ELECTROMYOGRAPHIC ACTIVITY OF MENTALIS MUSCLE IN ANGLE'S CLASS II DIVISION 1 MALOCCLUSION: A PILOT STUDY

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CONTENTS

page

page

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The relationship between lip morphology, in particular that of the lower lip, and its role in the aetiology, maintenance or an exacerbation of an Angle's Class II Division 1 malocclusion has long been the subject of orthodontic discussion and research.

Of primary interest to the orthodontist is the influence of the muscles of the lower lip on the positions of the anterior teeth. The lower lip is in the unique position in classical, gross Angle's Class II Division 1 malocclusion cases to influence both the maxillary and mandibular anterior teeth due to its rest position lingual to the upper anterior teeth.

An anatomical component of, and thus a major source of activity of, the lower lip is the mentalis muscle. It is the association between activity of this muscle and the lower lip during functional activities that is the basis of this project.

George Catlin (1862) wrote in a manuscript entitled the "Breath of Life":

> The lips in the day, are generally concerned with eating - drinking - singing - laughing - grinning - pouting - talking - smoking - scolding - whistling - chewing or spitting. Its endless modulations of sound may produce the richest, the sweetest of music, or the most frightful and unpleasant sounds in the world.
>
> It converses - it curses and applauds; it condemns and reproves - it slanders - it flatters - it prays and it profanes - it blasphemes and adores - blows hot and blows cold - speaks soft tones of love and affection, rough notes of vengence and hatred - it bites and it woos - it kisses - eats cherries - roast beef and chicken and a thousand other things - drinks coffee, gin and mint juleps and sometimes brandy - takes pills, rhubarb and magnesia - tells tales and keeps secrets - is pretty or ugly - of all shapes and of all sizes - with teeth white - teeth black and teeth yellow and with no teeth at all.

While acknowledging the immense range of activities of the lips, the purpose of this thesis is to monitor mentalis muscle activity as it is involved in everyday functions of the lower lip during chewing, swallowing, speaking and while at rest. Another objective of this project is to introduce the field of electromyography to the author as a means of gauging muscular activity.

Of perhaps a more practical nature is to attempt to ascertain whether any relationship exists between mentalis muscle activity in Angle's Class II Division 1 malocclusion cases and the accompanying soft tissue morphology compared to non-malocclusion Angle's Class I cases with acceptable lip morphology.

In other words, is mentalis muscle activity significantly different in the malocclusion cases compared to the non-malocclusion cases and if so, is it such that one could expect any detrimental muscular influence to be exerted on the anterior teeth by the lower lip?

A. REVIEW OF LITERATURE

1. ELECTROMYOGRAPHY

1.1 HISTORY AND DEVELOPMENT OF ELECTROMYOGRAPHY

The ancient Greeks were acquainted with the curious properties possessed by two minerals, amber and magnetic iron ore. The former, when rubbed, attracts light bodies, the latter has the power of attracting iron (Whittaker, 1951). At the end of the 16th Century, Gilbert coined the word "electricity", a Greek word meaning amber, but not until the 18th Century was the electric phenomenon investigated to any great extent (Joseph, 1960).

Basmajian (1979) records Galvani at this time as reporting his epoch-making experiments with nerve-muscle preparations and animal activity. For more than two centuries, biologists and associated workers have known and acted on Galvani's revelation that skeletal muscles will contract when stimulated electrically and, conversely, that they produce a detectable current or voltage when they contract from any other cause.

The flow of current from isolated contracting striated muscle was the next important observation, made independently circa 1840 by both Matteucci and du Bois-Reymond (Joseph, 1960).

Møller (1966) further describes du Bois-Reymond's work on the electrical activity of muscle during voluntary contraction in man:

> ... one finger on each hand of the subject was connected to the leads of a needle galvanometer. As each arm was flexed there was a deflection of the needle. The degree of deflection increased with the strength of contraction, was larger when the right arm was flexed in right-handed subjects, increased when the epidermis was removed and decreased at the onset of fatigue.

Møller (1966) also describes work done by Piper in 1907 and Buchanan in 1908 as recording the action potentials in the muscles on photographic paper. They found that contraction was associated with potential changes which increased in amplitude with the strength of contraction.

Galvani's discovery that muscles produce electricity, proved to be largely a scientific curiosity until the 20th Century when improved methods of detecting and recording minute electrical discharges became widely available. These advances in improved instrumentation included: the electronic amplifier of Forbes and Thanker, based on Fleming's thermionic valve invented in 1914; the electromagnetic oscillograph of Matthews; and the cathode-ray oscilloscope. These replaced the more slowly responding galvanometers previously employed and made it possible to obtain more detailed information about the conduction velocity and the time course of the action potential in different types of fibre (Joseph, 1960).

Further important developments in electromyographic technique were carried out by Adrian and Bronk (1929) through to Moyer's (1949) introduction of electromyography into dental research. During the decade of the 1950's, electromyography for anatomical studies became widespread. Frequent reports from American, British, Canadian, Scandanavian, French and German sources became commonplace in the literature (Basmajian, 1979).

Electromyography has become a recognized method of investigating the activity of a muscle both in its normal functioning and in disease and hence has been used extensively as a research tool in oral physiology.

1.2 DEFINITION OF ELECTROMYOGRAPHY

Dorland's (1975) definition of electromyography as "the recording of changes in the electrical potential in muscle" is a condensation of the definition by Møller (1958) as:

> ... the recording of muscle action potentials which, in voluntary contraction, represent the sum of the action potentials from the muscle fibres forming a motor unit. The single fibre potentials result from the breakdown and re-building of the potential difference, which at rest exists across the surface membrane surrounding the individual muscle fibre.

1.3 ELECTROMYOGRAPHIC INSTRUMENTATION

1.31 Electrodes

The electrodes used in electromyography consist of a wide variety of types and construction. Their use depends on the first principle that they must be relatively harmless and must be brought close enough to the muscle under study to pick up its electrical activity (Basmajian, 1979).

Recording of muscle action potentials can be performed extra-muscularly or intra-muscularly, that is, with surface electrodes or inserted electrodes. In both cases, the recording technique can be either bipolar or unipolar.

In the bipolar technique, recording is done with two similar electrodes both placed in or on the muscle.

In the monopolar technique, recording takes place between an electrode placed in or on the muscle and an "indifferent electrode". This indifferent, or reference electrode is either placed so that its possibilities of recording action potentials are a minimum, or by letting it cover an extensive area so that the action potentials recorded from underlying muscles are so small, that they do not interfere with the potentials picked up by the different electrode (Møller, 1958).

The potential difference is measured in both the bipolar and the monopolar techniques; thus the electromyogram shows the difference between the potentials at the two electrodes.

Types of electrode

A)	Surface electrodes	a)	Disposable surface type
		b)	Spray-on electrode
B)	Inserted electrodes	a)	Bipolar concentric
		b)	Unipolar
		c)	Fine-wire
C)	Microelectrodes	a)	Glass
		b)	Metal

A) Surface electrodes

Joseph (1960) reports that the first successful demonstration of action potentials from the intact human subject was made by Herman in 1877 using two loops of rope soaked in zinc sulphate solution and placed around the forearm.

Surface electrodes today are obtained commercially but are generally regarded as being only suitable for use on superficial muscles (Basmajian, 1979). Agreement is expressed by Møller (1966) who feels that surface electrodes, in the orofacial sphere, are primarily suitable for functional analysis of temporal, masseter and orbicularis oris muscles. Simpson (1975), using surface electrodes for recordings of orbicularis oris, mentalis and supra-hypoid muscles at rest, in lip seal and during swallowing, considers that, assuming the recordings are made under ideal conditions, the data may be accepted as a true and reproducible measure of muscle activity.

Basmajian (1979) feels that due to the widespread pick-up of surface electrodes, their chief usefulness could be where simultaneous activity or interplay of activity is being studied in a fairly large group of muscles under conditions where individual palpation is almost impossible. This viewpoint is supported by White and Basmajian (1973), Yemm, El-Sharkawy and Stephens (1978).

The overall attitude towards surface electrodes is that they are not accurate enough in the study of fine measurements, deep muscles, the presence or absence of activity in various postures and, overall, any circumstances where precision recording is desirable.

B) Inserted electrodes

Analysis of duration, amplitude and shape of action potentials from individual motor units necessitates intra-muscular recording (Møller, 1966). This statement supports earlier reports by Møller (1958), Moyers (1949) and Basmajian (1962).

Basically, there are three types of inserted electrode:

a) Bipolar, concentric, needle electrode

These electrodes were originally described by Adrian and Bronk (1929) for physiological experimentation although Joseph (1960) records a much earlier existence of needle electrodes when, in 1883, Wedenski used needle electrodes in his own biceps brachii.

The concentric needle electrode consists of a simple stainless steel hypodermic needle which contains an insulated wire in its barrel. The tip of the wire is bared and acts as one electrode while the barrel of the needle acts as the other.

Many workers in the field of electromyography have used this type of needle electrode. They include Moyers (1949); Møller (1958); Leanderson, Öhman and Persson (1966); Leanderson, Persson and Öhman (1971); Hrycyshyn and Basmajian (1972); Carey and Cooker (1977).

b) Unipolar needle electrodes

Originally reported by Jasper and Ballem (1949), the unipolar needle electrode consists of a fine, insulated needle for insertion. To obtain a differential potential for electromyographic recordings, the unipolar electrode needs to be paired with a neighbouring surface electrode or with another unipolar needle. Clinical electromyographic investigations in the dental field using unipolar needle electrodes have been performed by Baril and Moyers (1960); Jacob, Haridas and Ammal (1971); Moss and Chalmers (1974); Moss (1975).

c) Bipolar, fine-wire electrodes

The use of these electrodes involves the implanting of bipolar, fine, insulated wires (0.0028 inch diameter) into the desired muscle location by way of a carrier hypodermic needle of suitable gauge. The needle is used to direct the wire into position within muscle and is then withdrawn leaving the hooked, de-insulated wires in position. The free ends of the wires are also de-insulated and connected to the recording device. Being thin, flexible wire, withdrawal of the electrodes is simply performed by a firm tug.

Bipolar, hooked-wire electrodes were originally described by Basmajian and Stecko (1962) but further developed by Schipp, Fishman, Morrissey and McGlone (1970) and Basmajian (1979).

Investigators having used these electrodes include Sumitsuji, Matsumoto, Janaka, Kashiwagi and Kaneko (1967); Abbs (1973); Ahlgren, Ingervall and Thilander (1973); Isley and Basmajian (1973); White and Basmajian (1973); Vitti, Basmajian, Oullette, Mitchell, Eastman and Seaborn (1975); Perkins, Blanton and Biggs (1977); Folkins (1978a & b); Ingervall and Warfvinge (1978); O'Dwyer, Quinn, Guitar, Andrews and Neilson (1980).

Basmajian (1979) lists the advantages of using fine-wire electrodes for kinesiological studies as being (a) extremely fine and hence painless (b) easily implanted and withdrawn (c) as broad in their pick-up from a specific muscle as are the best surface electrodes (d) produce sharp spikes similar to those from needle electrodes.

c) Microelectrodes

These electrodes are used to record the electrical activity within individual cells, thus, the active electrode tip of these micro-electrodes must be small enough so as not to interfere with the cell's normal function. These glass or metal electrodes may be expected to have tip diameters within the range from 0.1 micron to 10 microns (one micron = 10^{-6} metres).

1.32 Apparatus

A) Amplifiers

Physiological signals acquired by electrodes are typically below 10 millivolts (mV) [1 mV = 10^{-4} Volts] in amplitude and must therefore be amplified to be compatible with visual display devices and recorders. In almost all physiological measurement situations, two signals are produced by the subject: a desired physiological signal such as the raw electromyograph and an "interference" signal comprising amplifier "noise", general non-muscular "tissue noise" and movement antifact. The purpose of a differential amplifier is to reject this interference signal (usually 50 cycles per second or 50 Hz) and to amplify the desired signal (Strong, 1970; O'Dwyer *et al.*, 1980).

B) Integrators

Integrators are electronic devices which can produce, when an electromyograph or other potentials are fed into them, an arbitrary quantitative figure derived from the variables of amplitude, frequency and spike shape. This absolute integral of the electromyograph is used as a measure of the quantity of electrical activity produced by a muscular contraction (Strong, 1970; Basmajian, 1979; O'Dwyer *et al.*, 1980).

C) Recording techniques

a) Graphic recorders

A graphic recorder allows a continuous visual record of physiological data to be obtained. Graphic recorders utilize some form of stylus to traverse a strip of chart paper while the chart paper is in motion, leaving a visible tracing which is a record of the time variations of the input voltage or current.

b) Photographic recordings

Photographic recordings may take various forms. Continuous strip photographic recording on either positive paper or negative film operates by photographing the biophysical information displayed on the cathode-ray oscilloscope (Strong, 1970).

c) Magnetic-tape recording

Electric signals fed into a magnetic tape recorder are stored on the magnetic tape with the same electrical signals readily available from the tape recorder when required. This method is the only one which allows convenient storage and accurate reproduction of the recorded data at any time.

The magnetic tape recorder allows biophysical signals to be recorded in real time during a physiological measurement. The advantage of this method also is that the experimental results can be later replayed, integrated and the data analysed after the experimentation has been completed (Strong, 1970; Basmajian, 1979).

2. ELECTROPHYSIOLOGY OF NEUROMUSCULAR ACTIVITY

2.1 THE CELL AS A BIOLOGICAL GENERATOR

The basic source of all biological potentials is the cell. A definition of a bioelectric potential is the difference in potential between the inside and the outside of the cell in living tissues (Dorland, 1975); that is, the difference in potential existing across the cell wall or membrane. A cell consists of an ionic conductor separated from the outside environment by a semipermeable or selectively permeable cell membrane. Any one species of living matter comprises many different cell types and human cells may vary from 1 micron to 100 microns (1 micron = 10^{-4} centimetres) in diameter, from 1 millimetre to 1 metre in length and have a typical membrane thickness of 100 Angstrom units (10^{-8} centimetres (Ruch and Patton, 1965; Strong, 1973; Guyton, 1976).

Bioelectricity is studied both with respect to the source of electrical energy within the cell and also with respect to the laws of electrolytic current flow relative to the remote ionic fields produced by the cell.

In electrophysiology, the internal potential of the cell may be investigated but, more commonly, measurements are made external to a group of cells while these cells are supplying electrolytic current flow (Strong, 1973).

2.2. ACTION POTENTIALS IN MUSCLES

The classic electrical response of excitable tissue can be recorded from a whole isolated skeletal muscle. If two silver/silver electrodes are placed on the muscle surface, and the muscle is then stimulated to contract, each electrode becomes, in turn, relatively negative to the other giving the well known diphasic response (Joseph, 1960).

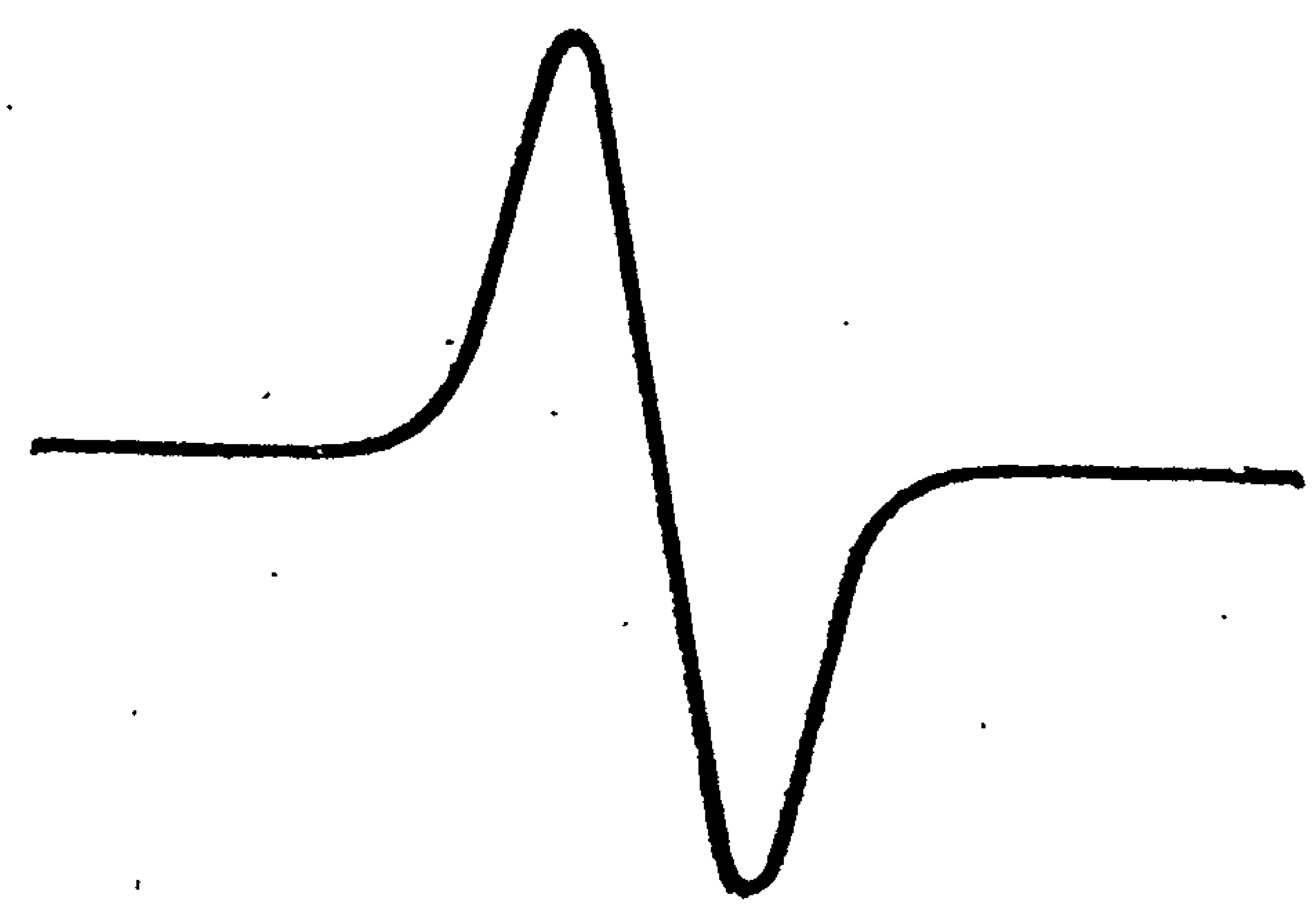

Fig. 1. Diphasic curve (From: Whitfield, 1968, p. 58)

2.3 THE MOTOR UNIT

The motor unit, as the name implies, is the biological unit of muscle function (Strong, 1973).

A muscle and its nerve may be thought of as an additive assemblage of motor units. This motor unit, which is the unit of voluntary and reflex activity of muscle, consists of the alpha motor-neuron, its axon and all the muscle fibres innervated by that axon (Fig. 2).

The number of muscle fibres that are served by one axon, that is, the number in a motor unit varies widely, but, generally, muscles controlling fine movements and adjustments have the smallest number of muscle fibres per motor unit. Conversely, large, coarse-acting muscles have larger motor units (Ruch and Patton, 1975; Guyton, 1976; Basmajian, 1979).

Strong (1973) states that, in men, one motor unit may contain from 25 to 2,000 muscle fibres with the force developed by a motor unit ranging from 0.1 to 250 grams weight. In a motor unit, the muscle fibres are not clumped together in one part of the muscle, but rather the muscle fibres of different units are interlaced.

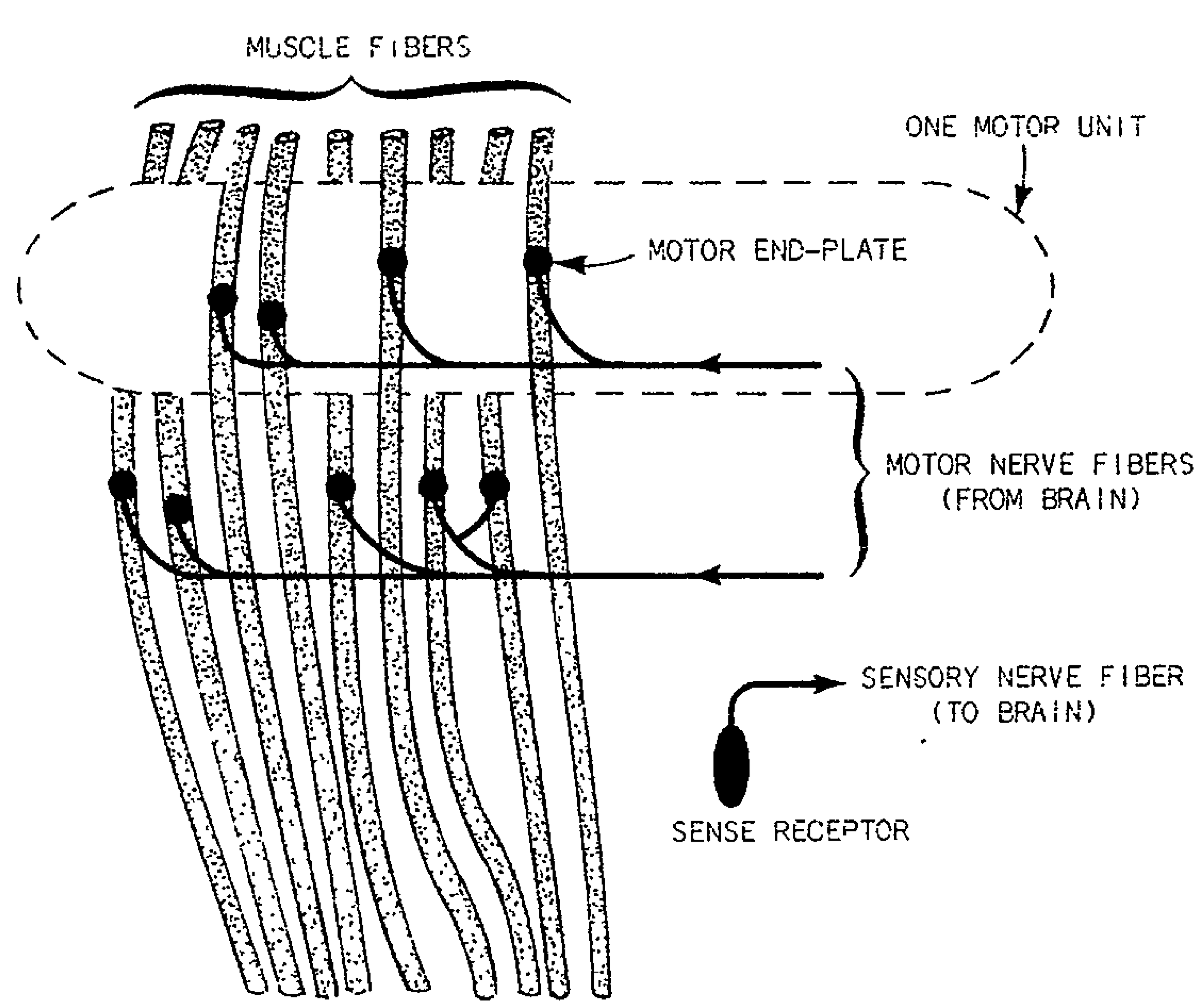

Fig. 2. Relationship between nerve and muscle (From: Strong, 1973, p. 31)

This is in agreement with Møller (1966) who states that the motor neuron represents the final path from the central nervous system and the activity of muscle is graded changing the number of active motor units and their frequency of contraction.

In mammalian muscle fibres at rest, a membrane potential of about -90 millivolts exists between the inside and the outside of the muscle cell (Strong, 1973; Ruch and Patton, 1975; O'Dwyer *et al.*, 1980).

Once the motor neuron is activated, a nerve action potential travels along its axon to the individual fibres of the motor unit causing a depolarization on their surface membranes at the neuromuscular junction (Katz, 1966; Strong, 1973).

2.4 SOURCE OF INTERNAL CELL POTENTIALS

Ruch and Patton (1965), Katz (1966), and Strong (1973) confirm that the internal resting potential within a cell is approximately -90 millivolts with reference to the outside of the cell. This potential changes to approximately +20 millivolts for a short period during cell activity.

The Hodgkin-Huxley theory, initially postulated during the 1950's is claimed by Strong (1973) to be generally considered the best explanation as to the source of the potentials and provide equations that give an empirical mathematical fit to experimental data. This theory is briefly described as follows.

The interior of a cell primarily contains concentrations of sodium (Na^+) and potassium (K^+) ions. These concentrations within a cell differ markedly from the concentrations of these ions in the space outside the cells. Elementary ionic theory states that, under suitable conditions, any uneven distribution of ionic concentration in an aqueous solution will result in a potential difference between the regions of different concentrations.

This potential, which is referred to as the chemical gradient is given by the Nernst relation:

$$\text{Potential (millivolts)} = \frac{61.6 \log \text{Concn., one side of membrane}}{\text{Concn., other side of membrane}}$$

(Guyton, 1976; Strong, 1973).

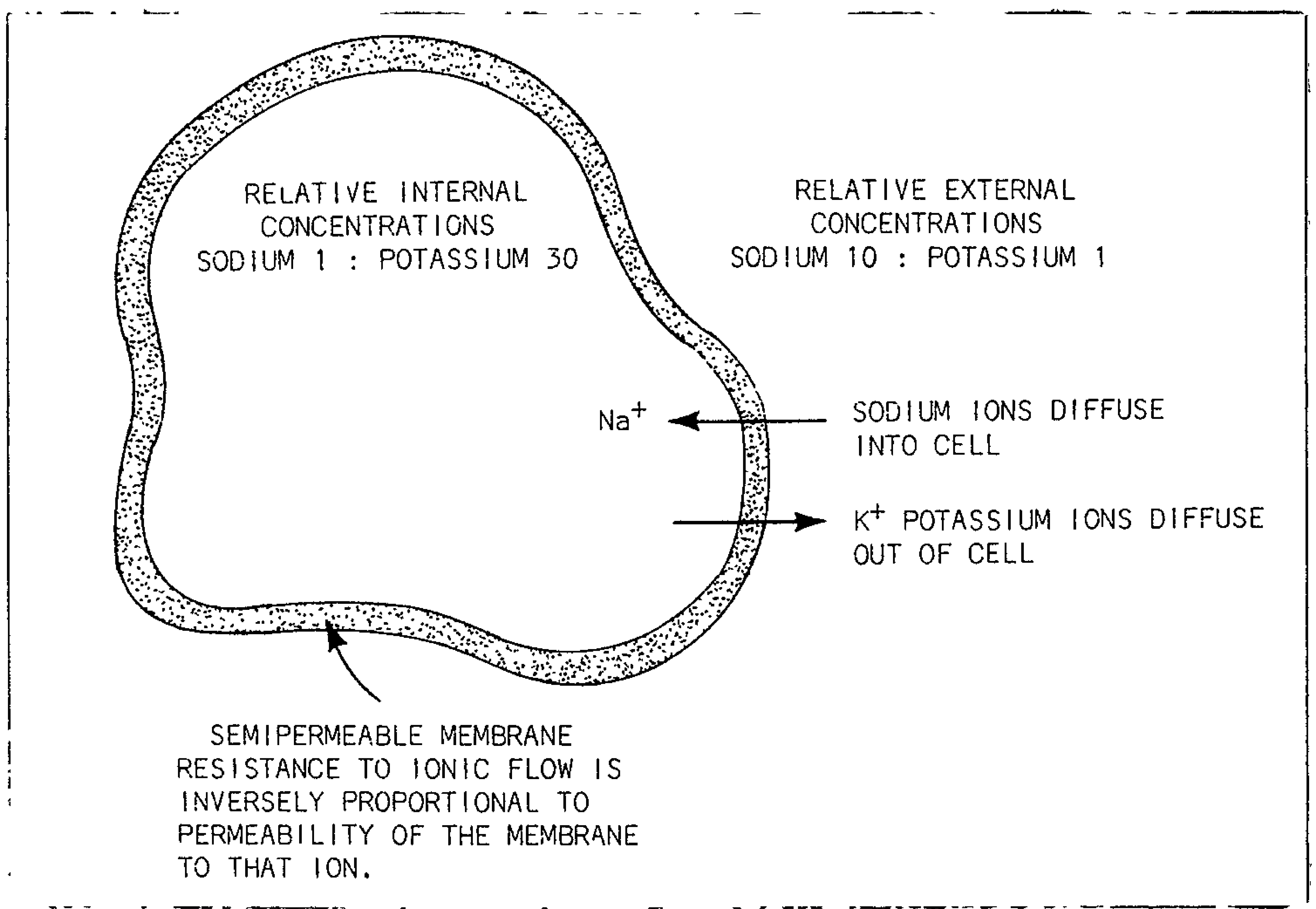

Fig. 3. Typical concentrations of sodium and potassium ions within a cell. (From: Strong, 1973, p. 9)

When the cell receives a stimulus from an outside source, the characteristics of the membrane at the point of stimulation will be markedly altered and, thus, the ionic currents will also change.

Following stimulation, the permeability of sodium ions is increased, while the membrane permeability to potassium ions is unaltered.

A much lower resistance is offered to the flow of sodium ions, thus increasing the sodium ionic current. This increased sodium ionic current causes more positive ions to pass into the cell than are passing out of the cell, causing the internal cell potential to drop from -90 millivolts (mV) to try to achieve sodium current and potassium current balance. With this decrease in potential, the nett sodium gradient across the membrane increases, causing the currents to decrease and increase, respectively. Until current balance is obtained, this process continues, at which time the internal cell potential is +20 mV. The cell is then referred to as being in a depolarized state (Ruch and Patton, 1965; Katz, 1966; Strong, 1973).

By the time the cell has fully depolarized, the membrane initiates the reverse process, called repolarization which continues until the -90 mV resting potential of the cell is once again achieved (Fig. 4).

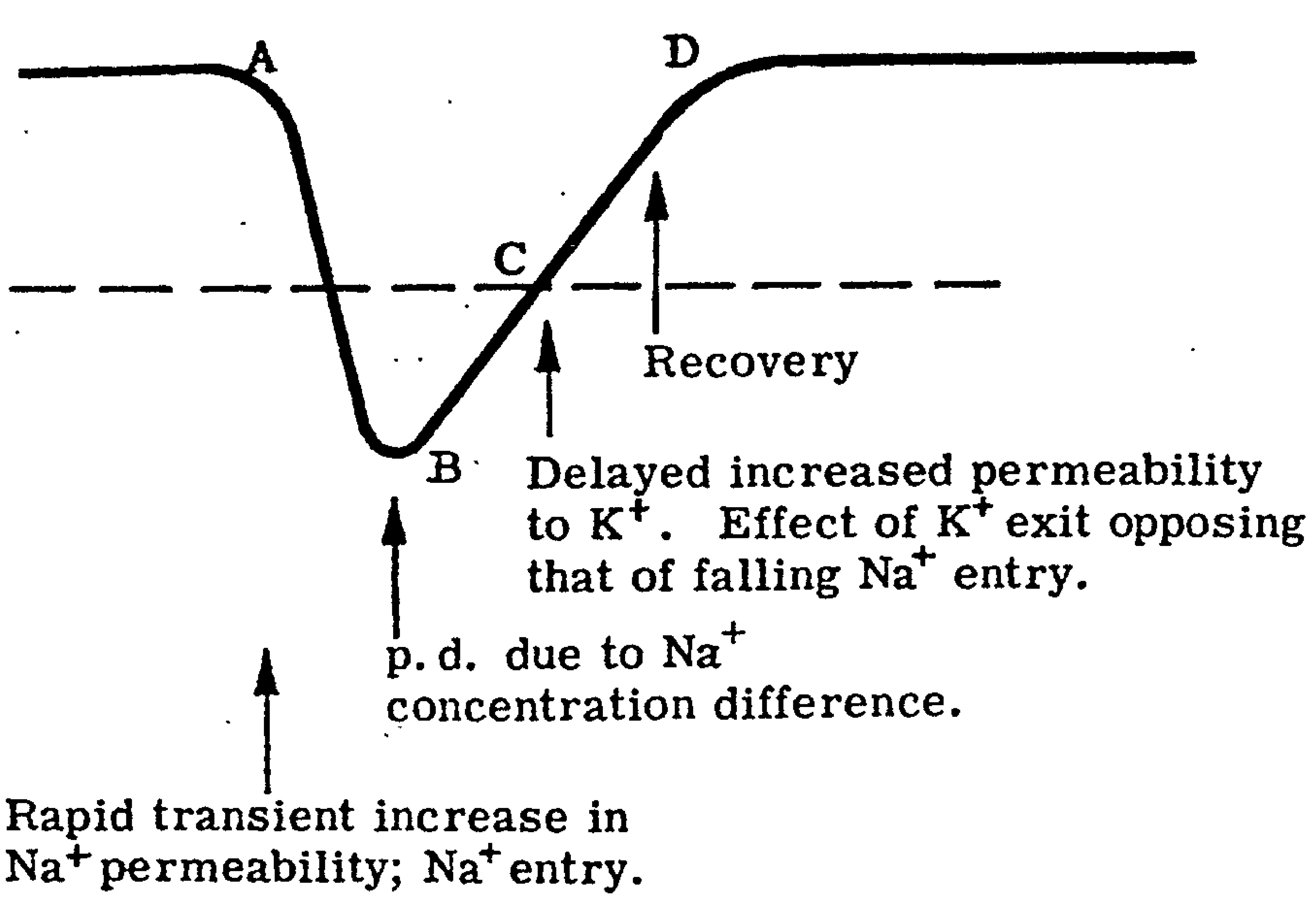

Fig. 4. Diagram to illustrate the movement of ions which takes place during contraction of a muscle fibre. (From: Joseph, 1960, p. 22)

2.5 MOTOR UNIT POTENTIAL

During depolarization, the membrane potential rises rapidly from its resting level to a peak of about +20 mV. This depolarization, called the muscle action potential, or motor unit potential, spreads over the fibres at 3-5 m/second and initiates the change in length or increase in tension appearing as the mechanical activity of muscle (Strong, 1973; Basmajian, 1979; O'Dwyer *et al.*, 1980).

The difference in potential between polarized and depolarized regions establishes an electric field in the conductive extracellular fluid and surrounding tissues. If this electric field sweeps over a pair of electrodes, it will induce a voltage difference between them which, when amplified and displayed, is referred to as an electromyogram (EMG).

With two electrodes outside the muscle fibre and separated by a distance greater than the length of the wave of depolarization, the diphasic form of action potential can be recorded together with the contraction of the fibre (Fig. 5).

The characteristics of EMG voltage recorded are importantly influenced by several factors other than the contractile state of the muscle fibres. The amplitude and high frequency content of the EMG signal diminish as the distance between the electrodes and muscle fibres increase. Moreover, the number of muscle fibres from which an electrode pair can satisfactorily record, decreases as electrode size and the distance between the pair of electrodes is reduced. Thus, small, closely spaced electrodes placed within a muscle, record larger amplitude and shorter duration "spikes" of electromyographic activity from a smaller region than do large, widely spaced electrodes placed on the surface of the muscle (Basmajian, 1979; O'Dwyer *et al.*, 1980).

In normal muscles it is accepted that all the fibres supplied by one motor nerve fibre - the motor unit - contract as a result of a single nerve impulse passing along the nerve fibre. Guyton (1976) calls this principle "wave summation". He describes the phenomenon as occurring when the frequency of individual muscle twitches is 10 per second; the first muscle twitch is not completely over by the time the second one begins. Therefore, when the muscle is already in a partially contracted state when the second twitch begins, the degree of muscle shortening this time is slightly greater than that which occurs with the single muscle twitch. Additional twitches add still more shortening.

Since all the muscle fibres of a motor unit do not contract at exactly the same time, some are delayed for several milliseconds. As a result, the electrical potential developed by the single twitch of all the fibres in the motor unit is prolonged to about 5-8 milliseconds. The electrical result of the motor unit twitch then is an electrical discharge lasting about 5-8 msec with a total amplitude measured in microvolts (μV). When displayed on a cathode-ray oscilloscope, or similar device, the result is a sharp spike that is most often biphasic but it may have a more complex form (Fig. 6).

Thus, in normal voluntary contraction as above, the recorded electrical activity is the result of many motor units firing together to provide a smooth pattern of muscle force. Such an electromyogram is referred to as an "interference pattern", indicating that it represents the combined electrical activity from many motor units in which, with increasing levels of contraction, one generally cannot discern the firing pattern of individual units.

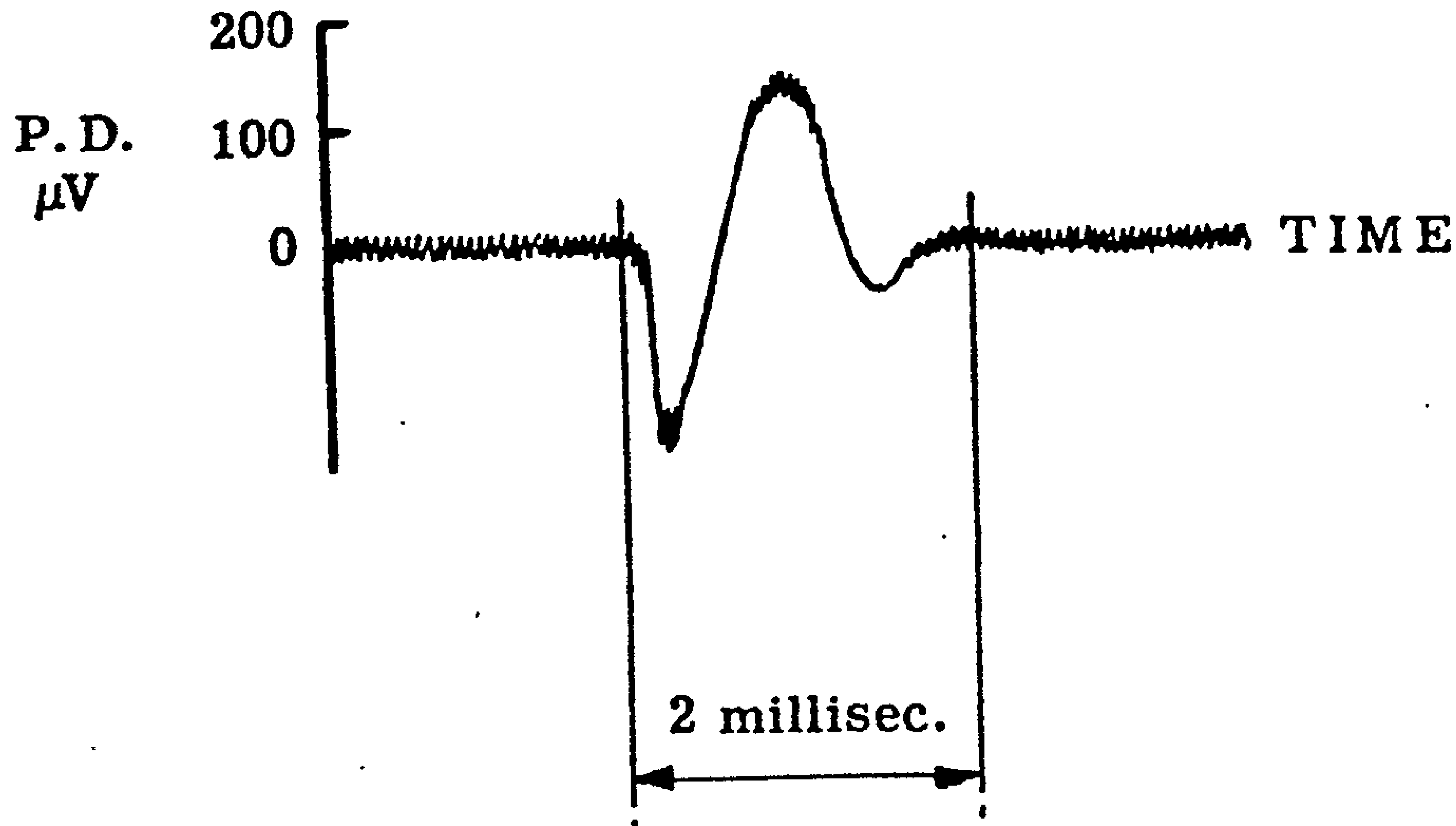

Fig. 5. Potential obtained from a contracting muscle fibre using a concentric needle electrode on or near the surface of the fibre.

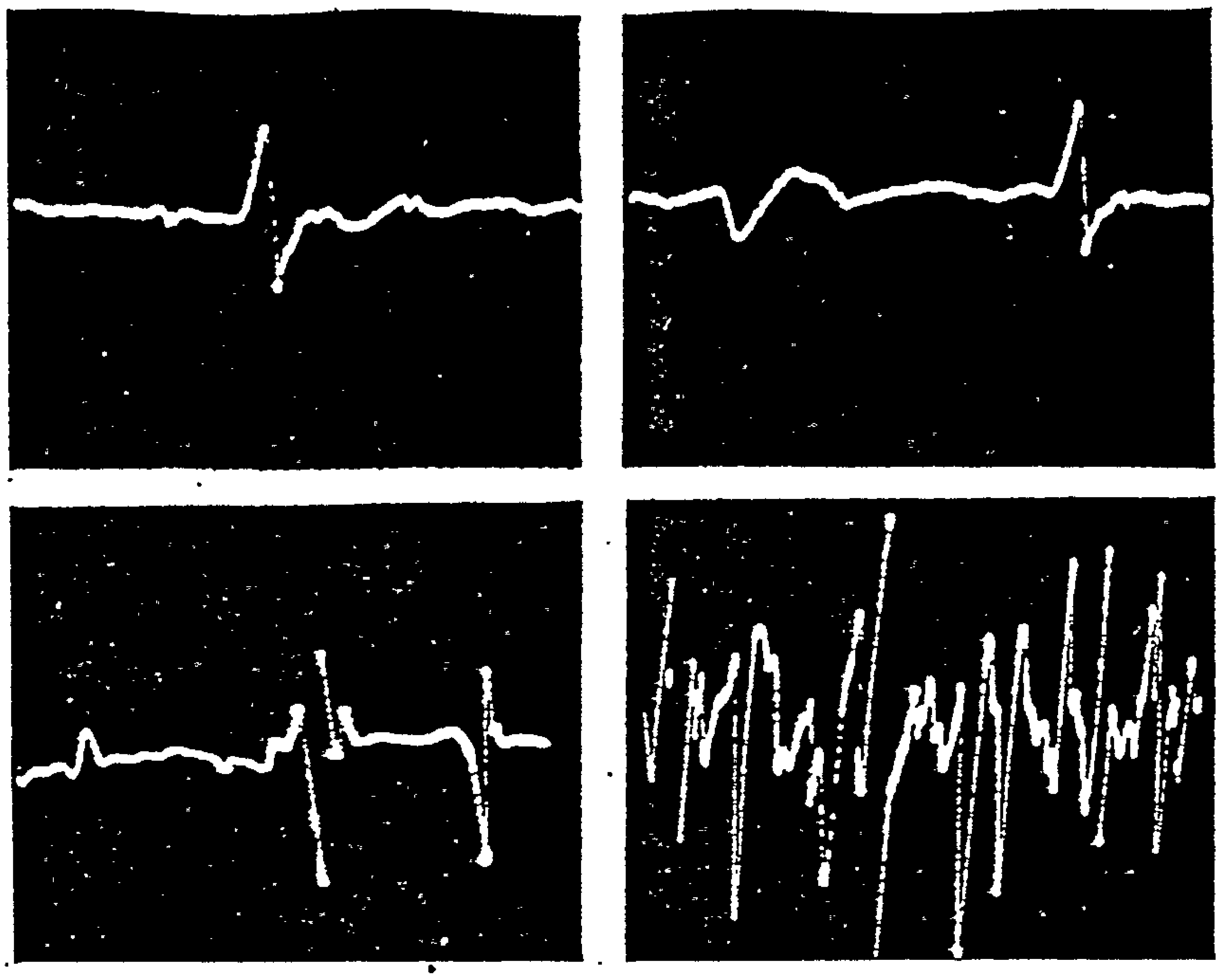

Fig. 6. Sample normal electromyograms showing one, two and many superimposed motor unit potentials ("interference pattern"). (From: Basmajian, 1979, p. 13)

3. THE MENTALIS MUSCLE

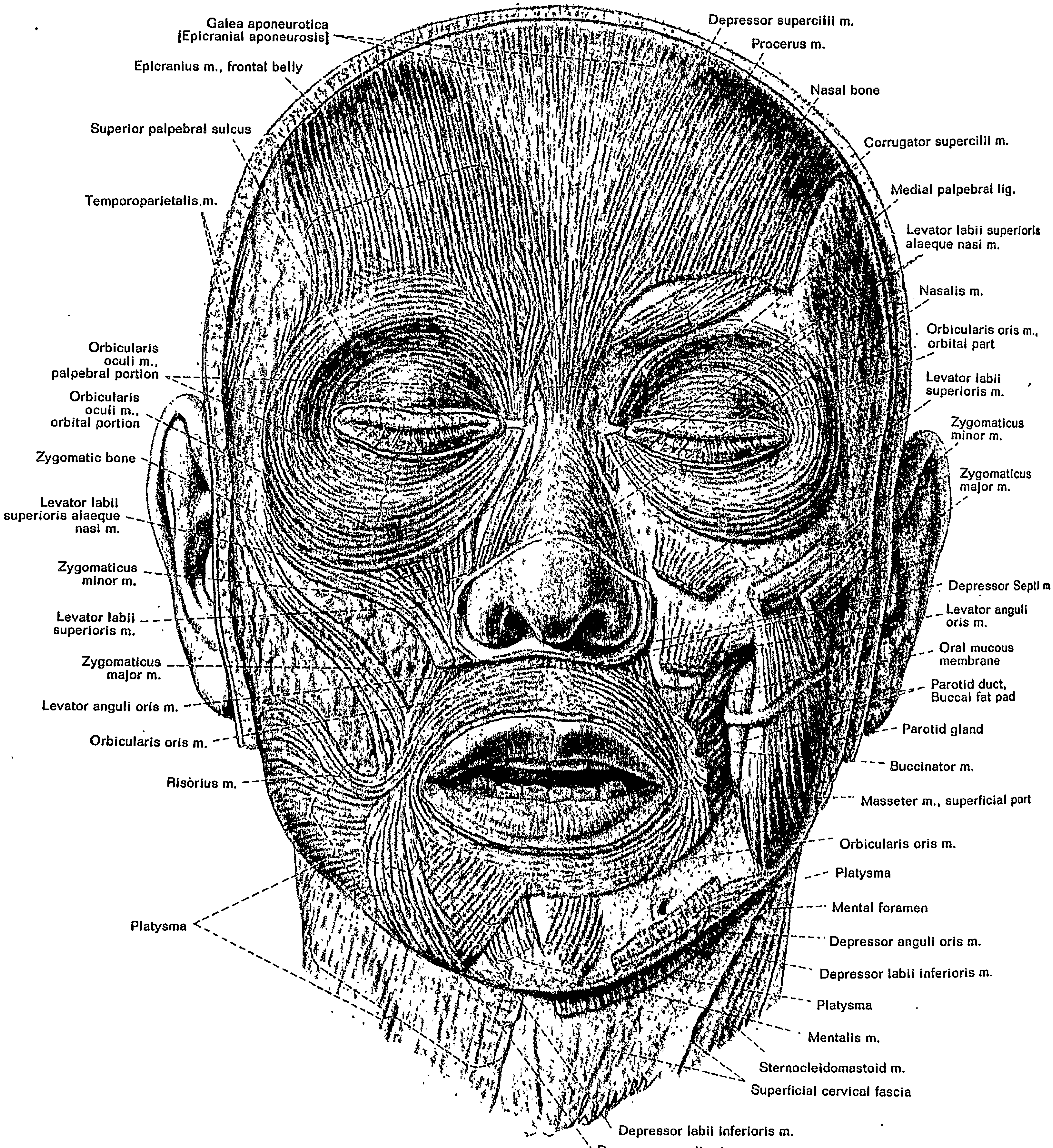

Fig. 7: Muscles of the face. Right: Superficial (expression layer). Left: Deeper layers (muscles of expression and chewing) of the facial muscles. (From: Sobotta, 1974).

3.1 DESCRIPTIVE ANATOMY

3.11 Muscles of facial expression

Common features of this group of muscles in the head are their superficial arrangement and their attachment to, or their influence on, the skin. To this group belongs also, the platysma muscle, which extends from the face over the entire length of the neck to the chest.

These superficial muscles can be divided into five groups (Sicher and Du Brul, 1975):

(i) comprised of the platysma alone

(ii) muscles arranged around the mouth and nostrils

(iii) muscles serving the movement of the eyelids

(iv) muscles concerned with the movements of the outer ear

(v) the muscles of the scalp.

The mentalis muscle belongs to the group arranged around the mouth.

Almost all of the above muscles having an influence on facial expression are, therefore, collectively called the muscles of facial expression. Beyond this, they perform major functions such as closing of the eyelids, closing and opening of the lips and auxiliary functions during intake of food and its mastication, or in speaking.

All of the muscles of facial expression are supplied by the facial nerve (Sicher and Du Brul, 1975; Dubner, Sessle and Storey, 1978).

Dubner *et al.* (1978) stated that particularly in relation to the gaining of nutrient does the facial musculature have reference to dentistry, since abnormal patterns of activity in mastication and swallowing are of special orthodontic significance. The speech pathologist is interested in the reflex activity of facial muscles particularly in its communicative function and some attention has also been focussed on muscle activity in facial expression and musical performance (Isley and Basmajian, 1973; Herman, 1974; Porter, 1967c; Dubner *et al.*, 1978.

3.12 Anatomy of the mentalis muscle

Lightoller (1925) gave a very complete description of the facial muscles which differs in a number of respects from that of standard texts. As an example, Lightoller (1925) contended that the orbicularis oris muscle consists of fibres that are its own; fibres of other muscles may enter it but they are not constituents of it. This is in contrast to the descriptions given by Møller (1966), Gray (1967) and Cunningham (1976) which indicated that the orbicularis oris muscle is made up of fibres from all the other muscles about the mouth, with some intrinsic fibres.

It is the inferior component of orbicularis oris muscle function with which the mentalis muscle action is frequently confused in clinical orthodontics.

The description of the mentalis muscle was taken by Lightoller (1925) from the Australian aboriginal. He described the muscle as consisting of two main portions - a median and a lateral. The fibres from each of these portions arise similarly from the fossula incisiva and run in parallel directions, being spread out in the shape of a vertical fan. The upper fibres of this fan run horizontally forwards, or even may be inclined slightly upwards, whereas the lowest fibres run almost vertically downwards. The lateral fibres are inserted directly into the skin of the chin, whereas the median fibres interlace with their fellows of the opposite side to form a series of arches or loops.

This description of mentalis muscle anatomy has been supported by other researchers and anatomists including Cunningham (1964), Gray (1967), Hollinshead (1967), Gianelli and Goldman (1971), Grant (1975), Nairn (1975), Sicher and Du Brul (1975) and Cunningham (1976).

Lightoller (1925) further adds that the centre of these loops is not an empty space but is completely filled by a large pad of very firm fibrous tissue below, and at times a smaller pad above this and in direct contact with it.

In people whose chins are smooth and rounded, Lightoller (1925) stated that we should expect to find, behind the fibrous pad and separating it from the mandible, a small bursa. This allows the pad of fibrous tissue to slide more easily over the underlying bone.

In people with a dimpled or cleft chin we should expect to find the mentalis muscle anatomy a little different to above as described by Cunningham (1964) and further supported by Nairn (1975). Lightoller (1925) explained that in these situations there are a few or no median loops but most or all of the fibres on each side are inserted into the skin of the chin on the same side. In these cases, the dimple or cleft of the skin is due to the skin being bound to and drawn inwards by the fibrous tissue pad lying between the two muscles.

Thus, in one case we have a complete muscle cylinder surrounding a fibrous tissue pad, and in the other, an incomplete muscle cylinder in as much as its anterior

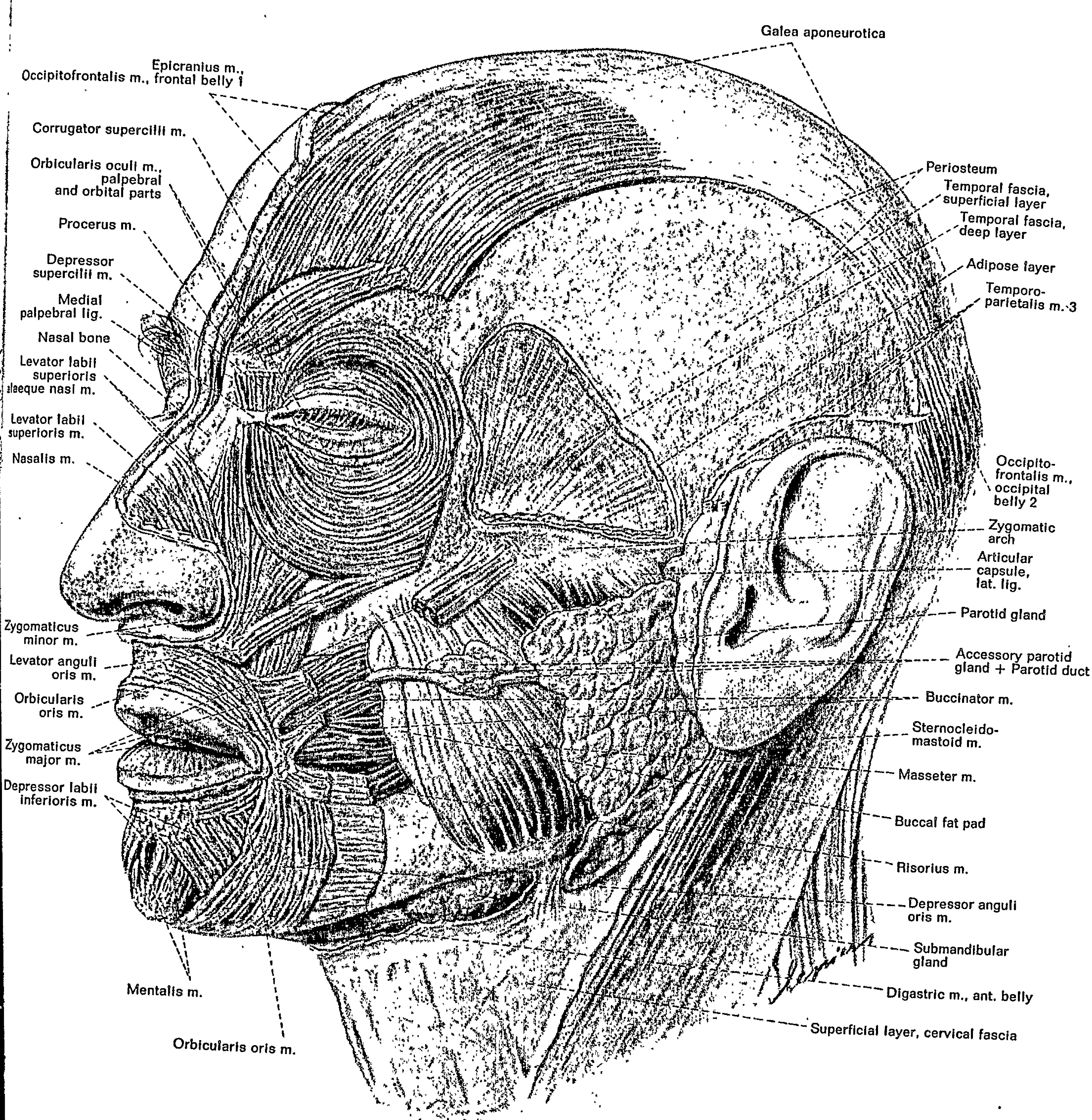

Fig. 8: Muscles of the face from the left side.
(From: Sobotta, 1974).

wall is formed by the skin which is also adherent to the underlying fibrous tissue pad. Nevertheless, the action of the muscle will be the same in both cases, though more easily understood if we study the primitive type as seen in the Australian aborigine and many Europeans.

3.2 FUNCTIONAL ANATOMY

3.21 Morphology

In clinical orthodontic practice, frequent observation is made of patients with a deep sublabial furrow, dimpling of the skin of the chin, a palpably "tight" lower lip and/ or shallow vestibular region intra-orally. As a consequence of the above diagnostic observations, these patients are usually considered to possess what is commonly termed a "hyperactive mentalis", a "strong lower musculature", a "mentalis habit" or a "powerful mentalis activity" (Rix, 1953; Tulley, 1956; Moyers, 1962; Ricketts, 1968; Posen, 1972).

In consideration of these apparent musculature features, the direction of appropriate orthodontic therapy may be varied with respect to profile considerations, choice of extraction or non-extraction therapy and choice of which teeth to extract in the lower arch.

The opinion of some clinical orthodontists including Rix (1953), Tulley (1956) and Posen (1972) is that if a patient has "hyperactive mentalis" activity then the consequence of this mentalis activity will be a lingually directed pressure on the lower anterior teeth resulting in a retroclination of their crowns.

Let us now consider the views on mentalis muscle activity as expressed by anatomists.

Lightoller (1925), as previously stated, felt that the lowest fibres of the muscle orbicularis oris also often interlace with the upper fibres of the muscle mentalis. Therefore if the muscle cylinder tries to expel its semi-fluid contents, it exerts great pressure against the cylinder head and moves the cylinder head cranially. However, as the cylinder head consists of the muscles comprising the lower lip it must mean a cranial movement of the lower lip.

Hence, according to Lightoller (1925), the activity of the mentalis muscle pushes the lower lip either directly upwards, or upwards and forwards, and the actual position taken is dependent upon two conditions:

(a) the position of the upper lip and the degree of contraction of the muscle orbicularis oris superioris.

(b) the relative resistance of the orbicularis oris inferioris and muscle quadratus labii inferioris.

Widespread support exists for Lightoller's (1925) statement of upwards or upwards and forwards action of the lower lip due to contraction of the mentalis. Martone (1962), Gray (1967) and Nairn (1975) all confirmed the elevation of the lower lip while Cunningham (1964), Gray (1967), Gianelli and Goldman (1971), and Sicher and Du Brul (1975) also commented on the lower lip protrusion.

All the authors mentioned above commented on the insertion of muscle fibres into the skin over the chin, producing the finely dimpled area which appears when the lower lip is elevated.

Due to his extensive studies of facial muscles, Lightoller (1925) further commented that the ram-like action of the mentalis muscle causes the lower lip to be pouted or protruded in spite of the "modiolus" being fixed in a posterior or neutral position: this accomplishment otherwise being impossible.

Lightoller (1925) defined the modiolus as six chief perioral muscles entering into a composition to form the radiating spokes of an imaginary wheel. It is an area of great importance both anatomically and physiologically such that its strength and position enable the movements of the lips to be made with such precision and accuracy as are necessary for all forms of speech.

The pouting or protruding of the lower lip is a movement quite peculiar to the lower lip and not possessed by the upper lip. Nairn (1975) also made this observation and further added that in possessing this ability, the lower lip plays an important part in pushing lip to lip contact in those with structurally incompetent lips. While various definitions of incompetent lips will be given subsequently, they can be regarded for the present as being a lips apart posture with the mandible being in the physiologically rest position. Nairn (1975) further commented that, as is the case of orbicularis oris, the mentalis muscle depends for its proper activity on the support of the lower anterior teeth and integrity of the bony origin. If these are absent or malpositioned he felt that such function may well be disturbed.

Lightoller (1925) finally commented that this ram-like action of the mentalis is quite unlike that of any other skeletal muscle and its nearest counterpart in the human body is the contraction of the heart.

Of the anatomists reviewed, only Sicher and Du Brul (1975) made comment on the possible action of the mentalis muscle with respect to the lower anterior teeth. They stated that since the muscle origin extends to a level higher than that of the fornix of the vestibule, the mentalis muscle, in contracting, renders the lower vestibule shallow. Its reflectory contraction may, therefore, interfere greatly with dental work on the labial surface of the lower front teeth. This statement would tend to support the often expressed clinical orthodontic viewpoint.

Orthodontic literature contains many references on the effects of perioral musculature, including the mentalis muscle, on the lower incisor teeth and this will be reviewed in subsequent chapters.

3.22 Functional Activities

A) Facial expression

Mortone (1962) stated that man, as well as being an anatomic and physiological unit, is also a complex of intellect and emotions. Generally, man communicates his thoughts through speech but his feelings and emotions are most frequently conveyed through facial expression - one of the prime components being the mouth.

The lips, sometimes termed the curtains of the mouth (Mortone, 1962), become the main factors in facial expression.

As has previously been discussed, the mentalis muscle plays a dominant role in the protrusion and elevation of the lower lip.

Under the title "The Expression of the Emotions in Man and Animals", Darwin (1872), in classical observations on the means and principles of expressive behaviour, made little reference to lower lip actions and positions but rather refers to the upper lip, the mouth as a whole and to the eyes.

In a comparative study of muscles of expression, Duckworth (1904) noted a difference in muscle morphology with respect to distinction of muscle bundles, anatomical location and muscle bulk when comparing "white", "yellow" and "black" races.

Extensive work was performed by Lightoller (1927-28) on the action of the mentalis muscle in the expression of emotion and distress. He concluded that in the younger child, the mentalis muscle is used only to end a bout of weeping although with increasing age the muscle action is more commonly used to prevent an outburst of weeping. By stiffening the lower lip, the mentalis muscle assists man to control overt emotional expression which is contrary to the adage of a stiff upper lip.

Another author to have studied facial expression in different human types was Huber (1931). He felt that in the evolution of the mimetic muscles in man, great importance should be placed on the analysis of the psychic component during the development from the new-born to the adult within the varying human races. Huber (1931) also felt that a modifying influence on facial muscles about the mouth may be language in that certain muscles may be involved more vigorously and more frequently in one language, while in another language other muscle portions may be of greater functional importance.

Mortone (1962) also commented on the upward thrusting of the mandibular lip in the expressions reflecting sadness, grief, despair or contempt.

Gray (1967) felt that the lower lip posture during contraction, together with the wrinkling of the skin of the chin, expresses doubt and disdain.

The important human facial expression produced by contraction of the sphincter muscles of the mouth resulting in rounding or forward thrusting of the lips in a pout was noted by Andrew (1965). In the higher animals, as lip mobility increases, the movement develops into an important visual signal. Andrew (1965) notes this rounding of the lips, covering the teeth in the human face, as an expression often accompanied by a strong intake and expulsion of breath in a display of indignation.

B) <u>Speech production</u>

Lightoller (1925) also observed the activity of mentalis muscle during speech production. He observed that in the pronunciation of the consonants "p" and "b", the downstroke of the lower lip is dominant, with the cylinder muscle action being reversed. The cylinder head presses down the fatty pad and hence the pad of fibrous tissue and this in turn pushes downwards the whole cylinder wall or muscle mentalis.

While not precisely a study involving speech production, Sumitsuji *et al.* (1967), during an electromyographic study of the activity of eight facial muscles using fine-wire electrodes, observed that with the pursing of the lips during whistling, the highest level of activity was recorded by the mentalis muscle. In fact, of the muscles studied during facial movements including opening and closing of the mouth, the mentalis muscle was found to have the highest amplitude of all the facial muscles in all subjects.

In an electromyographic study of the facial muscle's co-ordination during speech, Leanderson, Öhman and Persson (1966), using concentric needle electrodes, observed the pronunciation of the consonants "p" and "b" under phonetically standardized conditions. These workers found that the implosive peaks are, throughout, slightly bigger for the voiceless plosive "p" than for the voiced "b". The release peaks on the other hand are bigger for "b" than for "p". They explained these differences by the fact that the vocal cords are abducted for "p", producing a higher intra-oral pressure which must be counteracted by firmer lip closure. In the opening phase, the higher pressure facilitates the spreading of the lips and less muscle energy is required than for the voiced consonate when the glottis is closed and the intra-oral pressure is lower. It is suggested that in the production of a bi-labial consonant, the depressor anguli oris pulls the corners of the mouth downward so that the upper lip becomes stretched and embraces the lower lip. The mentalis muscle pushes the lower lip upwards by pulling the skin of the chin point upwards. The release is brought about by the relaxation of these two muscles and the contraction of the depressor labii inferioris, which pulls the lower lip upwards.

Sussman, MacNeilage and Hanson (1973) using fine-wire electrodes in perioral muscles, supported the view of mentalis activity functioning to elevate the lower lip. However, they could not reveal any differential levels of activity for the three stop consonants "p", "b" and "m".

A further electromyographic study into facial muscle activity in speech by Leanderson, Persson and Öhman (1971) found that for the rounding gestures of "y" and "u", muscle activity can be seen in the orbicularis oris superioris, orbicularis oris inferioris, depressor anguli oris and muscle mentalis.

Abbs (1973) raised some doubt as to the strength of activity of muscle mentalis on the lower lip movement during speech production. In an electromyographic study, he found that the mentalis muscle did not add any additional strength to the lower lip inferior-superior movements when testing orbicularis oris inferioris and depressor labii inferioris. He then continued to perhaps excuse his findings by stating that perhaps his techniques were too rudimentary to allow description of mentalis influence.

The muscles used for the pronunciation of the rounding gestures "y" and "u" and implosives "p" and "b" were again later confirmed by Leanderson and Lindblom (1972) in another electromyographic experiment. Making observations on Swedish nonsense words, the intervocalic consonants "p", "b" or "h" were co-articulated with "c", "y" or "u" so as to form all possible combinations in connected speech. Interestingly, they found that for a normal-speaking group, all cases had the common characteristic that the degree of activation of a certain muscle for a certain phoneme depended upon the activity for the proceeding phoneme.

C. <u>Mastication</u> The activity of the mentalis muscle
D. <u>Swallowing</u> during these activities will be reviewed subsequently.

E. <u>The Embouchure</u>

The way in which the lips and mouth are applied in the blowing of a wind instrument is known as the "embouchure" (Strayer, 1939; Cheyney, 1949; Grove, 1954; Engelman, 1965; White and Basmajian, 1973).

The superstructure of the embouchure apparatus consists mainly of the muscles of the lower part converging into the modiolus at each side of the mouth. All these muscles are co-ordinated in function to give the lips the utmost assistance in behaving as a sensitive generator of the musical sounds, as an efficient washer to prevent escape of air and as a sensitive buffer able to select spontaneously the mouthpiece pressure required for each resonating tone (Porter, 1968b).

Muscle mentalis is regarded as being a component of the scheme of musculature of embouchure due to its influence in lower lip activity (Porter, 1967c; Herman, 1974).

Brass instruments differ from woodwind in basic functional demands, since the lips perform the dual purpose of washer (preventing escape of air) and reed (being allowed to vibrate as a double reed with the cup of the mouthpiece) to produce tone (Porter, 1967a). White and Basmajian (1973) feel that while students of brass instruments should attempt to concentrate more muscle activity in the lower lip, the embouchure of experienced players should remain as motionless as possible during brass performance.

In the woodwind, the lips form a washer-like sphincter around the mouthpiece in single- and double-reed instruments, while in the flute and piccolo, the lips direct the exhaled air column across the hole at the head of the instrument (Porter, 1967a).

Labial pressure on lower incisors

Most players of single-reed instruments (for example, clarinet and saxophone) are taught to cover the lower incisors with the lower lip. A comparatively smaller number are taught to contract the lower lip against the labial surfaces of the lower anterior teeth, presumably to avoid either "linear pressure" or "point pressure" on the mucous membrane of the lower lip. The result of the latter method of embouchure adaptation is "surface pressure" against the lower incisors. The player may also have a short lower lip in relation to the length of the lower incisor teeth and thus find it more comfortable to stretch the lower lip over the incisors (Cheyney, 1949; Porter, 1967b; Herman, 1974).

A method of lower lip to lower anterior incisor position to overcome the positioning of the lip over incisal edges (Porter, 1953) was found by that author to be unsuccessful and has subsequently received no support by other researchers in the field.

Some types of both fixed and removable orthodontic appliances could prevent the playing of a wind instrument altogether. At the initial examination, therefore, it would be advisable to enquire about the interests and hobbies of a young patient and to record the fact that a wind instrument is being played, the type of instrument and the time devoted daily to such playing (Porter, 1968a; Herman, 1974).

The Flute

The flute (and the piccolo) requires an embouchure quite different from the reed instruments or brass. While it is of the woodwind variety, like the single-and double-reed instruments, the mouthpiece is applied extra-orally, but in a different way from the brass instruments (Cheyney, 1949; Porter, 1968a).

The embouchure of the flute permits the projection of a column of exhaled air from the lip aperture, which is comparatively remote from the hole at the head of the instrument, at which it is aimed and the edge of which vibrates. To accomplish this, an extremely delicate control of the contraction of the embouchure musculature (particularly the risorius and the modiolus) is essential to produce an optimum volume of air at an appropriate pressure. The head of the instrument rests in a suitable position on, or just below, the lower lip with little labial pressure on the lower anterior teeth while at the same time the upper lip is stretched and drawn downwards (Porter, 1968a; Herman, 1974).

Embouchure and Malocclusion

Instruments were classified by Strayer (1939) according to their type of mouthpiece and recommended that specific instruments be selected for their beneficial influence on existing malocclusion. Similar suggestions have been made by Heskia and Hospital (1957); Kessler (1959); Herman (1974).

Conversely, muscial instruments may be chosen to fit the prevailing malocclusion from the ease-of-playing viewpoint, disregarding any detrimental influence that may be exerted on the dentition (Cheyney, 1949; Seidner, 1964; Herman, 1974).

The playing of the flute has been shown to benefit the person who has a short upper lip, a protruding lower lip or a strong mentalis habit (Herman, 1974). This author also feels that the playing of a flute would help a person with a Class II Division 1 malocclusion. Here the upper lip is pushed downwards to form a small opening for directing air into the instrument.

Engelman (1965) suggests that increased tonus in the muscles of the upper lip results from flute playing.

Single-reed instruments are usually contraindicated for Class II Division 1 malocclusion patients as the mouthpiece would tend to maintain the overjet already present (Herman, 1974). The double-reed instrument player with a Class II Division 1 malocclusion is in virtually the same position as the person who plays a brass instrument in that he could derive some benefit from the playing of one of these instruments (Herman, 1974).

Herman (1974) feels that there may be some myofunctional benefit to a Class III malocclusion during the playing of double-reed instruments. He also claims that the flute might also be advantageous in improving the occlusion in a Class III case with a short upper lip.

4. MUSCLE FORCES AND THE ANTERIOR TEETH

4.1 LINGUAL PRESSURES VERSUS LABIAL PRESSURES

The principle of equilibrium of a labio-lingual muscle environment in the positioning of the teeth has long been accepted by the dental profession. Tomes (1873) is recorded as suggesting that "the agency of the lips and tongue is that which determines the position of the teeth".

If the clinical orthodontist should make an evaluation of a patient's musculature as being "hyperactive", "hypoactive", "flaccid", etc., what effect then could one expect on the equilibrium muscular environment of the teeth referred to by Tomes (1873)? A method whereby one could simply determine the influence of the lips and tongue on the dentition of patients not affected by habits is, unfortunately, not readily available.

Ballard (1953), being a prominent researcher in myology, supported the concept of lip and tongue determination of the position of teeth. He felt that if the dento-alveolar structures from a normal dental base relationship are to be directed through growth to establish a normal occlusion, then one must have a normal resting position of the lips and tongue and normal behaviour of these structures during speech, feeding, smiling, etc. Other protagonists of this theory include Rogers (1918), Swinehart (1950), Strang (1950) and Brodie (1952).

Rix (1953), another British orthodontist contributing to this doctrine, came to the conclusion that the mechanism of abnormal swallowing brings forces to bear in the incisor regions which run counter to the moulding forces of mastication and normal swallowing. These swallowing forces promote a discrepancy in the position of the crowns of upper and lower incisors in the antero-posterior plane. The cause of this tooth displacement, Rix (1953) reasoned, is due to the emerging permanent incisors being repeatedly subject to pressure from the taut lower lip, due to contraction of mentalis and orbicularis oris muscles. With insufficient counteracting pressure on their lingual sides, due to the tongue moving upwards and forwards away from their lingual sides, the lower incisors do not tend to move adequately anteriorly, thus resulting in a tendency to flatten, retrocline or imbricate.

Hovell (1962) also commented on active mentalis muscle action as observed by dimpling of the skin of the chin. He emphasized that the effect of soft tissue morphology is always relative to the associated skeletal morphology and that the activities affecting the dental arch form are swallowing, speaking and expressive behaviour. Of these activities, Hovell (1962) considered swallowing to be the most important.

Another researcher of long standing is Gwynne-Evans (1948). He then stated that the muscle behaviour was pre-determined, patterned and dominated by the central nervous system whatever the relationship between the jaws might be. Gwynne-Evans (1972) commenting further on the oro-facial muscles, felt that the muscles forming the lower lip can, in certain circumstances, contract to influence the alignment of the anterior teeth. He also added that much depends on the contour, position and behaviour of the lower lip in relation to the incisors at rest, in facial expression and in swallowing.

Scott (1961) questioned the hypothesis apparently accepted by many at this time that arch form and tooth position are determined primarily by muscle action. He felt that the form of the dental arches is the consequence of a number of developmental and functioning influences including genetic factors, regulating skeletal form, tooth/ jaw size ratio, developmental position of teeth and the forces exerted by the oral and masticatory musculature. According to Scott (1961), as long as the pressures exerted by the lips, cheeks and tongue are within the range of normal functional activity, they have only a very limited effect on the form of the dental arches.

As early as 1926 Friel was questioning the relative pressures exerted on the dentition by the lips and the tongue. Friel (1926) could not accept the concept of the time that teeth were held in their normal bucco-lingual relationship by equal and opposite forces of the tongue and the cheeks and lips. In support of his argument of the predominance of tongue pressure over labial/buccal pressures, Friel (1926) postulated that static function, the constant state of mild tension of the muscles, is more important than the dynamic function when one considers the muscular forces acting on the dentition during a twenty-four hour period.

Supporters of the concept of lingual pressures exceeding lip pressures include Winders (1956, 1958, 1962); Hopkins and McEwen (1957); Kydd (1957); Sims (1958); Warner (1976); Pierce (1978); Dubner *et al.* (1978).

Kydd (1957) also mentioned other factors which may influence this apparent muscle imbalance. They include inclination of the teeth, length of the roots of the teeth, length of clinical crown and the forces of occlusion.

Other authors to also acknowledge the imbalance in pressures include Luffingham (1969); Lear and Moorrees (1969); Proffitt (1975).

Proffitt (1975) seemed to summarize current thinking on the question by stating that while the greater lingual force is generally accepted, the form of the dental arches dictates the functional pattern of tongue and lips to a much greater extent than function alters form. This supported the ideas of Werner (1964), Gould and Picton (1964, 1968), and Luffingham (1967-68) who have shown that subjects with increased incisor overjets show greater lip pressure than those with normal degrees of overjet.

These current views then lend support to those of earlier researchers (Tulley, 1956, 1964; Straub, 1960) who felt that whenever there is an imbalance in the musculature such as those which are associated with habits, certain malocclusions will result.

4.2 MEASUREMENT OF MUSCLE FORCES

4.21 Pressure transducers

In order to attempt to determine the relative pressures exerted on the dentition by the tongue and lip muscles, various mechanical and electronic devices have been employed.

Early work by Friel (1926) employed the use of three types of dynamometers to measure maximum forces created by the tongue, lips and buccinator muscles. Electrical strain gauges to measure oral forces were used by Howell and Manley (1948) and variations of these have since been used extensively.

Winders (1956, 1958, 1962) using electrical strain gauges concluded that perioral and lingual musculature are intimately associated with "facial pattern" and the morphological variation of the skeletal parts.

Margolis and Prakash (1954) used a device called a photoelectric myodynagraph consisting of a compressible rubber capsule which received the muscle pressures. Various other electronic strain-gauge transducers have been used and described by Alderisio and Lahr (1953); Kydd (1957);

Dixon (1959); Gould and Picton (1964, 1968); Weinstein, Haack, Morris, Synder and Attaway (1963); Werner (1964); Proffitt, Kydd, Wilshire and Taylor (1964); Jacobs and Brodie (1966); Jacobs (1967); Luffingham (1967-68, 1969); Lear and Moorrees (1969); Posen (1972).

4.22 Electromyographic investigations

Electromyography has also been widely employed as an aid into the investigation of muscular forces and their relative activities. Moyers (1949) was an early follower of electromyographic techniques and even using fairly rudimentary techniques compared with those of today, observed that, electromyographically, the mentalis muscle is used more by those subjects displaying gross hypertrophy. Tulley (1953, 1956) also performed electromyographic studies on patients with normal and abnormal swallows using the masseter and circum-oral muscles.

Useful work was performed on the circumoral muscles and incisor relationship by Marx (1963) in determining that electromyography is an acceptable method for the study of muscle activity. Marx (1965) in a later study concluded that, in the resting state, the activity of the mentalis, upper and lower lips does not influence the position of the incisors. He felt that the position of the incisors is predominantly related to the dispersing effect of the tongue, the skeletal pattern and lip morphology.

An interesting electromyographic study was performed by Nieberg (1960) on twenty-nine Caucasian children. He found that in patients with a low IMPA and in those with a high IMPA, there was a predominance of the lower lip musculature. Those with a lower angulation exhibited considerably more activity. He also found that contraction of the mentalis musculature was predominant in those patients with the large mandibular sulcus. However, perhaps one should not give much credence to these results as the small sample size includes normal as well as malocclusion groups.

Electromyographic studies of the action potentials of the oro-facial muscles have also been performed by Moyers (1956, 1962); Schlossberg and Harris (1956); Baril and Moyers (1960); Møller (1966, 1976); Sumitsuji *et al.* (1967); Ahlgren, Ingervall and Thilander (1973); Ingervall (1976); Perkins, Blanton and Biggs (1977); Folkins (1978a, 1978b); O'Dwyer *et al.* (1980).

In recent years, electromyography has become one of the most accurate means for analyzing the muscular components of the oral apparatus. With the development of bipolar, fine-wire, hooked electrodes (Basmajian and Stecko, 1962), recording wires can be inserted directly into the muscles being examined thereby producing a more selective recording than that obtained by surface electrodes.

Perkins, Blanton and Biggs (1977) considered that recordings of duration, degree and sequence of activity of the musculature surrounding the dental arch would serve as an indication of the force applied to the teeth by the muscles.

Let me then review relatively current electromyographic observations on the perioral musculature as it relates to the lower anterior teeth.

Jacob, Haridas and Ammal (1970) in an electromyographic study of 80 subjects of both normal and tongue-thrust swallowers, found a significant difference in pattern of electrical activity between the two groups indicating that perioral muscle activity is affected by morphology. Activity of the muscles,especially mentalis muscle activity, was greater in the malocclusion group. This supported an earlier study by Schlossberg and Harris (1956).

Ingervall (1976) on the other hand found less dependence on facial morphology as related to lower lip activity. In an electromyographic study of 50 girls with normal occlusion, he claims that the activity of the lower lip was related only to the size of the upper dental arch. However, he did find a close correlation between the upper lip activity and morphology and also between the activity in the upper and lower lips.

In an electromyographic study of the activity of the temporal and lip muscles during swallowing and chewing, Invervall (1978), found greater amplitudes of activity for the lower lip than for the upper lip during swallowing. He also concluded that in the lip, there are two different and independent degrees of activity during the swallowing of fluid and solid substances. This concurred with the views of Perkins, Blanton and Biggs (1977).

5. DEGLUTITION

Descriptions of the act of swallowing have remained remarkably similar despite the extensive attention of many investigators. The complexities of the swallowing mechanism are generally divided into three stages: (i) oral (ii) pharyngeal (iii) oesophageal (Strang, 1950; Rogers, 1961; Weinberg, 1970; Barrett and Hanson, 1974).

Since this review is concerned with the relationship between the perioral musculature, and in particular the lower lip, and swallowing, only the oral stage shall be considered.

5.1 NORMAL SWALLOW

Strang (1948) gave, in part, a description of the early stage of the oral phase: "The bolus is formed on the dorsum of the tongue by the action of the intrinsic and extrinsic muscles of this organ, aided by the muscles of the face bordering the mouth and those of mastication."

Disagreement about the activity of the muscles of the face is expressed by Winders (1956), Rogers (1961), Subtelny (1970), and Barrett and Hanson (1974).

Perhaps a more acceptable description of normal swallow would be that put forward by Subtelny and Subtelny (1973): (i) during swallowing, the muscles of facial expression are not used; (ii) the muscles of mastication bring the teeth and jaws together and hold them together during the entire act of deglutition; (iii) the tongue mass remains within the confines of the dental arches during swallowing. In an earlier study, Subtelny (1970) stated that if comparisons are to be made between various functional swallows, a baseline of normal swallow must be established. Using high-speed cine radiographs, Subtelny (1970) observed the position of the tip of the tongue to be slightly lingual to the lower anteriors in preparation for swallowing. The tongue tip was subsequently observed to progress towards the lingual aspect of the maxillary incisors as the mandible and lower lip were elevated with the lower incisors approaching the maxillary incisors. The upper and lower lips were observed to make contact just prior to tongue tip contact. The important fact noted in these observations was that in normal occlusion, an anterior oral seal was established during deglutition with no observable strain in the region of the lips. This inactivity of the lips is supported by Rix (1946); Winders (1956); Nieberg (1960); Barrett and Hanson (1974); Pierce (1978); Tulley (1953, 1956); Dubner *et al.* (1978).

Nieberg (1960) described three basic types of deglutition with respect to orofacial musculature:

(i) The "normal" pattern exhibiting marked contraction of the masseter muscles and limited activity from the labial and mentalis musculature.

(ii) The "visceral" swallow, a concept advanced by Gwynne-Evans (1954), demonstrates little or no activity from the masseter plus slight orbicularis oris contraction.

(iii) Marked contraction of the lower lip and mentalis muscles and considerable maxillary orbicularis oris contraction but with minimal contraction of the masseter muscle.

5.2 ABNORMAL SWALLOW

Subtelny and Subtelny (1973) felt that abnormality in swallow would be indicated by (i) circumoral muscle contraction, (ii) failure of the buccal segments or the molars to contact, that is, a teeth apart swallow and (iii) tongue protrusion between the incisors and/or buccal teeth during the act of deglutition.

Major research contributions towards the study of abnormal swallowing with respect to muscle function and malfunction have been made by the British workers Rix (1953); Gwynne-Evans (1954); Tulley (1956). These, and in fact most investigators who recognize the habit of abnormal swallowing, would concur with the view that any action of the muscles of facial expression during swallowing is abnormal. It is generally agreed that "perverted" swallowing takes place with the teeth apart, so that the tongue slips through the occlusion and contacts the anterior teeth and the lips. Further alternative names for abnormal swallowing are "reverse", "infantile", "tongue-thrust" and "atypical".

Although most clinical reports describe abnormal swallowing as being associated with malocclusion, abnormal tongue and lip muscle patterns have been reported in association with normal occlusion. Rogers (1961) in a study of 290 schoolchildren noted that in 20% of the cases, normal occlusion was associated with abnormal swallowing activity. Conversely, he found that in children with abnormal muscle patterns, there was no apparent effect upon occlusion.

Cineradiography has been another method employed to observe muscle functions and swallowing activity. Andran and Kemp (1955) noted many variations in individual behaviour of muscle activity but that tongue thrust and incomplete molar contact can be associated with normal swallowing.

Cleall (1965), also using cineradiography, found that the concept of "normal" swallowing in which the teeth come into occlusion, the lips remaining in repose and the tongue remaining within the confines of the oral cavity was no longer tenable. He concluded that tongue, mandible and lips rest and function as an integral unit and that positions and positional changes during deglutition are largely determined by the local skeleto-dental configuration.

Rosenblum (1963) also contradicted the concept of abnormal occlusion being associated with abnormal swallowing in an analysis of 150 trials of swallowing by 20 "normal" subjects. He found a minimum amount of mentalis activity during deglutition in normal subjects, but more significantly, showed peri-oral activity occurred in normal subjects with normal dentition more than 50% of the time.

Hence it must be concluded that if perioral activity is considered an indication of abnormality, then this abnormal muscle function was found to be associated with normal occlusion.

5.3 ABNORMAL SWALLOW AND THE LOWER LIP

Ballard (1953) observed that in the abnormal swallow the tongue is thrust between the incisor teeth and usually against the upper incisors and over the lowers. He felt that this thrust is balanced by a contraction of the lower lip, as is evidenced by a contraction of the mentalis muscle. The tip of the tongue labially inclines the upper labial segment and the contraction of the lower lip against the tongue thrust lingually inclines the lower labial segment. Ballard (1953) also felt that the effect of the abnormal swallow is to produce a degree of increased over-bite and/or overjet, the variables being dependent on such factors as skeletal morphology and lip competency/incompetency.

Rix (1946) also commented on contraction of the mentalis muscle in children with abnormal swallow and resultant lower incisor irregularities. This view of mentalis and orbicularis oris contraction during oral myofunctional disorders and their effect on occlusion was supported by Pierce (1978).

Møller (1966), in extensive studies of orofacial muscles, stated that the degree of activity of muscles in the lower lip is dependent on morphology but that strong activity in the lips during swallowing was associated with retroclination of the lower incisors and crowding in the lower arch.

More support for lower lip activity come from Jacob, Haridas and Ammal (1976) in an electromyographic study of mentalis and orbicularis oris muscles. They determined there is a greater degree of activity of muscles, especially of the mentalis muscles in tongue thrust swallowers compared to normal swallowers.

Tensing of the mentalis muscle with possible lingual displacement of anterior teeth as part of increased tension of the circumoral musculature to maintain the oral seal was further supported by Barrett and Hanson (1974); Rogers (1961) and Dubner *et al.* (1978).

Tulley (1956) mentioned a "mentalis habit" as being a peculiar pattern of lip morphology and thus making it impossible to permanently change the axial inclinations of the lower incisors. In an electromyographic study of the perioral and masseter muscles, Tulley (1953, 1956) distinguished between the two types of atypical swallow and lip positions. In the non-dispersing tongue behaviour, the tongue does not exert any force on the lingual of the incisors; hence the lip may or may not contract excessively thus resulting in upright or retroclined incisors. The dispersing type of tongue behaviour results in actions of the tongue and lips which are associated with a dispersal of upper and lower incisor relations.

Considerable doubt and confusion still exists concerning the relationship between swallowing patterns, lip musculature and anterior teeth positions. Many variations have been noted in "normal" patterns of deglutition and conversely much of what has been described as an abnormal pattern of deglutition could really be an acceptable variation with a normal pattern of deglutition. Such is the variation of the orofacial complex.

6. LIP MORPHOLOGY AND THE LOWER LIP

6.1 DEFINITIONS

6.11 Lip competence

Ballard (1953) defined competent lip posture as being the state of normal resting posture of the lips and tongue. The lips being in apposition without contraction of the orbicularis oris or mentalis muscles and with the mandible in the physiological rest posture, that is, the facial muscles are in resting tonus.

This definition is agreed upon by many authors including Jackson (1962); Hovell (1962); Marx (1965); Simpson and Richardson (1975).

6.12 Incompetent lips

Hovell (1962) defined incompetent lips as those which cannot seal without muscular contraction. He felt that this was readily observed by dimpling of the skin over the attachment of the mentalis muscle. Ballard (1953) included the orbicularis oris muscle with the mentalis muscle as necessary to contract vigorously to obtain lip contact while Jackson (1962) adds the requirement of physiological rest position of the mandible and anatomically adequate lips.

Hopkin and McEwen (1957) did not concur with the above common definitions of competent and incompetent lips. They questioned the dividing line between competence and incompetence. A definition preferred by them related contact or lack of contact of the lower lip with the upper incisors at rest rather than contact or lack of contact of the upper and lower incisors at rest. This distinction was made as they felt that it appeared, from an anatomical point of view, that closed or parted lips at rest are both within the range of normal morphological variation.

Electromyography has also influenced the definition of lip competency. Simpson and Richardson (1975) defined incompetent lip morphology as being the amount of electrical activity in the perioral musculature necessary to maintain the lightest possible seal with the jaws in centric relation. Nieberg (1960) and Marx (1963, 1965) illustrated electromyographically that in the majority of children there is perioral muscle activity during lip contact. This led to the implication that a great number of subjects have electromyographically incompetent lips not possible to diagnose clinically.

6.2 LOWER LIP ACTIVITY AND INCOMPETENT LIPS

Ricketts (1968) commented extensively on the mentalis habit being a common problem in malocclusion and one that is easily recognizable due to peripheral lip strain and chin elevation. He felt that it was associated with either isolated conditions of a protrusive denture, inadequate lip length and a long or retrognathic type of face. A combination of all three factors may be present requiring maximum effort to close the lips.

Gustafsson and Ahlgren (1975) felt that the principal muscle for lip closure is the mentalis muscle. They found significantly greater activity in both orbicularis oris and mentalis muscles associated with incompetent lips claiming that electromyography confirmed their clinical diagnosis.

While Marx (1963, 1965) recorded electromyographic potential during "resting posture" in the mentalis muscle in incompetent lip cases, Gustafsson and Ahlgren (1975) could find no difference in resting activity of the muscles studied when comparing competent and incompetent lips. However, significantly higher levels of activity in mentalis and orbicularis oris muscles were recorded in incompetent lip cases with the lips closed, during deglutition and during mastication. The recordings of Gustafsson and Ahlgren (1975) during mastication are in agreement with those of Møller (1966) and Ahlgren, Ingervall and Thilander (1973).

Gwynne-Evans (1972) felt that much depends on the contour, position and behaviour of the lower lip in relation to the incisors at rest, in facial expression and swallowing. Functional consequences of lower lip behaviour depends on whether the lower lip covers the upper incisors or slips under them to form a taut band against lower incisors or to meet a forward spread of the tongue between the front teeth to effect a lip seal.

Marx (1965), and Gustafsson and Ahlgren (1975) tended to confirm each other's view that the lower incisors were significantly more protruded in conjunction with incompetent lips. The contradictory view was supplied by Møller (1966) and Ahlgren, Ingervall and Thilander (1973).

6.3 SUMMARY

What then is the effect of lower lip contraction in incompetent lip cases on the lower incisors? From various authors (Rix, 1953; Schlossberg and Harris, 1956; Hovell, 1962; Jackson, 1962; Marx, 1965; Gustafsson and Ahlgren, 1975) a consensus of opinion seems to emerge that the imbrication of the incisors may be of secondary importance to mentalis and orbicularis oris muscle activity. The above authors also feel that both competent and incompetent lips of varying severity can be associated with any type of incisor relationship, and that incompetent lips do not seem to have any direct adverse moulding effect upon the incisors.

Of more importance to perioral muscle activity, in particular the mentalis muscle, and hence incisor position, may be the skeletal vertical and antero-posterior relations of the jaws.

7. ANGLE'S CLASS II DIVISION 1 MALOCCLUSION AND THE LOWER LIP MUSCULATURE

7.1 DEFINITION

Brodie (1952) gave a simple definition of Angle's Class II Division 1 malocclusion as being characterized by a mandible that is posterior to the maxilla. In this antero-posterior skeletal abnormality, Brodie (1952) stated that the mutual support enjoyed by the two arches is lost in the anterior region particularly, and each comes under the influence of only a part of the total muscular complex that normally contributes to stability. Continuing, he described how the restraining force of the lower lip having been lost, the upper incisors fan out and the upper lip rolls back while the lower lip takes up its place beneath or behind the upper incisors.

7.2 THE UNTREATED SITUATION

While acknowledging that the tongue plays a great influence on incisor positions, Rix (1953) also maintained that vigorous contraction of the lower lip, in conjunction with abnormal swallow, causes retroclination and imbrication of the lower incisors and consequent increase in overjet. Ballard (1957, 1962) generally followed the same viewpoint, stating that incompetent lips have an influence on the aetiology of Class II Division 1 malocclusion due to the contraction of the orbicularis oris and mentalis muscles thus maintaining the lower lip segment in a more lingually inclined position.

However, both Tulley (1964) and Hayes (1975) tended to disagree, claiming that only a small proportion of Class II Division 1 malocclusions are associated with adverse tongue and lip behaviour.

Hayes (1975) also claimed that the only lower lip position to have any real clinical meaning is that of the trapped lower lip. In the cases he investigated, it was found that the aforementioned lower lip/maxillary central incisor relationship was consistently associated with overjet values greater than 6 mm. Hayes (1975) further suggested that abnormal incisor overjets are caused by either abnormal paths of eruption of the incisor teeth, or by abnormal antero-posterior relationships of the jaws thus also subscribing to the view that skeletal morphology discrepancy is dominant in the aetiology of Class II malocclusion.

Hovell (1962) also felt that if the dental base relationship is post-normal, the lower lip itself is "post-normal" to the upper and this Class II Division 1 relationship is maintained or even increased during function by the lower lip-to-tongue anterior seal.

This positive correlation between Class II Division 1 malocclusion and perioral muscle contraction, especially of the lower lip involving orbicularis oris and mentalis, is acknowledged by many authors. They include Schlossberg and Harris (1956); Scott (1961); Gould and Picton (1968); Jacob, Haridas and Ammal (1971); Simpson (1976, 1977); Fränkel (1980).

Using electromyography to study the mentalis muscle in Class II Division 1 malocclusion cases, Moyers (1949) found that the mentalis muscle is used more by those subjects displaying muscular hypertrophy. Support for the viewpoint comes from Fränkel (1980), who, in discussing Class II Division 1 cases, states that whereas the lip musculature is weak and flaccid, the marked bulk of the mentalis muscle is evidence of hypertonicity.

Tulley (1956) concluded from electromyographic studies that if a strong contraction of lower lip to tongue is present in Class II Division 1 malocclusions, the stability of the end result may be jeopardized. This could be caused by the lower lip retaining the upper incisors but causing secondary effects on the lower incisors causing them to imbricate. These statements have been supported by Burstone (1967).

Baril and Moyers (1960) in an electromyographic study of muscle activity in Class I and Class II Division 1 malocclusions, found equal amounts of abnormal mentalis muscle activity in both malocclusions although this study is also associated with thumb and finger sucking.

Posen (1972) in another electromyographic study of Class II Division 1 malocclusions observed that in those malocclusions which were less severe, that is, overjet of 2-3 mm, the maximum perioral forces were similar to those of normal occlusion at the same age level. However, where severe protrusion of the maxillary incisors existed, normal lip function was curtailed and maximum perioral force was significantly lower than in those with normal occlusion.

Winders (1958) also recorded no statistical difference between the pressures incurred during swallow in the normal group, as opposed to the Class II Division 1 malocclusion group. However, one perhaps cannot draw extensively on these conclusions since no values of overjet for the malocclusion group are given.

7.3 POST-TREATMENT

Subtelny and Subtelny (1973) stated that in cases of treated Class II Division 1 malocclusion, the lower lip at rest was postured labial to the upper incisors. This position was maintained during deglutition and was not functionally postured lingual to the maxillary incisors as before upper incisor retraction. The authors claimed that the lower lip function changed with the environment or with the repositioning of the anterior teeth.

Similar statements about the return to a more normal pattern of muscle activity post-treatment have been made by Brodie (1952); Cleall (1965); Subtelny (1970).

In an electromyographic investigation of perioral musculature in Class II Division 1 malocclusion pre and post treatment, Simpson (1977) noted that the most striking changes of activity were in the lower lip, mentalis and suprahyoid muscles with overjet reduction. Reduced mentalis activity was also noted with the changes in the upper incisal inclination and interincisal angle.

Support for the concept of "auxiliary" muscle function of mentalis and suprahyoid muscles comes from Fränkel (1980). The cineradiographic studies of this author substantiate the electromyographic findings of Simpson (1976). Fränkel (1980) feels that mentalis and suprahyoid muscles meet a "compensatory function" when the orbicularis oris is incapable of attaining a competent lip seal thus requiring the mentalis and suprahyoid muscles to contract in an auxiliary capacity. He further supports his statements with the observations that in treated Class II Division 1 cases, a marked decrease in muscle bulk is recorded since the mentalis mass is reduced as a result of forced inactivity.

Explanation of the concept, as expressed by Fränkel (1980), linking mentalis muscle "bulk", muscle hypertrophy and hypertonicity comes from anatomical and physiological researchers.

Hypertrophy refers to an increase in volume of tissue produced entirely by enlargement of the existing cells (Robbins, 1967). This increase in size of individual muscle fibres is known as muscular hypertrophy and results from extensive use of a muscle, as in exercise (Robbins, 1967; Vander, Sherman and Luciano, 1970). Such is the situation existing in an Angle's Class II Division 1 malocclusion case when the mentalis muscle is extensively exerted in order to form a lip seal.

In a treated malocclusion situation, the reverse process occurs. Atrophy refers to an acquired decrease in the size of a normally developed tissue or organ (Robbins, 1967). Disuse atrophy occurs when inactivity or diminished function of a muscle results in a diminution of its size (Robbins, 1967; Vander *et al.*, 1970; Jacob and Francone, 1974). Hence one could expect the mentalis muscle to progressively decrease in bulk once the overjet had been reduced with the muscle fibres becoming a fraction of their pre-treatment size. According to Jacob and Francone (1974), within six months to two years, some fibres are actually replaced by fibrous tissue.

B. ORIGINAL WORK

1. STATEMENT OF HYPOTHESES TO TEST

A consensus of opinion from the literature reviewed regarding the lower lip (thus involving the mentalis muscle) is that activity is within the limits of normal behaviour if only a small overjet discrepancy of 2-3 mm exists between the maxillary and mandibular incisor teeth. However, most workers in the field of perioral myology express the opinion that if an overjet of 6 mm or greater exists, increased activity of the lower lip can be expected. This increased activity is necessary to overcome the lack of lip seal, principally for aesthetic and speech purposes and invariably to maintain a lower lip to tongue tip seal during deglutition.

Since this is a pilot study involving small sample sizes in both control and experimental groups, statistically significant results cannot be obtained. However, certain trends of behaviour may become evident with respect to mentalis muscle activity and any conclusions will be expressed in relation to the following hypotheses.

HYPOTHESES

1. Patients with Angle's Class II Division 1 malocclusions with overjets exceeding 6 mm have different patterns of mentalis muscle activity compared to subjects with a normal occlusion.

2. There is inter-subject and/or intra-subject variability in electromyographic potentials of the mentalis muscle during the performance of given oral sphincter tasks.

3. Dental and soft tissue morphology relates to degree of mentalis muscle activity.

4. The results of the experimental work show a pattern which supports or refutes the concensus of opinion regarding mentalis muscle activity as ascertained from the literature.

2. METHOD

Electromyographic signals of mentalis muscle activity were recorded at rest and during functions of swallowing, chewing, speech and maximum contraction. These recordings comprised a comparative pilot investigation between a group of subjects with normal, Angle's Class I occlusion and a group of subjects with Angle's Class II Division 1 malocclusion.

The aim of the study is to correlate mentalis muscle activity during functional activities with the antero-posterior jaw relationships and to ascertain whether the results obtained show a pattern which supports or refutes the views expressed in the literature.

<u>SUBJECTS</u>

The subjects of the study comprised:

A) A <u>control group</u> of five undergraduate dental students from the University of Sydney with a normal range of oro-facial muscle activity and with excellent dental occlusion.

The dental criteria were:

1) Angle's Class I molar relationship with good buccolingual and mesiodistal cuspal relationships of the posterior teeth.

2) No missing or supernumerary teeth.

3) Minimal crowding, spacing or marked rotations.

3) Overbite not to exceed one half of crown height of the lower central incisors.

5) Overjet not to allow loss of contact between the upper and lower incisors in occlusion.

The normal subjects, three females and two males, with an age range of 19-22 years were all native speakers of Australian English. None of the control group had received orthodontic treatment.

B) An experimental group comprised one female and four males aged between 13 and 16 years awaiting orthodontic treatment at either the Staff Orthodontic or University Orthodontic clinics at the United Dental Hospital of Sydney.

The criteria for the experimental group were:

1) Angle's Class II Division 1 malocclusion relationship with preferably both canines and first permanent molars in Angle's Class II relationship.

2) All permanent teeth to be present and erupted up to the first permanent molars.

3) An overjet of at least 7 mm.

4) No tongue thrust observable during swallow and no other habits detected or reported.

5) The upper and lower lips to be apart when the mandible is in the physiological rest position. To obtain this position, each subject was asked to sit in a quiet, relaxed position with the teeth not contacting.

EXPERIMENT

The electromyographic recordings were made exclusively from bipolar, hooked-wire, implanted electrodes prepared according to the descriptions of Schipp *et al.* (1970) and Basmajian (1979). 25-gauge disposable needles with a 19 mm shaft (Terumo) were double threaded with 0.0028 inch polyeurethane coated copper wire (I.W.A. bicelflux). Commercial paint stripper (Triton Paints) was used to deinsulate 1 mm from the ends of the wire which were to be inserted into the muscle. The wires were bent back along the needle to form 2-4 mm hooks with the bared tips separated by approximately 1 mm. This electrode configuration was chosen in order to monitor the activity of the individual muscles while minimizing the problem of field spread from neighbouring muscles. Approximately 1 cm of the free end of each wire was also deinsulated to allow for subsequent connection to the cables of the electromyographic preamplifier (Fig. 9).

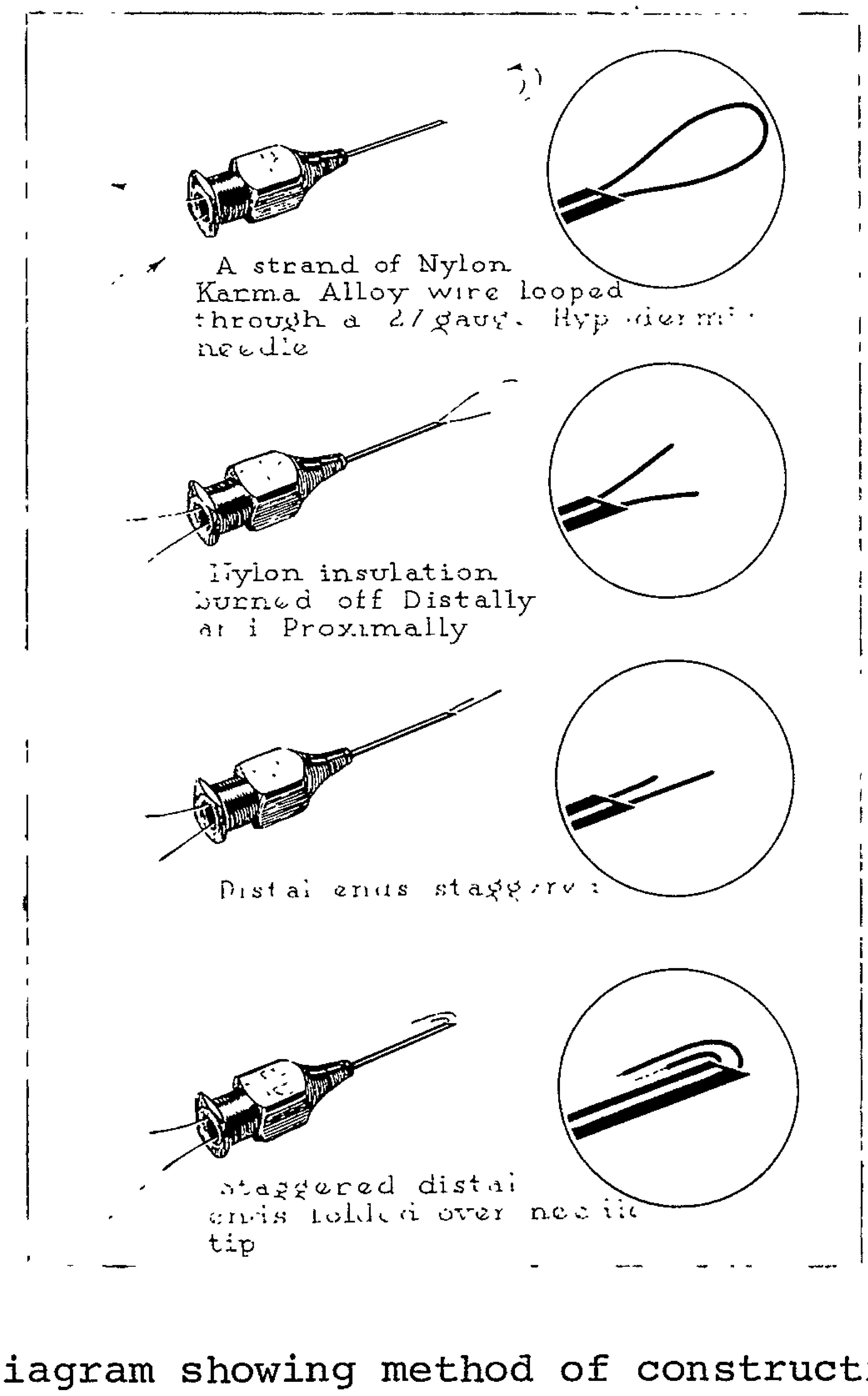

Fig. 9. Diagram showing method of construction of bipolar, fine-wire electrodes. (From: Basmajian and Stecko, 1962)

Following protection of the electrodes and needle point by reinserting into the needle cap attached to firm cardboard,the whole assembly was sealed in an autoclaving bag and dry-heat sterilized at 180°C for 20 minutes.

Prior to electrode insertion, the puncture area was disinfected with 70% Isopropyl Alcohol B.P. in the form of a disposable swab (Medi-Pack). To avoid patient discomfort during needle insertion a topical anaesthetic of 2% lignocaine (Lidocaton) was administered at the point of insertion with a Syrijet Mark II (Mizzy, Inc.) airjet spray (Fig. 10).

Fig. 10. Method of anaesthetization of the point of needle insertion.

Fig. 11. Hypodermic needle and contained electrode wires in-situ.

Fig. 12. Electrode in position

The subjects were earthed by a prejelled, silver/ silver chloride, disposable, surface electrode (Rogo Medical, Inc.) attached to the side of the neck at the level of the sixth (6th) cervical vertebra.

Following insertion of the hooked-wire electrodes, the wires were attached to the face with adhesive tape to reduce movement artifact. They were then led to alligator clips being part of the preamplifier cable and attached to the opposite side of the neck to the reference surface electrode. The wires and cable were attached and secured to the patient in such a manner that the patient's head and the cable would move together, thereby minimizing the risk of disturbing the electrodes. During the electromyographic recordings, subjects were seated in an upright position with the head unsupported (Fig. 13).

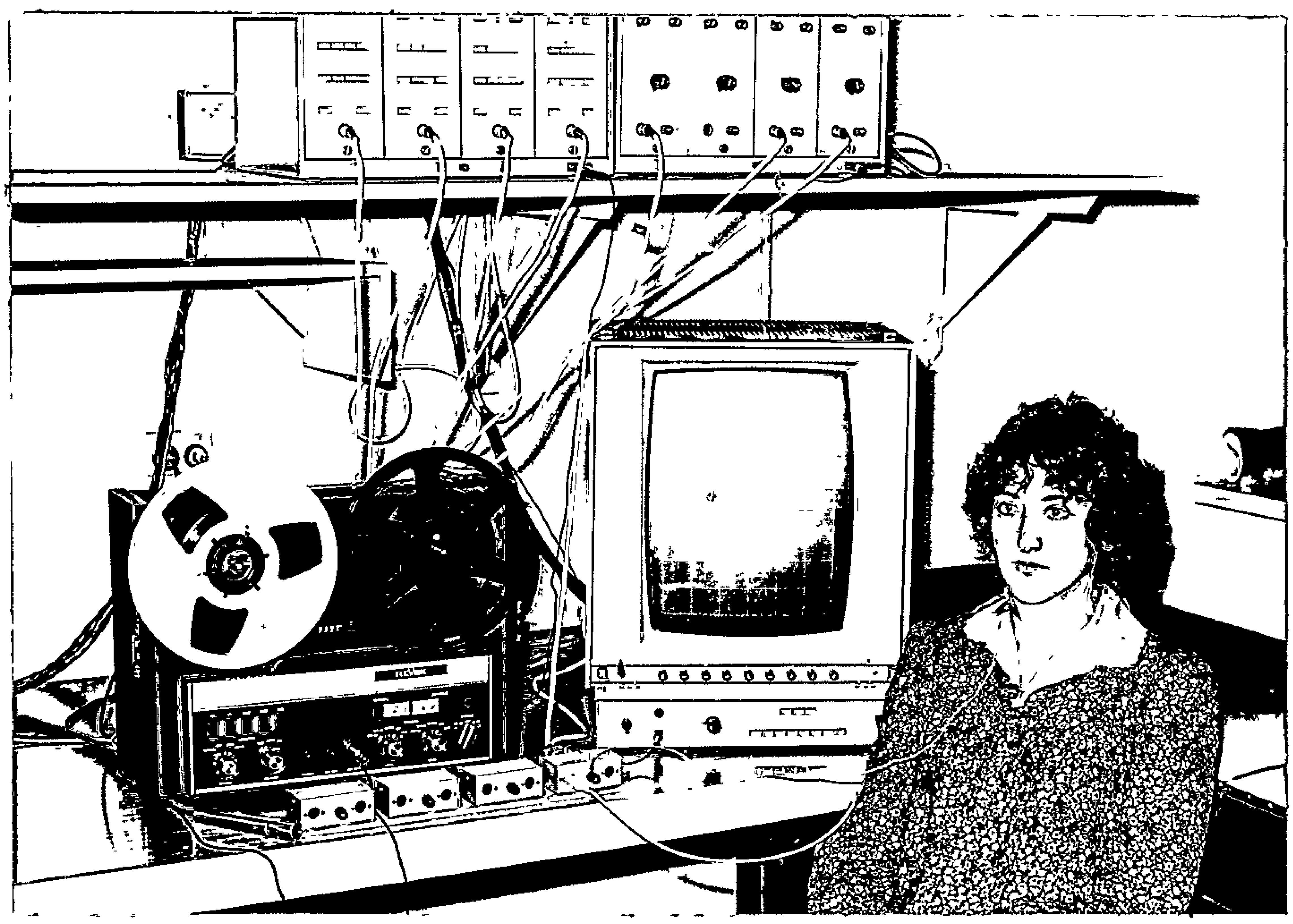

Fig. 13. Patient seated ready for recording.

The electromyographic signals from the electrodes were led via twin-wire shielded cable of minimum capacitance to maintain high frequency, to an eight-channel rack of differential preamplifiers (Disa, Type 14C12). For this experiment, only one channel was required, the same channel being used throughout.

The preamplifier possessed the capacity to adjust the frequency response from 2 Hz to 20 Hz on the low end of the spectrum to 3 kHz to 10 kHz on the high end of the spectrum. This made an available band width of 2 Hz to 10 kHz. The selected sensitivity was 200 μV per inch of display with the average amplitude on display being 1 millivolt (1,000 μV). An internal calibration facility was present on the preamplifier to enable calibration of the entire recording system. The signal output from the preamplifier was split into two parts.

One signal was led to an 8 channel, 18" conventional oscilloscope display (Disa, Type 14B75) to allow continuous monitoring of the electromyographic signal. This system allowed movement artifact and poor quality signals to be easily detected. Two channels of the oscilloscope were used, one for the direct signal display from the preamplifier, the other as will be described subsequently. The oscilloscope had a screen grid system of one inch graduations and the oscilloscope was calibrated to the preamplifier system.

The second split signal from the preamplifier was connected to a Revox A77, ½track stereo tape recorder running at a tape speed of 7½ inches per second and with a frequency response of 20 Hz - 20 kHz. Equilibration of the tape recorder was possible using the in-built NAB system. Being a three-head machine system, the operator was able to record signals and play back simultaneously, enabling the output to be fed into the other channel on the oscilloscope. The output level on the tape recorder meter was adjusted so as to coincide the amplitude on the oscilloscope display with that being fed from the preamplifier. By adjusting the output level to maintain a 1:1 relationship of the direct signal with the played back signal, the entire system was calibrated.

During gestures of maximum mentalis muscle contraction, the input recording level was adjusted for maximum signal/noise ratio and minimum distortion. The other channel on the recording tape (Scotch 250, 3M) was used to record the operator's audio commands. An amplifier and speaker unit built into the tape recorder was also used to monitor muscle activity during recording (see Appendix).

EXPERIMENTAL PROCEDURE

Prior to the experiment, each subject was briefed on the entire procedure and given training in front of a mirror in performing the gesture of maximum contraction of the mentalis muscle (Fig. 14). The elevation and protrusion of the lower lip as a result of contraction of muscle mentalis is a widely held view (Lightoller, 1925; Gray, 1967; Isley and Basmajian, 1973; Sussman *et al.*, 1973).

Fig. 14. Gesture of maximum contraction of mentalis muscle.

Each patient performed the following procedures in sequence:

1) Maximal contraction of the mentalis muscle by forced anterior-superior eversion of the lower lip combined with dimpling of the skin of the chin. This procedure is designed to produce the largest possible electromyographic potential for each electrode placement in each subject thus giving a calibration signal.

Each maximum muscle contraction was held for a measured time of five seconds. Maximum contraction of the muscle was recorded five times.

2) Resting potential
For the normal, Class I control group, mentalis activity was recorded for a measured time of five seconds with the mandible in physiological rest position, the teeth being apart and the lips in light contact.

The experimental, Class II Division 1 malocclusion group had five second duration recordings of mentalis muscle activity in a natural resting posture with unstrained lips and no active attempt at lip competency. The subjects in this group were recorded for a further period of five seconds when requested to bring the lips into contact.

3) Dry swallow
Each subject was requested to perform "dry" swallows of his/her own saliva. This procedure was recorded five times.

4) Wet swallow
Mentalis muscle activity of each subject was recorded during the drinking of a measured volume of water. 10 ml of water from a paper cup was held in the mouth for a period of five seconds for muscular stability and the subject was then instructed to swallow. This was repeated to enable five recordings of the procedure to be made.

5) <u>Chewing</u>

Recordings were made of each subject chewing a standard quantity of peanuts. The rate of chewing was regulated to one chew per second and the subject then requested to swallow the masticated peanuts. This also was repeated to enable five recordings to be made.

6) <u>Speaking a specified test</u>

The subject was asked to practise speaking the phrase "mama, papa, wobbles" before the mentalis muscle activity during such speech was recorded. In speaking this phrase, slow and distinct enunciation of each word was requested. This procedure was recorded five times.

7) <u>Maximum muscle contraction</u>

Five repeat recordings were made of maximum mentalis contraction, each contraction being held for a measured time of five seconds.

The magnitude of electromyographic potentials varies with such factors as individual anatomical differences, degree of separation of the tips of the inserted electrode and variations in the location of the electrode within the muscle. Since no direct controls of these variables are available, activity during each gesture will be later expressed as a percentage of the calibration maximal contraction, according to the procedure of Shipp and McGlone (1971). The data is thus normalised, making inter- and intra-subject muscle comparisons possible.

ELECTRODE PLACEMENT

In order to ensure accurate electrode placement within the mentalis muscle the following approaches were taken into account:

1) The location of muscle mentalis as described in anatomy texts (Cunningham, 1964; Gray, 1967; Grant, 1975; Sicher and Du Brul, 1975).

2) The examination of cadaver specimens in the Anatomy Museum, University of Sydney.

3) The variability in facial morphology and muscle topography.

4) The knowledge that on-line electromyographic signals from the tip of the electrode would be monitored during insertion.

Prior to the actual project investigation, it was necessary to familiarize oneself with the equipment, technique of electrode insertion, placement within muscle, etc., on a trial subject. The general electrode insertion technique was to advance the needle, in the subcutaneous tissue, towards the expected location of the target muscle, with regular checks of the electromyographic signal as displayed on the oscilloscope being made. Electromyographic activity was elicited by the maximum contraction gesture and monitored on the oscilloscope and the audio amplifier. When the signal consisted of a high frequency interference pattern of activity, the signal was considered acceptable for recording purposes. The spikes obtained indicated proximity to active muscle fibres. It was occasionally necessary to make several attempts to locate the muscle adequately. On each attempt a new needle/electrode was used. Whilst probing, the needle was always moved forward rather than withdrawn, even partially, for fear that the hooked electrode ends would lose continuity with the needle tip if the latter were retracted. When the electrode was considered to be satisfactorily positioned, the needle was withdrawn leaving the electrode in situ and the wires were reconnected to the preamplifier. The electromyographic signal was then checked to ensure that withdrawal of the needle had not disturbed the electrode location.

Basmajian (1979) describes a method to depolarize the electrodes by passing a small electric current through the two electrode wires with an ohmmeter. Towards the latter stages of some of the experiments, the electromyographic signals did tend to deteriorate presumably due to polarization of the electrodes and this method just described was of great assistance in decreasing the interference.

At the conclusion of the experiment, the electrodes were simply withdrawn from the tissues by a firm tug and checked for breakage. No electrodes were observed to have broken during this project.

<u>Location of insertion point</u>

The superior surface of the tuberculum mentale was palpated and the needle inserted perpendicularly through the skin at a point approximately 5 mm above the tubercle. The needle was advanced until the tip was estimated to be halfway between the skin and the periosteum of the mandible. The gesture for maximum contraction of the mentalis muscle was raising and everting the lower lip while also wrinkling the skin of the chin.

3. EVALUATION OF DATA

For the purposes of quantification and visual inspection, the recorded electromyographic (raw EMG) signals were played back from the tape recorder through a 1/3 octave graphic equalizer (MXR) to Grass 5P3 preamplifiers. The cutoff levels on the graphic equalizer were set so as to minimize 50 Hz line frequency interference and low frequency movement artifact. Recorded signals were played back, at a reduced speed of 3 and 3/4 inches per second, through the preamplifier set to "integrator" mode where they were full-wave rectified and low-pass filtered to yield integrated electromyographic (IEMG) signals. The time constant of the IEMG filter was modified to 0.16 seconds, but with the 2:1 reduction in tape speed this was equivalent to a time constant of 0.08 seconds. The resultant IEMG signals were recorded on a 4-channel Grass Model 5D polygraph recorded running at a paper speed of 10 mm per second.

The high frequency filter of the driver amplifier was set at 3 Hz which, with the reduced tape speed, gave an effective corner frequency of 6 Hz. These time constant and filter settings were chosen to provide the best compromise between smoothing the raw EMG signal and reproducing rapid changes in muscle activity. Small amplitude fluctuations associated with individual spikes in the raw EMG interference pattern could often just be seen in the IEMG signal. Thus, the IEMG filter was sufficiently sensitive to follow any meaningful variations in the average level of the interference pattern.

The amplitude of the activity was determined directly by hand in terms of the height of the polygraph trace above the baseline. Measurement to the nearest millimetre were made of the peak amplitude of the third signal of each gesture. These measurements were then expressed as a percentage of the peak "calibration" amplitude of the third signal for the maximum contraction gesture.

While it is unlikely that peak IEMG measurements have a linear relationship with force of contraction, nevertheless, it is generally accepted that IEMG increases directly with force of contraction. Some researchers (Lippold, 1952; Bigland and Lippold, 1954; Bigland-Ritchie and Woods, 1974; Milnar-Brown and Stein, 1975) have reported a linear relationship during voluntary submaximal isometric or isotonic contraction. The peak amplitude measure is therefore considered to provide an assessment of the maximum contraction force developed during each gesture.

4. RESULTS AND DISCUSSION

Table 1, derived from the IEMG polygraph records, presents the mentalis muscle activity during each gesture expressed as a percentage of the maximum (calibration) activity level for each subject in the control group.

Table 2 displays the corresponding values for each subject in the experimental group.

Subject	Rest	Dry Swallow	Hold	Wet Swallow	Chew	Chewing Swallow	Speaking	Max	Max Repeat
P.G.	0	6.0	0	7.3	46.3	26.8	41.4	41	41
D.E.	0	3.3	2.2	6.6	84.4	62.2	47.7	45	23
M.A.	0	0	0	0	32.3	0	23.5	34	29
J.S.	0	0	0	0	26.3	0	31.5	19	19
D.D.	0	0	0	0	10	0	10	20	12

Table 1. Measurements of the peak amplitude of the third signal of each gesture expressed as a percentage of the maximum (calibration) value for each subject. Control group.

	Rest										
	Apart	Together	Dry Swallow	Hold	Wet Swallow	Chew	Chewing Swallow	Speak	Max	Max Repeat	Overjet
L.M.	0	9.5	14.2	14.2	14.2	23.8	23.8	23.8	21	17	10.5
P.M.	0	7.1	35.7	14.2	50	64.2	14.2	35.7	14	12	12.0
S.F.	0	20	46.6	46.6	36.6	60	40	80	15	15	11.5
K.N.	0	13.7	65.5	17.2	44.8	48.2	58.6	27.5	29	17	13.5
E.P.	0	10	15	15	30	25	15	30	20	20	8.5

Table 2. Measurements of values recorded for each gesture expressed as a percentage of the maximum (calibration) value for each subject. Experimental group.

As a consequence of the experimental procedure and, in particular, the instructions to the subjects, maximum activity was never recorded during the performance of any gesture. It may be noted, however, that significant interference patterns were still observed especially for the gestures performed by the experimental group as displayed in Table 2. The interference patterns for subject S.F. in Table 2, for example, during the speaking gesture, constitute 80% of the recorded maximum calibration activity value.

During the calibration recordings, not only did the interference patterns increase in intensity within the muscles but also the pattern of activity was altered. In the recordings of calibration activity the subject was requested to exert maximum contraction of the muscle, to hold the contracted position for five seconds and then repeat the gesture a further four times. In most cases, the amplitude of activity decreased towards the end of each segment of contraction. When repeat maximum contractions were recorded, in all subjects in both the control and experimental groups, the repeat activity was either the same as or less than the initial recorded values. The decrease in maximum contraction levels is no doubt due to muscle fatigue from prolonged activity. The importance of the degree of effort on the part of the subject in electromyographic recordings of movement was emphasized to each participant prior to recording. This has been pointed out previously with respect to facial muscles by Blanton, Biggs and Perkins (1970) and Isley and Basmajian (1973).

The amplitude of the early bursts relative to the remainder of the activity in a muscle was highly variable, presumably due to intersubject variability in the velocity of the initial movement to achieve the posture.

The patterns of activity elicited by the individual gestures for each group are described below. Refer to Tables 1 and 2.

Resting Potential

All subjects at rest in both the control and experimental groups showed nil electromyographic activity of the mentalis muscle. However, in subjects in the experimental group, all having lips apart at rest, electromyographic activity was recorded and maintained when the subjects were requested to appose the lips from the habitual resting posture.

The existence of electrical activity in the lower lip in order to maintain seal, supports the findings of Nieberg (1960); Marx (1963, 1965); Gustafsson and Ahlgren (1975); Simpson and Richardson (1975).

Dry Swallow

The views of Ardran and Kemp (1955, Rogers (1961), Rosenblum (1963) and Cleall (1965) are that perioral activity during swallowing is not necessarily indicative of abnormality or of abnormal occlusion.

The normal group in this study displays this inter-subject variability of mentalis muscle activity during swallowing. Three subjects of the normal group exhibited nil activity and the remaining two subjects registering slight levels of mentalis muscle activity.

All subjects in the experimental group displayed substantially higher levels of muscle activity during saliva swallows as perhaps would be expected due to the large antero-posterior dental discrepancies existing in the group.

This finding of larger activity in an abnormal swallow situation is in accordance with the opinions of Ballard (1953), Rogers (1961), Møller (1966), Barrett and Hanson (1974), Dubner *et al.* (1978) and Pierce (1978).

A relatively constant pattern of activity was detectable in individual subjects, in agreement with the earlier electromyographic study of Hrycyshyn and Basmajian (1972) and the cinefluorographic study of Cleall (1965). However, as these two studies also demonstrated, considerable inter-subject variability was observed in the swallowing patterns.

It should be noted that the subject with the largest overjet value (13.5 mm) recorded the highest level of mentalis muscle activity during dry swallow of saliva, being 65.5% of the subject's calibration value. Noting the recorded values for the other subjects in the experimental group, there does appear to be some direct correlation between the degree of incisor overjet and muscle activity during dry swallow.

Wet swallow

The lack of muscle activity in the control group is again noted both in the holding of the lips together prior to water swallowing and also during the actual act of deglutition. During the holding of the fluid in the mouth, only one subject exerted any recordable activity. During the swallow, two of the five subjects exerted only small levels of activity. In all other measurements for the control group, nil activity was recorded.

In the experimental group, significant levels of electromyographic activity were recorded in mentalis muscle for all subjects during both the holding sequence and during the swallow. With such a small experimental group exhibiting marked variability, there was no discernible pattern as to whether the level of activity increased, decreased, or remained relatively constant between the holding period and the actual swallow.

Chewing

The variability of perioral muscle contraction during swallowing for normal occlusions and normal lip morphology is again apparent for this gesture. Three subjects in the control group exhibited nil activity of mentalis muscle during swallowing following chewing. One subject displayed 26.8% while another displayed 62.2% of their respective calibration levels during deglutition. For all subjects in this group, the recorded activity levels during the chewing strokes were significantly higher than were the subsequent swallow recordings.

In the experimental group, the trend towards greater activity during chewing than during the swallow is also evident. All subjects in this group were recorded as having mentalis muscle activity during the act of deglutition. These findings are in agreement with those of Møller (1966), Ahlgren, Ingervall and Thilander (1973) and Gustafsson and Ahlgren (1975).

For this gesture also, a loose correlation seems to exist between the degree of incisor overjet and the level of muscle activity but due to the small sample size no definite conclusion can be drawn.

Speaking

All subjects in both groups exhibited mentalis muscle activity during the speaking of the specified phrase. No subject in the experimental group displayed any abnormal, audible speaking habits. Variations exist in the overall level of activity recorded by subjects in both groups and no relevant comment can be made on the relative activity displayed by the groups as a whole.

The activity of mentalis muscle in the elevation of the lower lip in pronunciation of the consonants "m" in "mama", "p" in "papa" and "b" in "wobbles" confirms the views of Lightoller (1925), Leanderson and Lindblom (1972) and Sussman *et al.* (1973).

On close examination of the spikes recorded during speech, a trend towards increased amplitude during pronunciation of the letter "p" as in "papa" over the amplitudes recorded for the other words is noticed in the control group. In the experimental group, a tendency for greater activity for consonants "m" and "p" over that of "b" further supports the work of Leanderson *et al.* (1966).

The adaptability of the lower lip for speech production in the presence of dental abnormalities is indicated by the general similarity between activity levels for the experimental group as compared to the control group.

OBSERVATIONS

Although not a controlled aspect of this experiment, comparative observations of lateral profiles of the Angle's Class II Division 1 group and their respective mentalis muscle activities were made. Of this experimental group, only subject P.M. would be considered clinically to possess a deep sublabial furrow and possible hyperactive mentalis activity. The results indicate no such excessive muscle activity.

It should be stressed, however, that due to the small sample size, further experiments would be necessary to make definitive statements on this subject.

VARIABILITY

It is clear from the activity patterns of each gesture that a considerable amount of intersubject variability is present in the response of mentalis muscle. Such variability was also reported by Isley and Basmajian (1973) and O'Dwyer *et al.* (1980). Control for technical factors such as the degree of separation of the electrode tips following insertion into the muscles has been implemented through normalization of the data, but, obviously, minor variations in the location of the electrode within muscle may have contributed to the variability.

The anatomical differences that exist between the subjects both in muscle topography and facial morphology may be expected to impose constraints on the basic pattern of activity required for the performance of each gesture. However, while the instruction and training in the gestures given to the subjects was aimed at minimizing differences in their physiological use of the mentalis muscle, it was unlikely to completely control their previously learned behaviour. Furthermore, some interactive relationship may be expected between such anatomical differences and previously learned behaviour, the extent and significance of which is difficult to determine.

It has been shown that a correlation exists between facial morphology and the degree of activity of the masticatory and upper and lower lip muscles during various natural functions such as chewing and swallowing (Ahlgren, 1966; Møller, 1966; Ingervall, 1976). Therefore, the variability in the responses can be largely accounted for by these factors.

5. SUMMARY AND CONCLUSIONS

SUMMARY

An electromyographic investigation of mentalis muscle activity during a range of oral sphincter tasks was undertaken. Indwelling, fine-wire electrodes were inserted into muscle by way of a hypodermic needle so as to allow recording using the bipolar technique.

Mentalis muscle activity recordings were made both on a control group of five subjects with normal occlusion and orofacial muscle morphology, and on an experimental group possessing an Angle's Class II Division 1 malocclusion with an overjet of 7 mm or greater. Each participant in this project was investigated whilst performing a controlled series of procedures in order to exhibit mentalis muscle activity during common functions of the lower lip.

Electromyographic recordings were made during:

1. Maximum contraction of the mentalis muscle. This reading gave a calibration value for each subject. The gesture of maximum contraction of mentalis muscle is elevation and protrusion of the lower lip whilst dimpling the skin of the chin.

2. Quiet resting state with the mandible in physiological rest position. Angle's Class II Division 1 malocclusion cases were also recorded with the lips in light contact as well as in their habitual apart posture.

3. Saliva swallow.

4. Wet swallow of a measured volume of water.

5. Controlled chewing of peanuts and subsequent swallow.

6. Speaking a specified phrase.

7. Repeat maximum contraction of mentalis muscle.

CONCLUSIONS

From the results of these investigations, the following conclusions are submitted in response to the previously stated hypotheses:

1. Increased mentalis muscle activity was recorded in the malocclusion group subjects in order to appose the lips and hold them in light contact due to the degree of antero-posterior dental discrepancy.

   While both groups were at rest, no discernible electromyographic difference in mentalis muscle activity was apparent. During gestures resulting in swallowing of saliva, water and peanuts, there was an apparent trend indicating greater muscle activity in the experimental group compared to that in the normal group.

2. In the control group, intersubject variability is minimal in the recordings of resting potential, dry (saliva) swallow and wet swallow but exists to a greater extent for the swallow following chewing. This, however, may be explained by the nature of the medium being chewed and swallowed.

   For the speaking gesture, considerable variability exists for overall muscle activity recorded although most subjects concur in exhibiting greater activity during pronunciation of the letter "p".

   Great levels of intersubject variability are apparent in the experiment group for all gestures investigated with the exception of resting potential.

Levels of intra-subject variability tend to be less in the normal group than in the experimental group. Concurrent recording values exist for resting potential, dry swallow, wet swallow and chewing swallow in three out of five subjects in the normal group. Only one subject in the malocclusion group showed consistency in recorded values during these same gestures.

3. Clearly, overall increased levels of mentalis muscle activity exist when associated with greater than normal overjet values. Although not a controlled investigative aspect of this thesis, the one subject who did possess a deep sublabial furrow, often clinically associated with a so-called "hyperactive mentalis", did not exhibit any significantly superior activity levels compared to other members of the malocclusion group.

   Also no clear trend was apparent linking degree of overjet values to mentalis muscle activity levels.

   The small sample size is a restrictive factor in making conclusive statements relating morphology to muscle activity levels. Further research in this field is therefore indicated.

4. Generally, the results of this study concur with the widely held views relating lower lip activity to Angle's Class II Division 1 malocclusion, that is, that the lower lip, trapped lingually to the upper incisors does possess greater activity levels than in a normal morphological situation.

   It also seems conceivable to support the viewpoint that the "trapped" lower lip, in association with a pre-existing Angle's Class II Division 1 malocclusion, contributes to the maintenance of the abnormal antero-posterior dental relationship. The scope of this project is not wide enough to make meaningful comment on the influence of mentalis muscle contraction and lower lip function on lower anterior teeth positions.

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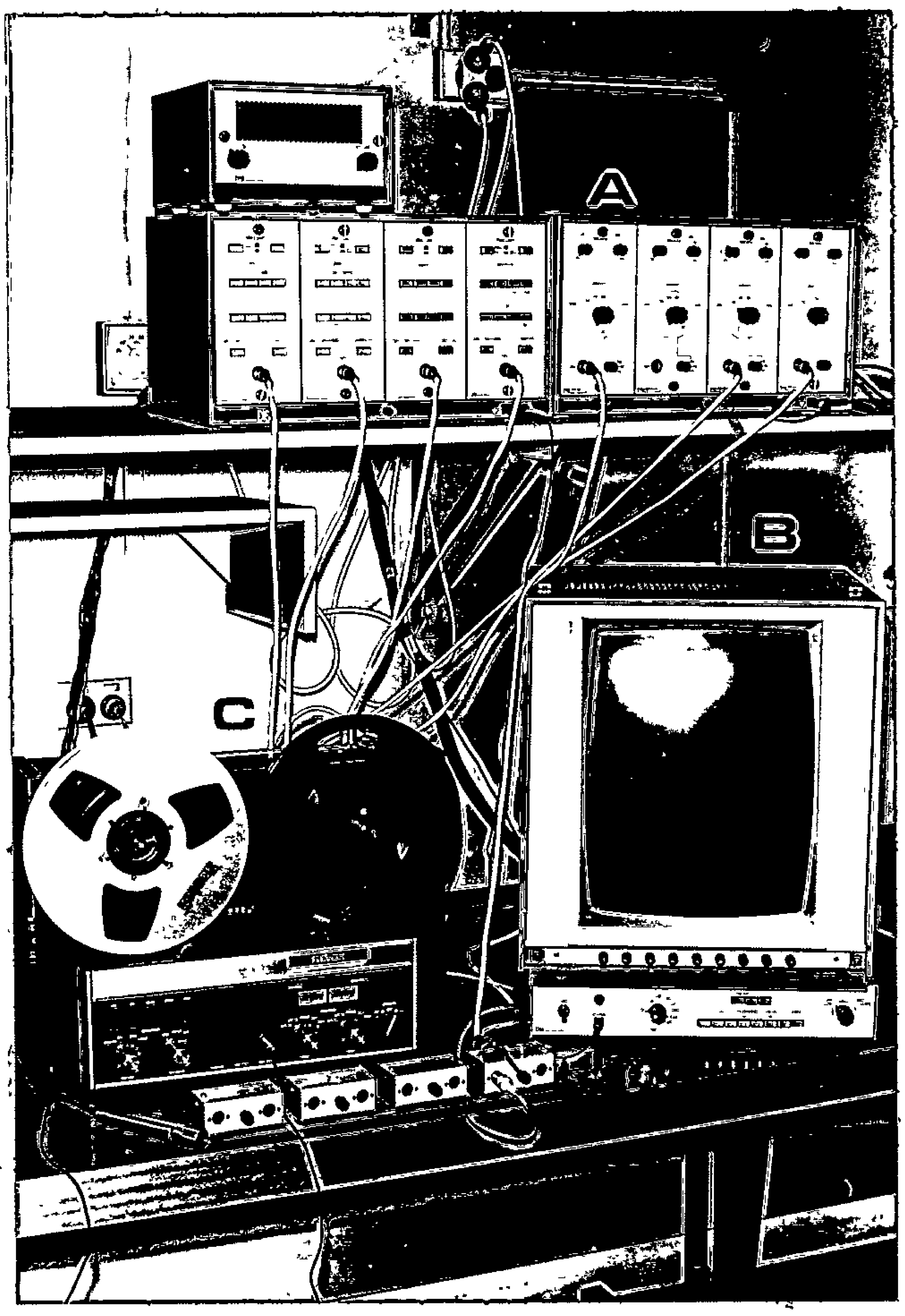
APPENDIX

A. ELECTROMYOGRAPHIC APPARATUS



A. Differential Pre-amplifier

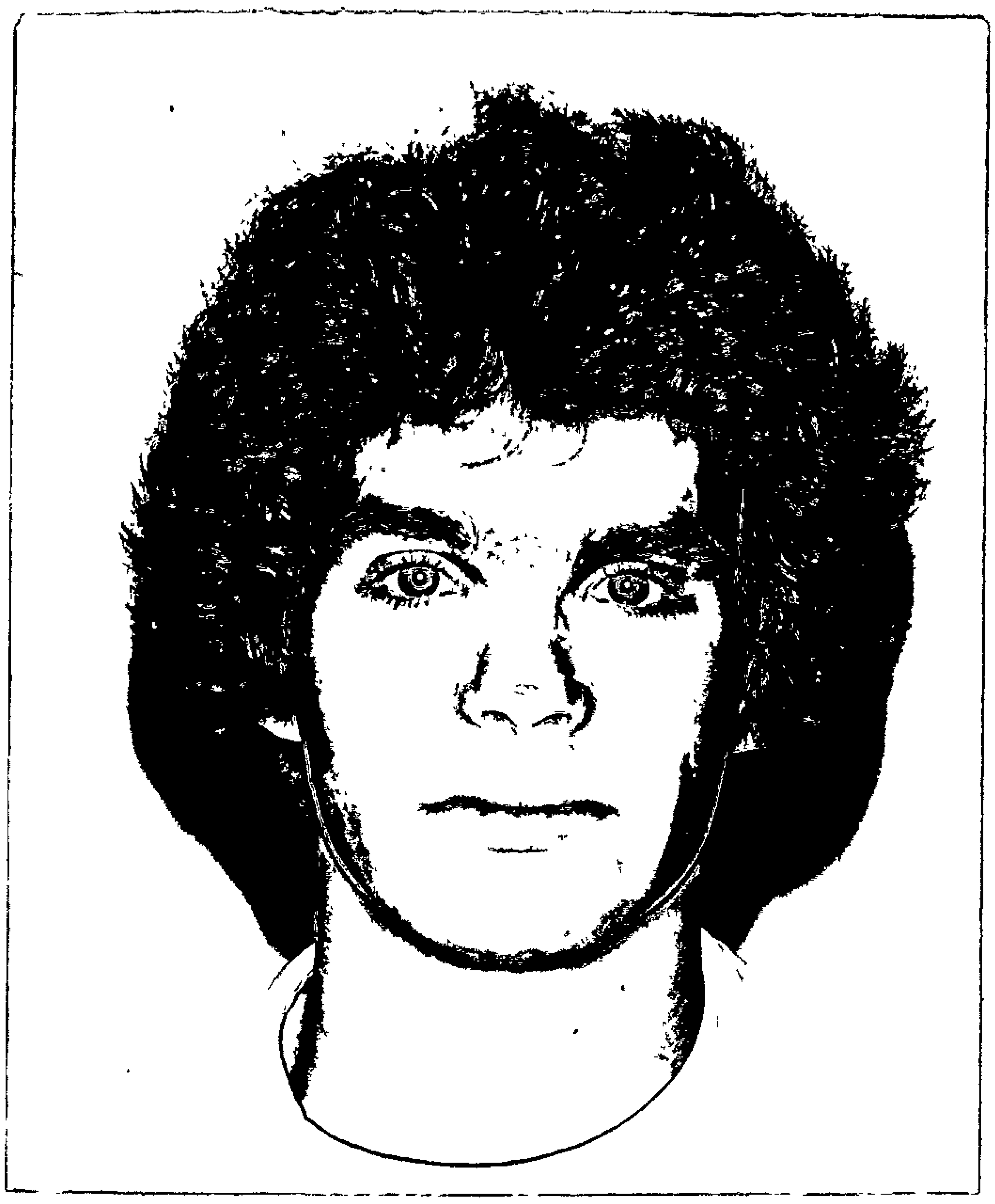
B. Cathode-ray Oscilloscope

C. Audio Tape Recorder

Circut Diagram: — RECORDING

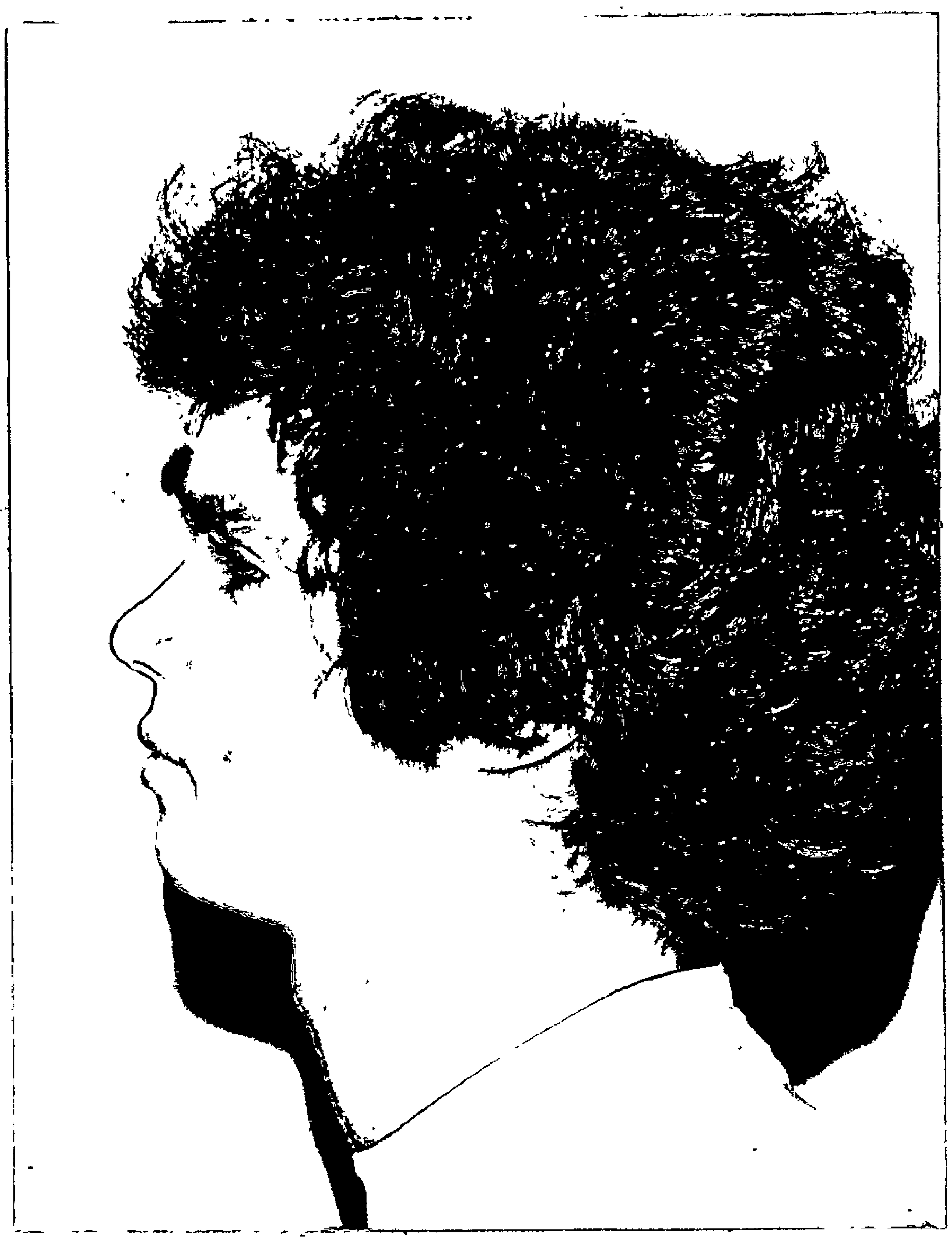
Circut Diagram:—ANALYSING

B. EXAMPLES OF SUBJECTS



Frontal facial profile: Control group subject P.G.

Frontal facial profile: Experimental group subject K.N.



Left lateral profile: Control group subject P.G.

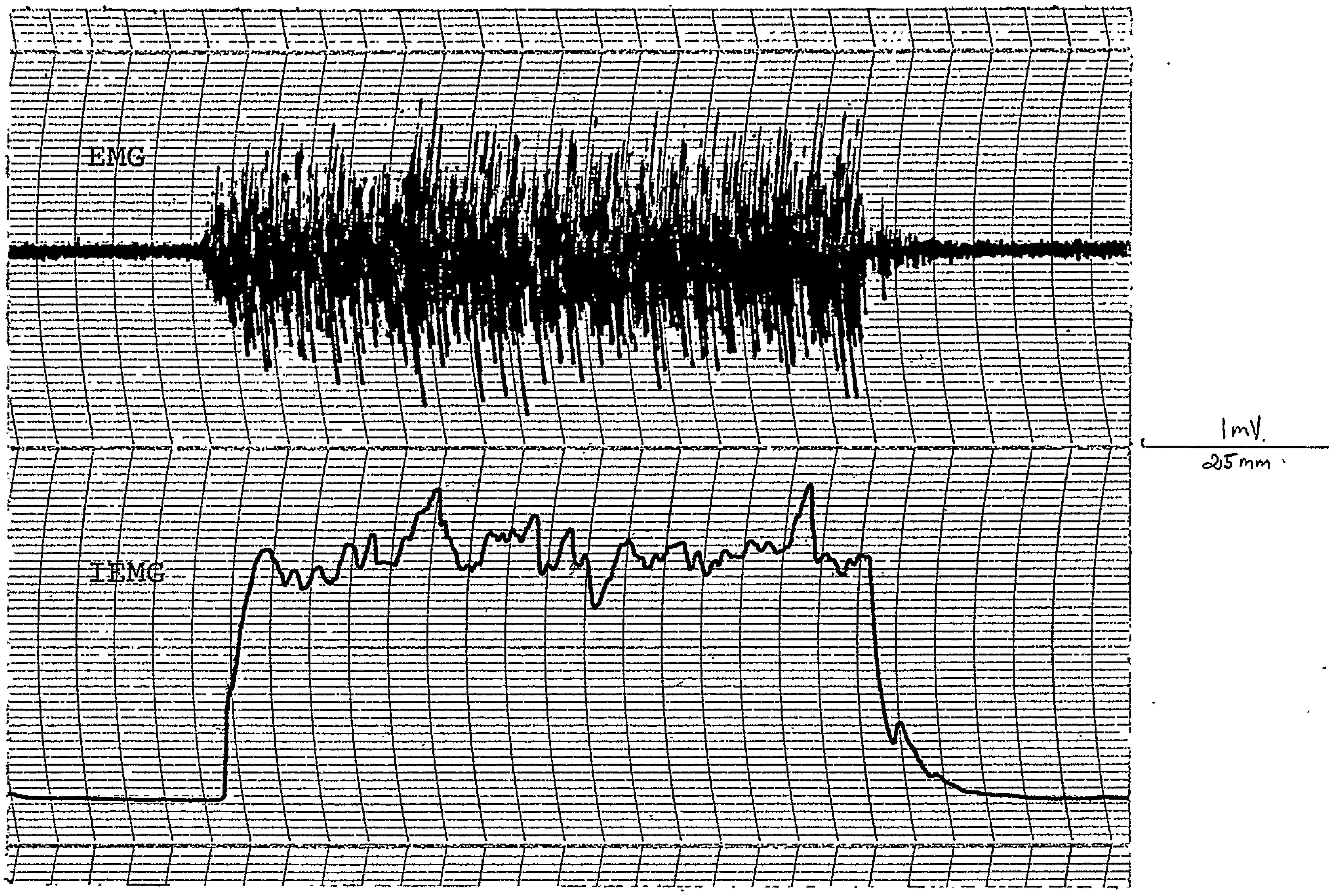
Left lateral profile: Experimental group subject K.N.

Dental occlusion from the left hand side: Control group subject P.G.

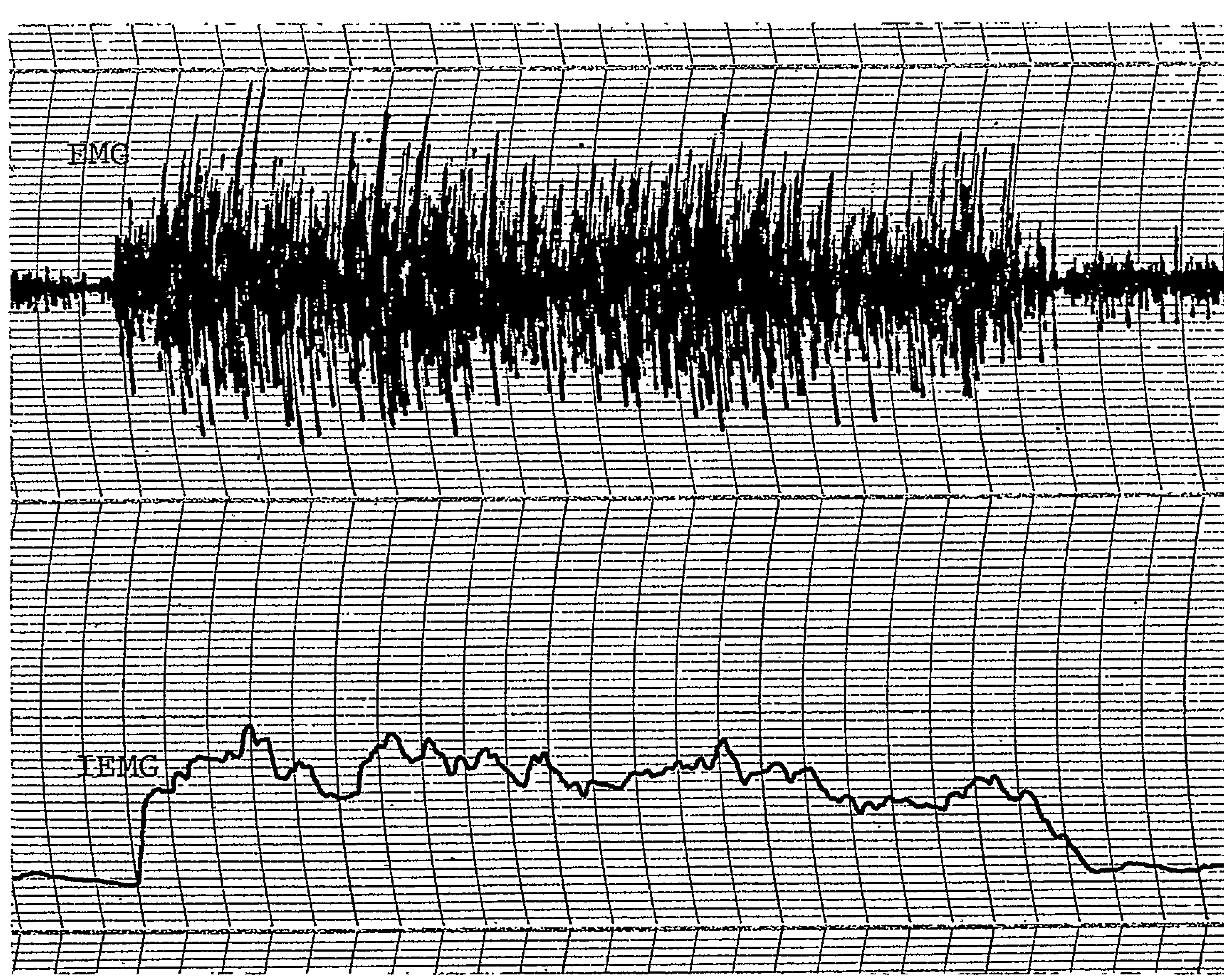
Dental occlusion from the left hand side: Experimental group subject K.N.

C. EXAMPLES OF ELECTROMYOGRAPHIC RECORDINGS

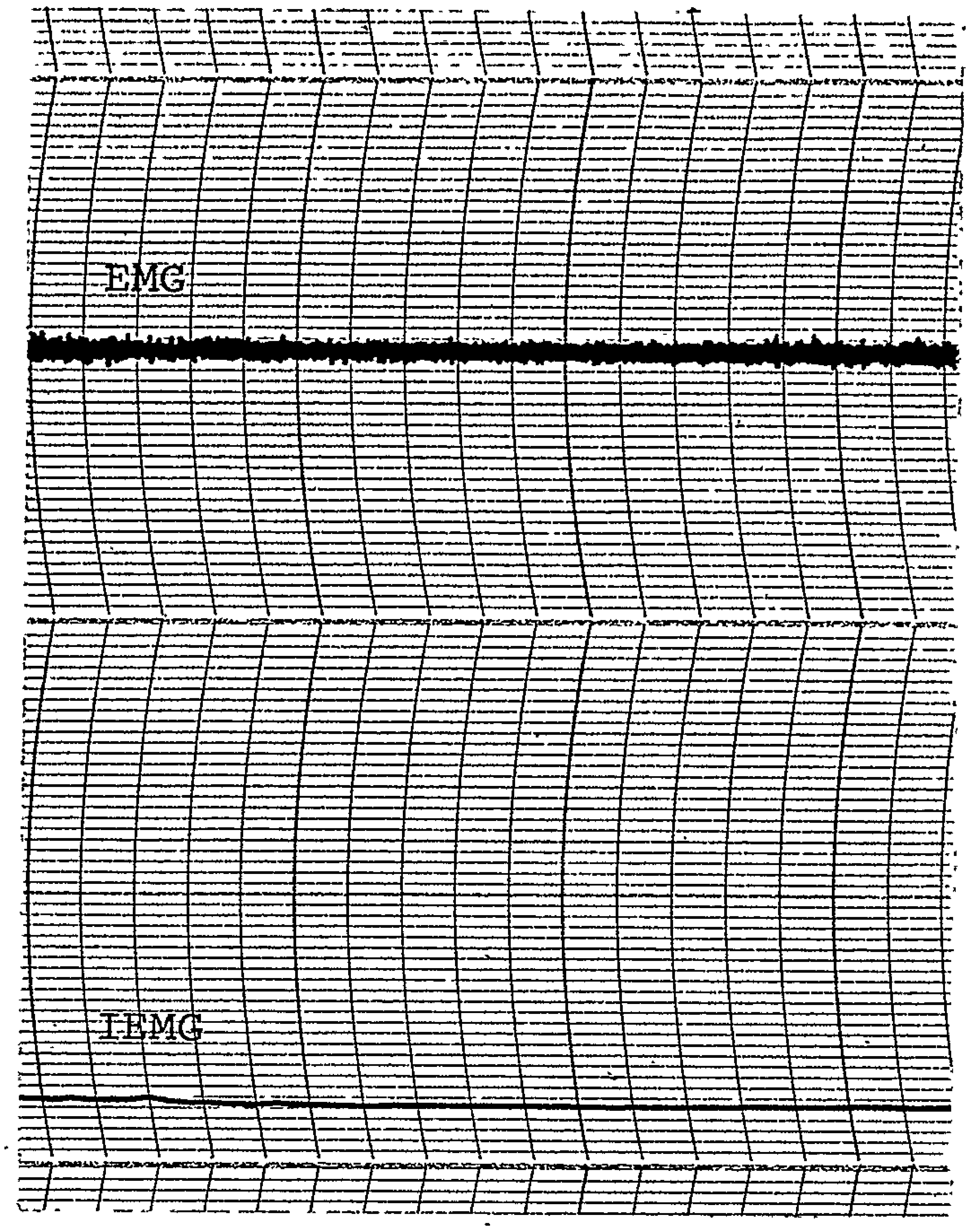
EMG = raw electromyogram; IEMG = integrated electromyogram



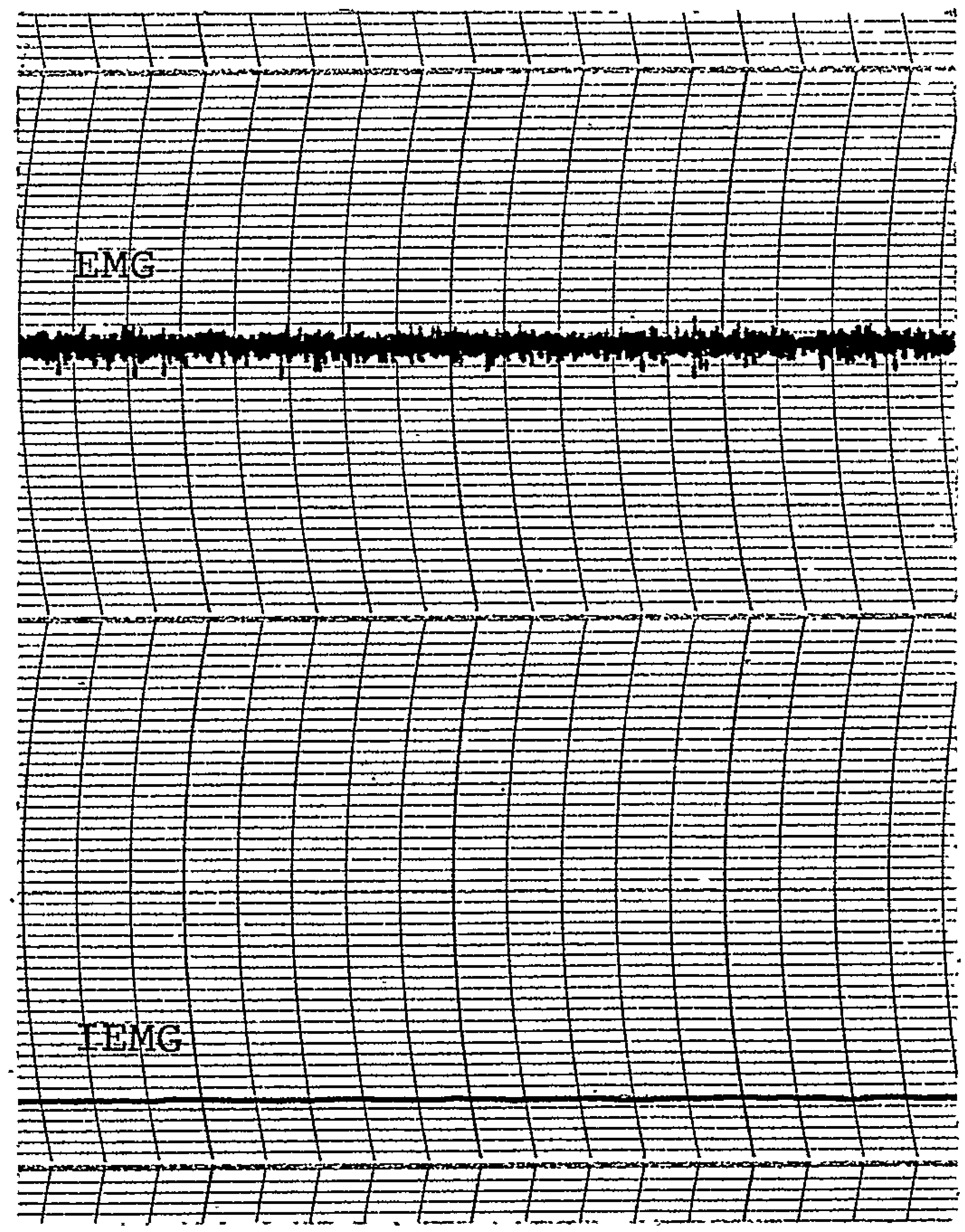
Maximum contraction: Control group subject P.G.



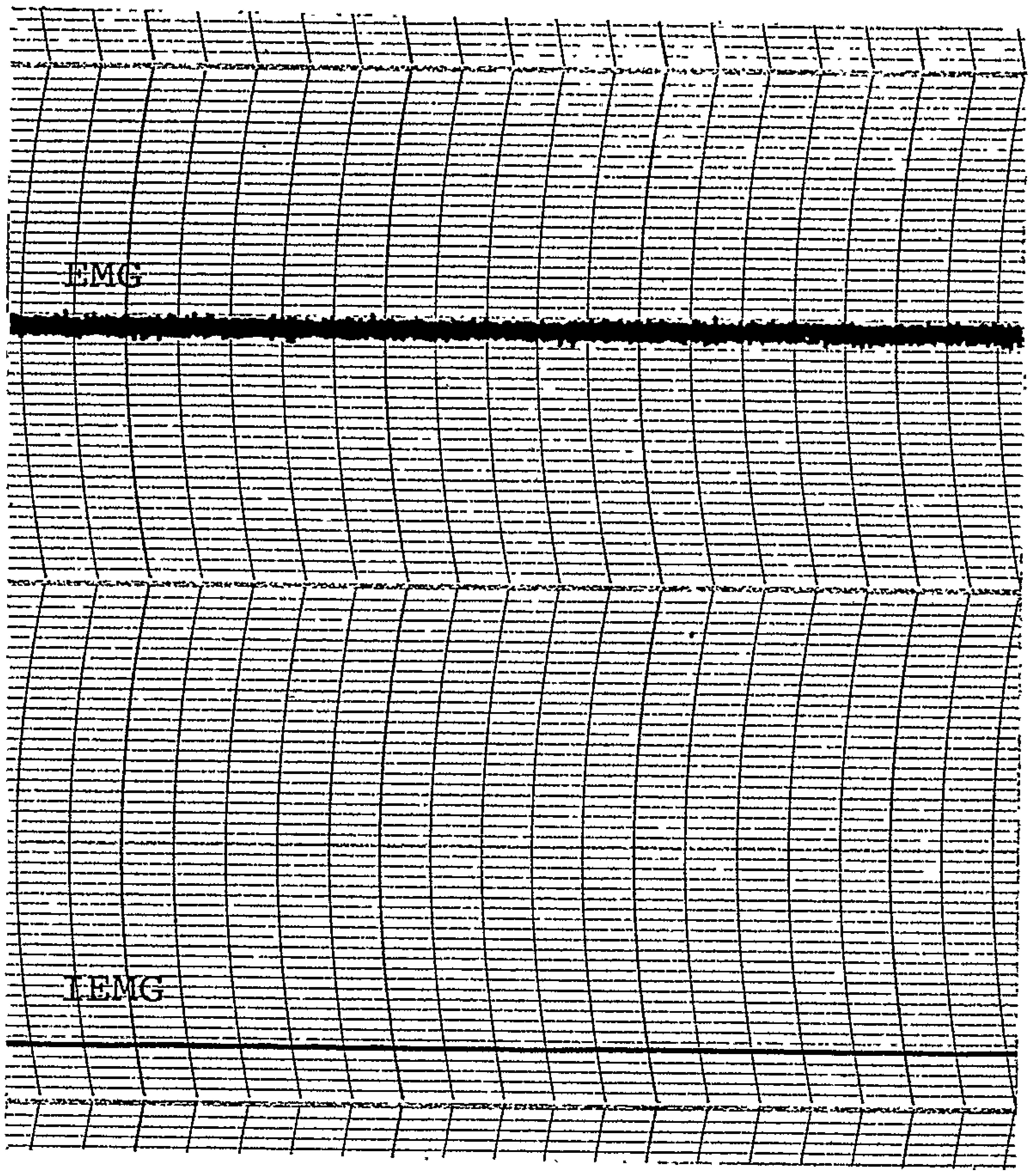
Maximum contraction: Experimental group subject K.N.



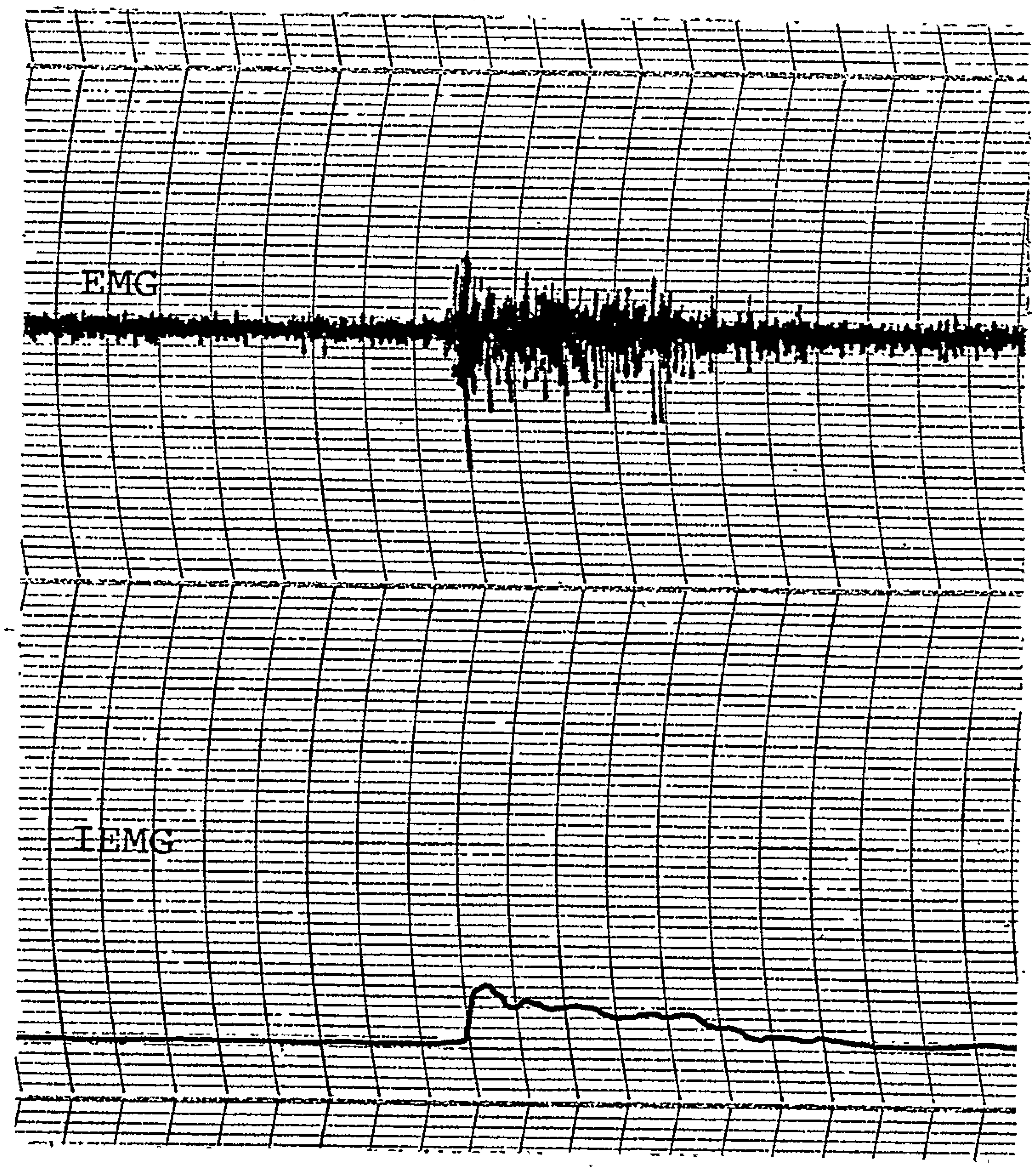
Resting potential: Control group subject P.G. with lips together.



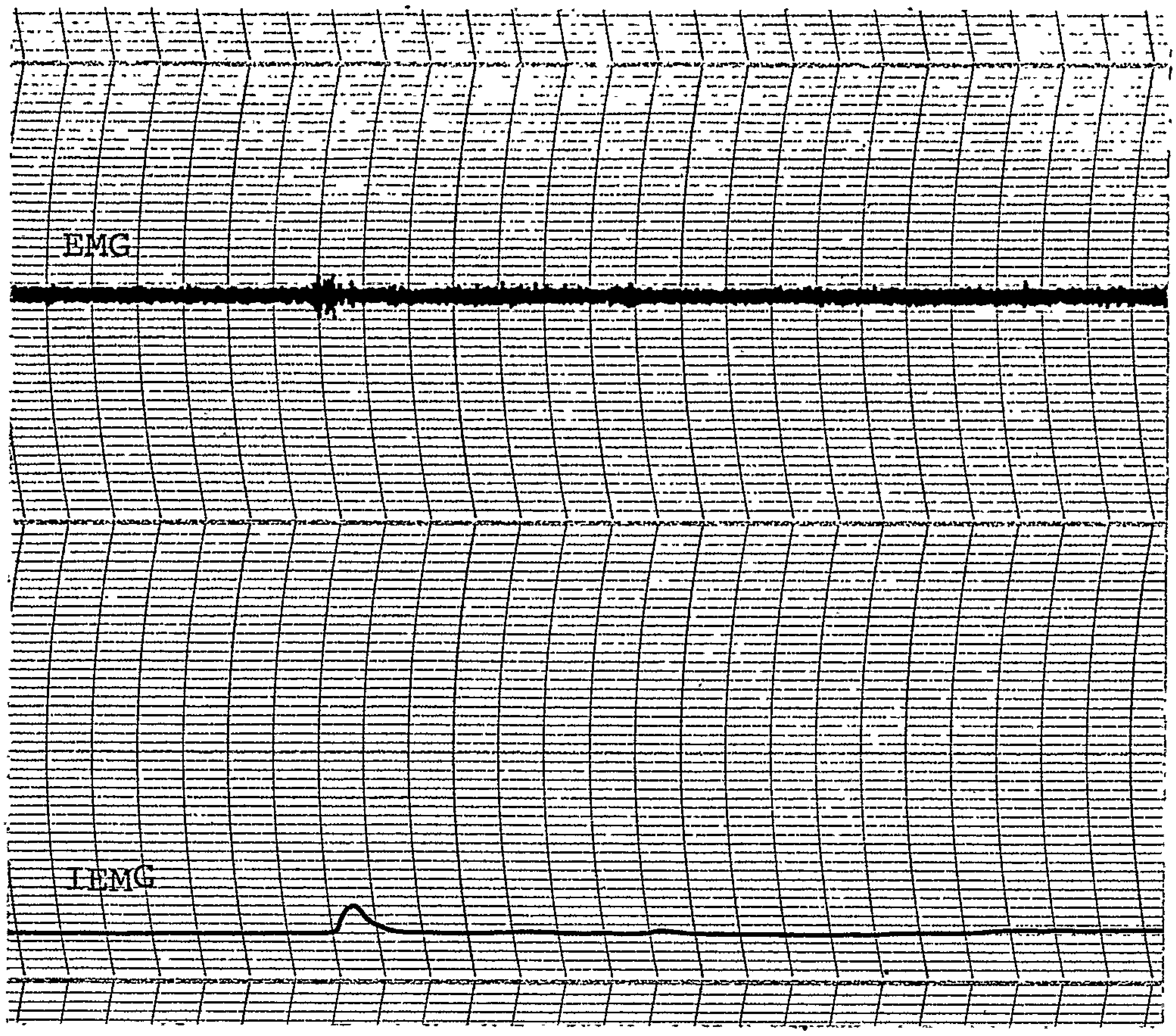
Resting potential: Experimental group subject K.N. with lips apart.



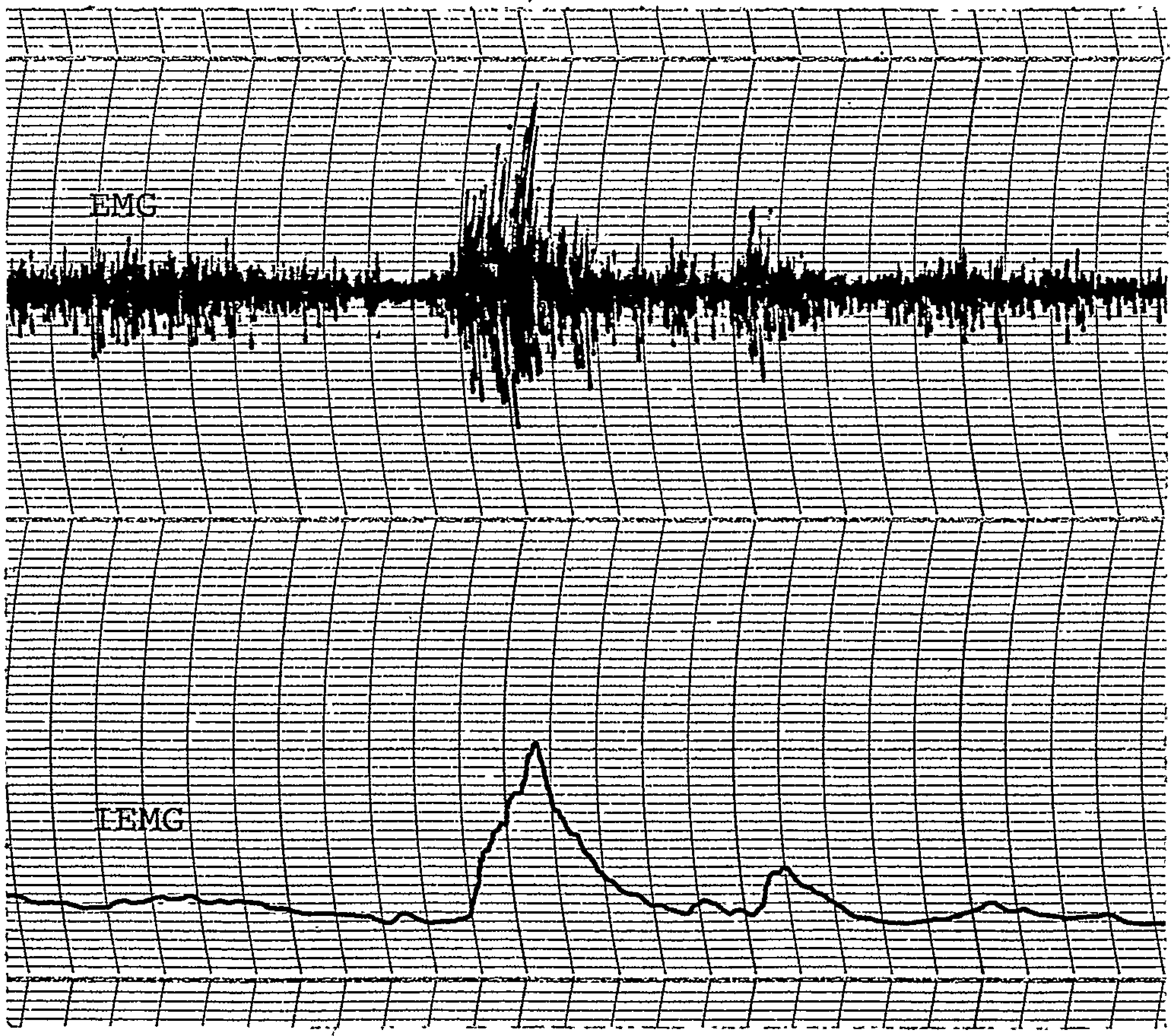
Resting potential: Control group subject P.G. with lips together.



Resting potential: Experimental group subject K.N. with lips together.



Dry swallow: Control subject P.G.

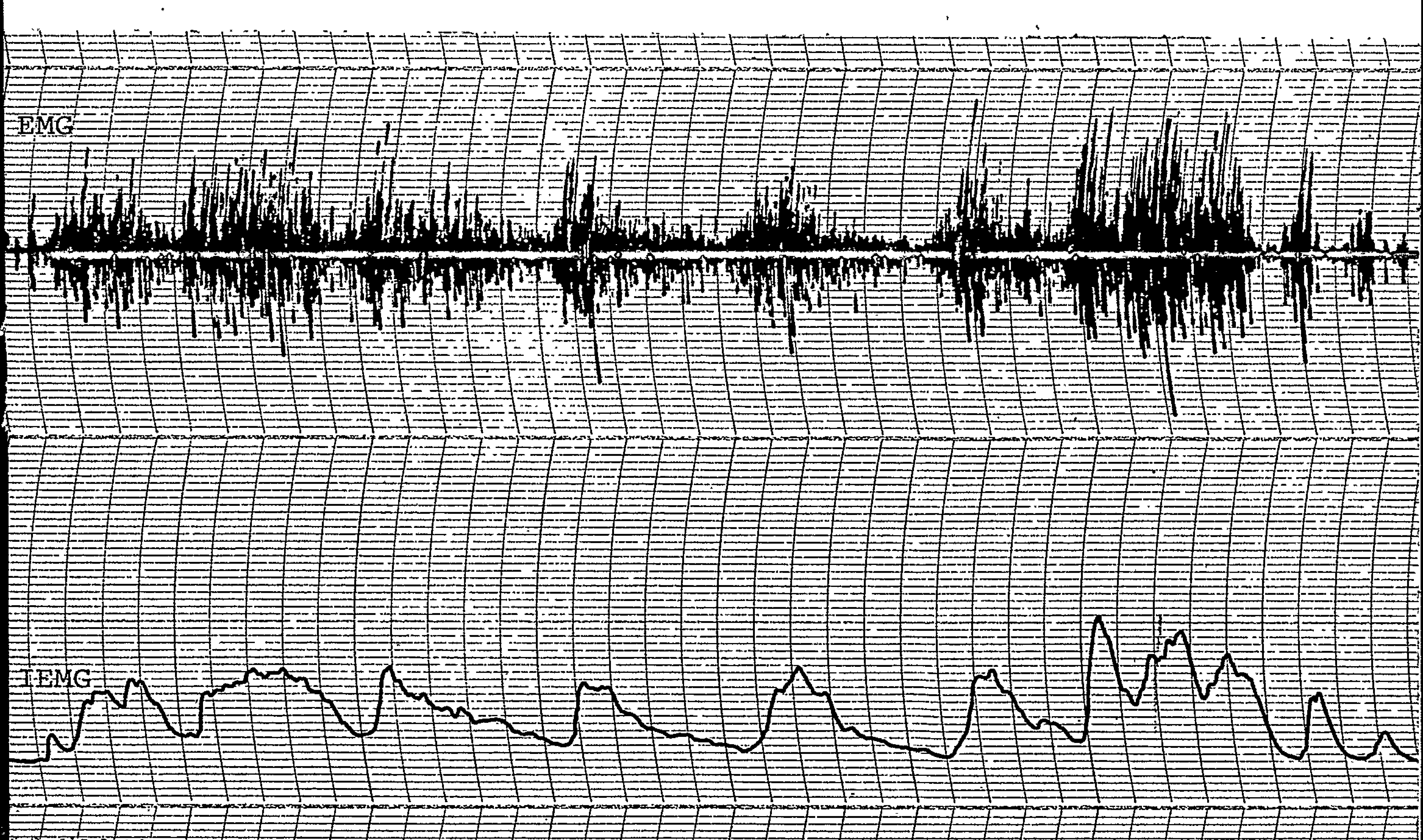


Dry swallow: Experimental subject K.N.

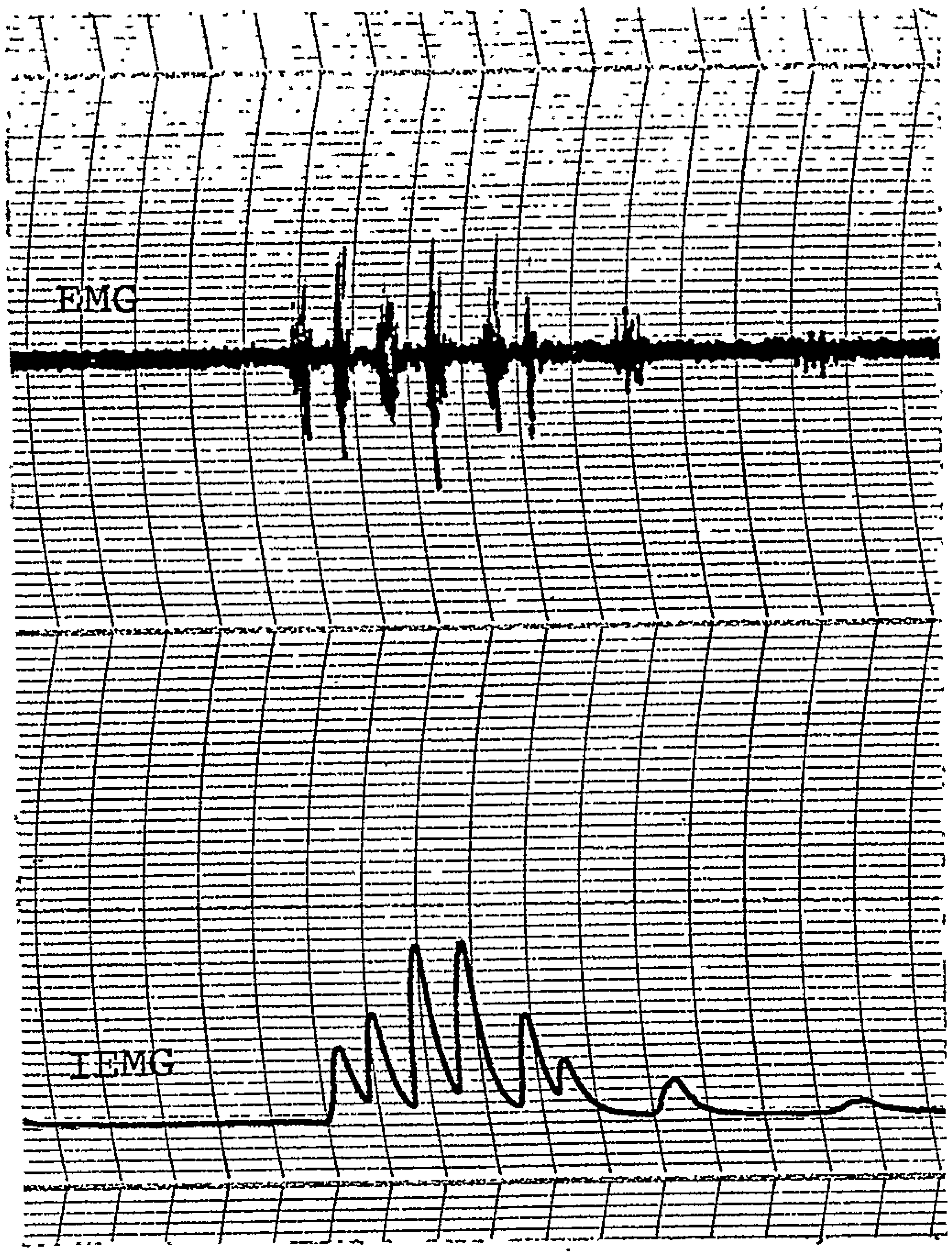
Wet swallow: Control subject P.G.

Wet swallow: Experimental subject K.N.

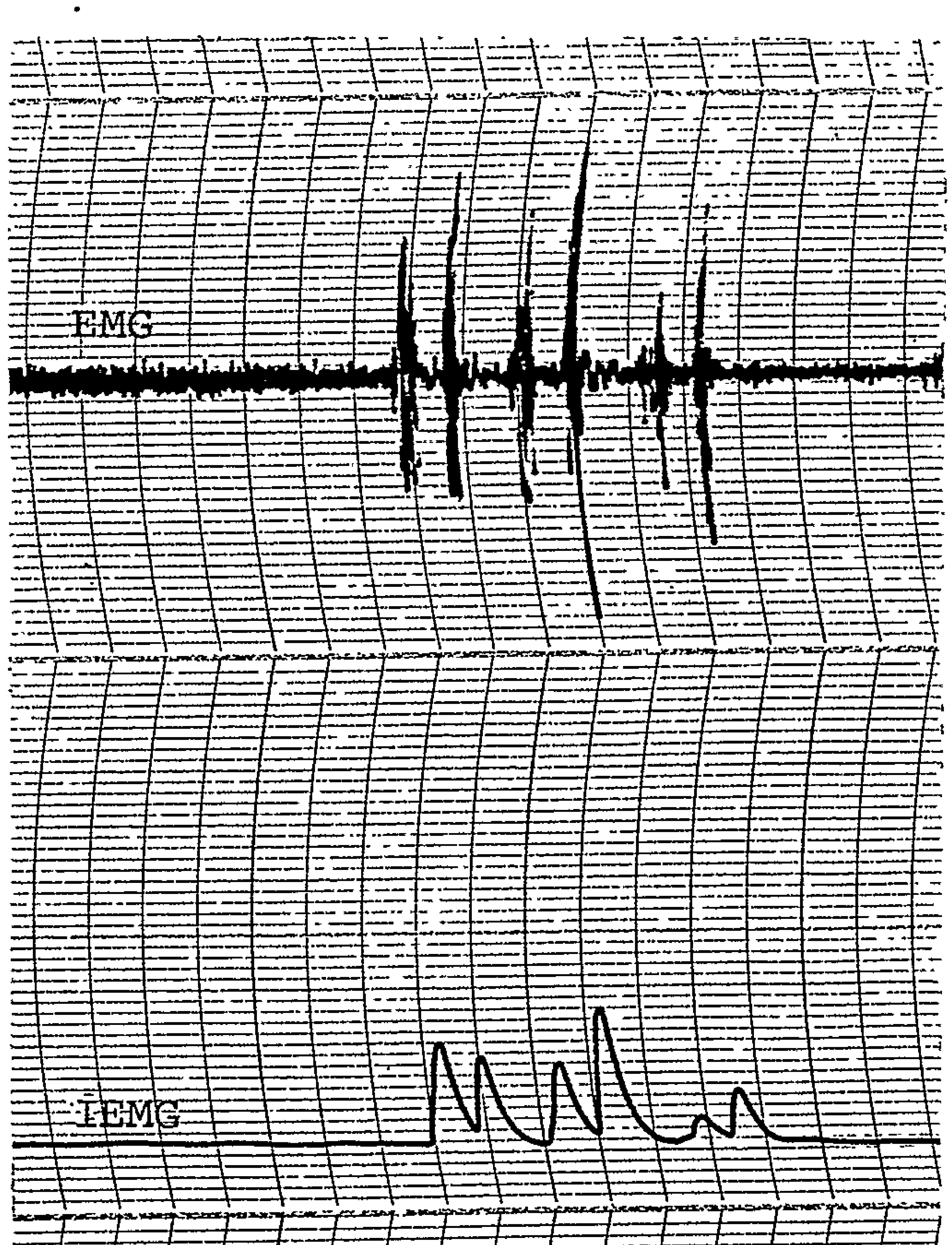
Chewing: Control subject P.G.



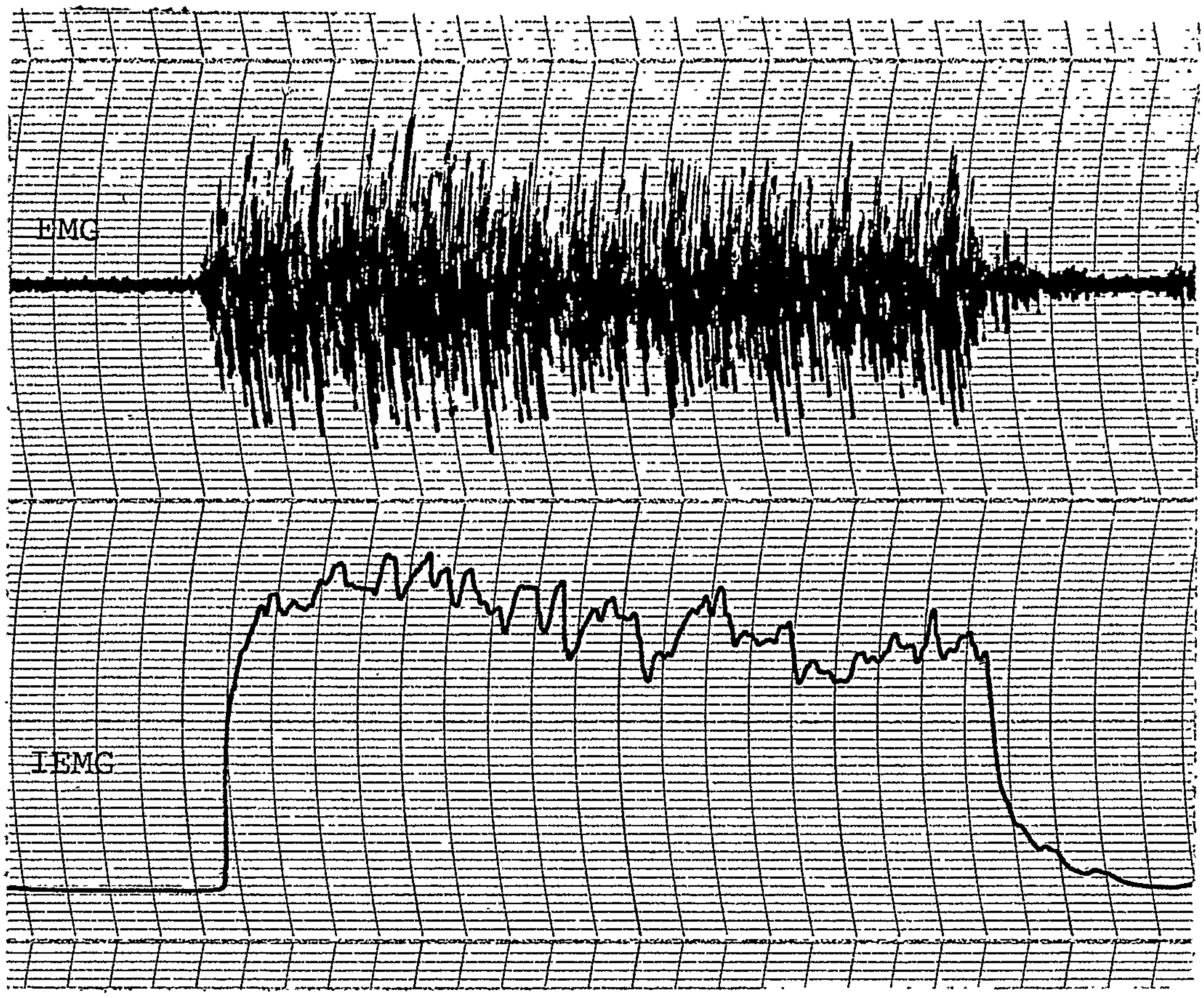
Chewing: Experimental subject K.N.



Speaking: Control subject P.G.



Speaking: Experimental subject K.N.



Maximum contraction (repeat): Control subject P.G.

Maximum contraction (repeat): Experimental subject K.N.