized receptor, the muscle spindle. The afferent input from the muscle spindle is due to tension on the nuclear bag of the spindle. These impulses are transmitted by A fibers from Group I, the most rapid conducting afferent fibers in the body. The muscle spindles are found in skeletal muscle and are especially numerous in the physiologic extensors. The myotatic reflex is consequently best developed in these antigravity muscles.

The spindle receptor, itself, initiates the reflex and is fired by passive stretch placed on the muscle. The postsynaptic efferent impulses terminate in motor end plates of the extrafusal muscle fibers, those fibers responsible for active tension developed in muscles. Tonic muscle tension is therefore influenced by the spindle receptor.

The threshold required to excite this receptor can be regulated by the central nervous system. This is accomplished by effecting contraction or relaxation of the intrafusal fibers within the muscle spindle. Tension on the nuclear bag is increased during contraction of these intrafusal fibers, and the receptor threshold to passive muscle stretch is consequently decreased.

Inhibitory pathways from higher brain centers which tonically suppress the myotatic reflex are interrupted in the decerebrate preparation. The overall result of the removal of the inhibitory brain centers, therefore, results in a dominance of the myotatic reflex. The extensor muscles of the animal become dominant since the myotatic reflex is best developed in these antigravity muscles. This reflex in addition is always facilitory to neurons affecting synergistic muscles and inhibitory to neurons supplying antagonistic muscles.

Reflex jaw closing and opening occurred when the mandible was forcibly depressed with a metal instrument (Sherrington, 1917 and Kawamura, 1958).

Digastric relaxation resulted from stretch applied to the masseter. A decrease in masseter tension occurred when stretch was applied to the digastric. These findings agree with Sherrington's work in which he reported that reflexes obtained from the decerebrate animal exhibit contraction in one muscle group accompanied by inhibition of the antagonistic muscle group. The reflexes initiated by the muscle spindles of the masseter and digastric are therefore reciprocal.

The application of light force stimuli along the long axis of the maxillary canine tooth elicited reciprocal alteration in tension for these muscles in all but one animal. Generally, these stimuli evoked a reflex which resulted in masseter contraction and digastric relaxation. Closure of the mandible is indicated by the action of these muscles. The lower jaw was stabilized in order to eliminate changes in proprioceptive input due to movement of the mandible.

Harrison and Corbin (1942) found that in the decerebrate cat light taps on the teeth elicited jaw movements. The type of movement was constant in any one animal but was equally divided between jaw opening and closing when several animals were examined. These investigators, however, failed to report the tooth or teeth employed and the magnitudes or directions of the stimuli.

Kizior (1966) found two types of functional receptors in the periodontal ligament of the cat. The ovoid encapsulated receptor had low thresholds for force application and was classified as proprioceptive in action. Activity in the inferior alveolar nerve as a result of sustained incisal force stimuli could be observed as low as four grams. Ness (1954) found that the threshold for rabbit teeth had a range from one to two grams. A threshold value of two to three grams for adult cats was reported by Pfaffman (1939).

A measurable increase in masseter muscle tension of the decerebrate cat was not observed until between 75 and 300 grams of sustained incisal forces had been applied. The mean threshold for this proprioceptive reflex was 155 grams. The threshold for digastric relaxation ranged from 300 to 600 grams with a mean of 500 grams. The ranges of 0-30 and 0-500 grams for the myographs employed limited the amount of initial tension which could be placed on the muscle. Initial tension is far below normal value since the muscles could not be stretched to their original physiological length (i.e. previous to detachment). A decrease in muscle tension, consequently, will be more difficult to record than in increase. This probably accounts for the different thresholds recorded for the masseter and digastric. Further, the digastric is one of a group of suprahyoid muscles with force vectors which tend to depress the mandible. These muscles are small in mass and are aided by gravitational pull; consequently, they may be expected to show less tension change than the mandibular elevators which are much larger in mass.

Light force stimuli (below 600 grams) applied to a single tooth caused minimal changes in muscle tension. In all likelihood very little input from the periodontal ligament of one tooth is associated with such low forces.

The reciprocal action of the masseter and digastric is in harmony with the electromyographic findings of Carlsoo in 1956. He reported a gradual decrease in digastric activity upon mandibular closure accompanied by an increase in activity of the elevator muscles.

The preparation which did not show a reciprocal relationship between the masseter and digastric is of particular interest. This animal was the only one stabilized by the aluminum palatal bar. Immobilization of this preparation created a strong continuous tactile input. Whereas the digastric muscle relaxed in the other animals at these forces, in this cat there was an increase in tension of both muscles. The threshold for digastric activity in this instance was 800 grams, 300 grams higher than the mean of the other preparations. It is conceivable that the animal was experiencing pain due to the palatal bar and at 800 grams of applied force some peridontal pain receptors were activated.

This input caused digastric contraction. The pain reflex was probably overriding the proprioceptive input from the periodontal ligament at this force level.

Pain stimuli were produced by high magnitude forces, mechanical pressure to the pulp of the canine tooth and electrical stimulation to the pulp or surrounding gingiva.

Relaxation of the masseter and contraction of the digastric throughout the application of high magnitude force stimuli occurred in only one preparation. These findings indicate mandibular opening as a result of painful stimuli. Carlsoo has stated that mandibular opening resulted in an increase in electromyographic activity of the digastric and decrease in the elevator muscles. The threshold for this reciprocal action was 4.54 kg.

A continuous reciprocal action was not noted in the other preparations consequent to high magnitude force stimuli. An increase in tension for both muscles occurred; however, in some instances an initial relaxation of the masseter was clearly evident. This reaction was transient and followed by contraction above the base tension. Mandibular opening is implied by the initial masseter relaxation when coupled with digastric contraction. Secondary mandibular fixation is probable when both muscles are contracting simultaneously. A delayed contraction of the masseter was noted in many instances where the initial relaxation was not obtained. The limitation of the myograph may explain the failure to record the initial masseter relaxation. The physiological significance of mandibular fixation could be a defense mechanism protecting the temporomandibular joint from injury due to a wide opening of the jaws.

Pain evoked by electrical stimuli to the gingiva was especially noticeable from 25 to 50 volts at 25 impulses/sec. The same initial masseter relaxation followed by contraction as occurred during heavy force application was observed in some preparations. This initial relaxation, however, was not as prevalent between 50 and 100 volts at the same frequency. Simultaneous contraction of both muscles occurred most often at these high voltages; yet, instances of delayed masseter contraction were again noted.

The lowest voltage and frequency resulting in a clearly evident pain reflex (mandibular opening) occurred at 17.5 volts and 25 impulses/sec. Masseter relaxation and digastric contraction occurred. Harrison and Corbin (1942) have previously reported that electrical stimulation to the tooth, gums and palate provoked mandibular opening.

Mechanical stimulation of the pulp produced a transient pain reflex of the musculature under investigation. A needle was placed in the pulp and allowed to remain. There was an initial relaxation of the masseter and a contraction of the digastric followed by a return of the muscles to base tension. A fairly rapid adaptation to this stimulus was evident.

Each digastric contraction spike due to electrical stimulation (ten volts and two impulses/sec.) of the pulp corresponded to a single stimulus. Sustained contraction due to a fusion of digastric twitches occurred when the frequency was increased to 50 impulses/sec. and the output retained at ten volts. This does not necessarily imply that the fusion frequency for the digastric muscle is 50 impulses/sec. The sustained muscular contraction was probably due to reverberative circuitry in the central nervous system with the result that the impulse rate along the efferent nerve to the muscle exceeded 50 impulses/sec.

# CHAPTER VI

## SUMMARY AND CONCLUSIONS

Alterations in tension of the masseter and digastric muscles elicited by proprioceptive and painful stimuli to the ipsilateral maxillary canine tooth were investigated in the decerebrate cat. The reflex response and relationship of the muscles were recorded by use of a physiograph.

Forces delivered by the torque wrench (75-1500 grams) evoked a proprioceptive input implying mandibular closure. The masseter displayed contraction in every instance, while the digastric relaxed in all preparations but one. The mean threshold for the digastric during reciprocal action at low forces was 500 grams and the masseter threshold was 155 grams.

Painful stimuli were administered by heavy forces applied to the ipsilateral maxillary canine tooth. This was accomplished by means of the hydraulic instrument. Electrical stimulation of the palatal gingiva and pulp of the canine tooth were also employed as pain stimuli.

Only one preparation responded to pain with a relaxation of the masseter and contraction of the digastric throughout the application of heavy force stimuli. Mandibular opening is implied by these alterations in muscle tension. Two phases of muscle response were encountered as a result of pain stimuli (heavy force and electrical stimulation) in the other preparations. Mandibular opening is effected in the initial phase due to masseter relaxation and digastric contraction. Both muscles contract in the second phase with a resultant fixation of the mandible.

The lowest strength and frequency to elicit a painful reflex due to application of the electrodes on the palatal gingiva was 17.5 volts and 25 impulses/sec.

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APPROVAL SHEET

The thesis submitted by Dr. Wesley H. Ardoin has been read and approved by members of the Department of Oral Biology.

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.

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