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Acuity of Dimension Proprioception and Difference in Arc of Incision for the Various Occlusal Types

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by

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LIFE

David Paul Stangl was born 21 January 1940 in Winona, Minnesota.

His educational background began with grammar school in Milwaukee, Wisconsin and continued through Marquette University High School with graduation in June, 1958. In September of 1958, he entered Marquette University and completed undergraduate predental education in 1961. Upon acceptance, he entered Marquette University Dental School in the fall of 1961 and graduated with the degree of Doctor of Dental Surgery in June, 1965.

Following graduation, he entered active duty as a Dental Lieutenant in the United States Navy, and served at Great Lakes and as a Dental Officer aboard the USS Hornet until June, 1967.

Having completed active duty requirements and upon acceptance in June, 1967, he began graduate studies in the field of Oral Biology at Loyola University, Chicago.

He is married to the former Helen Stamm of Milwaukee, Wisconsin.

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CHAPTER ONE

INTRODUCTORY REMARKS AND STATEMENT OF THE PROBLEM

Investigators have established the presence of proprioception end organs in the periodontal ligament of human teeth. They have also worked out Weber Ratios for the acuity of proprioceptive discrimination for stimulii which involve only these periodontal ligament receptors. These stimulii have been, for the most part, forces applied to the various surfaces of the dentition.

Although little work has been performed on dimensional proprioception, it is thought that this quantitative dimensional proprioception is dependent on more than afferent input from the periodontal ligament. It has been further postulated that the periodontal ligament receptors merely confirmed firm contact by the maxillary and mandibular anteriors with the wire. The actual dimensional proprioceptive discrimination would then be derived from the position of the mandible in relation to the cranial base. This position could be determined by sensory imput from attached muscles and/or receptors in the temporal mandibular joint.

The purpose of this thesis is to ascertain the acuity of dimensional proprioception for the normal and various types of malocclusion, in particular for Angle Class I, Class II division 1, and Class III malocclusion. It is the hope of this author that a subsequent work will test the same subjects after orthodontic treatment to determine gain or loss, if any of such proprioceptive function. Further, from such combined results it is hoped the role of various proprioceptive organs may be more accurately assessed. This study will apply its findings to the Weber and Fechner Law in a test of its validity for dental dimensional proprioception and cephlometric roentgenographic tracings of the arcs of incision for normal and Class I, II and III malocclusions will be correlated with the evaluation of the measured proprioceptive parameters.

CHAPTER TWO

REVIEW OF THE LITERATURE

1. DEVELOPMENT OF THE WEBER AND FECHNER LAWS AND THE STEVENS RATIO

In 1790, Bouguer cast a shadow of one candle on a screen which was at the same time illuminated by a second candle. He noted that the ratio dI/I was more nearly constant than the absolute I. (I is the absolute light intensity; dI is the least discernible increment of intensity.) The most noteworthy point is that he discovered that the ratio 1/64 remained constant even when the brightness of the candles varied.

Sixty years later (1850), a study by Weber dealt with the perception of small differences between weights and lengths, and tone pitch. He found that a subject noticed a change in a stimulus, called the just noticeable difference, when it constituted a certain proportion of the stimulus. This proportion was found to be a constant. He found this ratio (dI/I) to be 1/100 for length of lines, 1/30 for weight and 1/160 for tones. Weber then declared, "In comparing objects and observing the distinction between them, we perceive not the difference between objects, but the ratio of this difference to the magnitude of the objects compared."

Fechner, using Weber's proposals then attempted his correlation between the psychological and the physical. He measured the relation between the size of the stars (according to available astronomical information) and their photometric intensity. He then expressed Weber's principle as the formula $dI/I=C$ and called it Weber's Law. (dI is the change in intensity of the stimulus, I is the stimulus, C is the constant, and dI is commonly referred to as the J. N. D. or the Just Noticeable Difference.)

Later, Fechner performed additional experiments and stated his own law (Fechner's Law): The magnitude of a sensation is proportional to the log of the stimulus intensity. Formulated, this reads: $S=C \log I$, where S is the sensation, C is a constant fractional relation between the two intensities, and I is the stimulus. Thus, Fechner tried to determine the absolute threshold (minimum intensity of a stimulus to be perceived) and the differential threshold.

SOME TECHNIQUES AND RESEARCH ON WEBER AND FECHNER'S LAWS

Practically from the time of its development researchers had doubts concerning certain aspects of Weber's Law. In 1890, James stated that he felt it was probably purely physiological in nature and that one could not tell what the Just Noticeable Difference was without computing a great number of sensations.

~~By 1895, Waller was working with electrical stimulation to~~

muscle, nerve and retina (of the frog). He noted that Fechner's Law (S=C Log I) applied only in the middle range of his sensation scales. He then applied this to human function and reasoned it to be true here also on the grounds that if maximum increment of sensation equalled the increments of stimulation all the way down near the threshold this would result in ever minute ever present stimuli causing an intolerable state of hyperaesthesia.

Regarding the sense of smell, Gamble, in 1898, fixed the Just Noticeable Difference value of dI/I at 1/3 to 1/4. Thus, he demonstrated at least a partial application of Weber's Law to that sense.

By working with lifted weight, Fernberger in 1913 demonstrated that practice did not affect the measured sensitivity of this sense organ. Using a twofold technique of constant stimuli and then the Just Noticeable Difference, he determined the difference threshold to be constantly larger in the decreased stimulation direction and constantly smaller in the increase direction. This seems at variance to the work of Kawamura in his research with gradiated wires where he found that when the subject first hit on the larger wire (2mm then 1.9mm) there resulted 100% discrimination; whereas, when the subject first bit on the smaller (1.9 then 2.0mm) there was only 30% of correct discrimination.

Working with differences in weights, Cordwick followed Sanford's envelope weight experiment and showed a continuous decrease of the Weber Fechner Ratio from lighter to heavier piles of envelopes. He determined that the Weber Fechner Law could thus only be approximated.

In 1924, Hecht stated that he felt the Weber ratio to be constant only within the moderate ranges of intensities; and, like Cordwick, he believed the Weber ratio decreases steadily as the intensity increases.

Again in 1924, Woodward, et al, speaking on Weber's constant states that it is a rough emperical generalization for the mid ranges of most senses. He considered these mid ranges the working area of the senses.

Two years later, Culler contradicted Fernberger's findings by stating that under certain adaptive conditions with succeeding levels of stimulation the Weber Ratio appears constant. This suggests an inverse function of adaptation for Weber's Law. However, Zoethout, in his work with the evaluation of light intensities, (1927), explained the failure of Weber's Law in dim light to "selflight" of the retina.

Emphasizing the psychic aspects, Parsons (in 1927), states the apparent intensity (of a stimulus) is varied by the attention of the subject - being greater when total attention is paid to the stimulus. It then usually follows Weber's Law.

Adrian (1928) noted a proportionality between intensity of sensation and the frequency of impulses along the involved nerve fiber. He thus attempted to show a close correlation between the physical properties efferent sensory nerves and the mental evaluation of efferent imput.

Thurstone tested both the Weber and Fechner Laws by the equal appearing stimuli method. His results satisfied the Fechner equation but not Weber's Law. He concluded that there probably was no connective between these two laws.

In the same year, Helmholtz verified at least the approximate accuracy of Fechner's Law for light intensities.

In an experiment in tactile sensation, Cattell, et al, (1931) used an airblast stimulus on frog skin and was able to observe (in individual nerve fibers) that if the stimulation was longer than the rest periods, adaptation soon occurred. Also noted was that with shorter stimulations and longer rest periods the receptors followed a high stimulation rate for a longer period.

In a work somewhat more intimately related to the hypothesis of this thesis, Matthews (1931) experimented with the muscle proprioceptor and adaptation. He plotted the frequency during the first two seconds after the load was engaged against the log of the load and obtained an almost straight line. Interestingly, he attributes this phenomenon to properties of the end organs rather than the central nervous system.

In 1933, Urban, in an article, "The Weber Fechner Law and Mental Measurement," felt that equality could not be produced by a constant that attempted to equate psychic and physical entities.

From a geometric standpoint, Fechner's Law was restated by Best, et al, in 1955. "To cause a series of equal increments in sensation the strength of the stimulus must increase in geometric progression."

Supporting somewhat the tactile work of Cattell on skin, Leeford, et al, in 1935, noted that for audic intensity the Weber Fechner constant was, among other factors, a function of the interval between tones. In a similar vein, Cozier (1936) held that there was variation of sensation response to a particular organ but that this was due to the organ's ability to change its capacity to exhibit reactions.

In 1936, Grindly found evidence that the value of threshold is (in some cases) a function of the rate of stimulation. Also, he held that the threshold was usually greater for the decrease of pressure and that the threshold for increase of pressure was less. Kawamura, in his wire dimension experiment (1960), seems at variance to this. Steinhardt (in 1936, also) demonstrated a large Weber ratio for low intensity stimulation. The ratio decreased as the stimulus intensity increased but did not (normally) increase again at high intensities.

Holway, et al, (1937) concurred with the findings of Telford, et al, in that he held that variation does occur in the organism's discriminatory performance. This variation, he believed, could be used to establish various properties of the organism due to its capacity to vary performance. Holway had stated he felt the Weber Ratio was a specific dependent and reproducible function of intensity for particular sensory modalities.

Again in 1937, Holway, et al, found in his work with weight discrimination that precision of judgement varies directly with differential sensitivity and that this relation may be invariant.

The work of Van Leeuwen (1949) demonstrated the validity of Weber's Law as a property of a single stretch receptor of the frog muscle. He also cautions that Weber's Law only shows itself clearly when a large number of results are considered. Thus, there are individual cases of fluctuation.

Manly, (in 1952) worked with dentition natural vs. artificial and dimensional proprioception (that is thickness of discs, pressure of fibers, food texture and hardness of objects). He showed the sensitivity of anterior teeth to be about ten times that of posterior teeth. Kawamura (1960) in his wire discrimination work is (for wire thickness proprioception, anyway) at complete variance and finds anteriors and molars to be about equal.

Geldard (in 1953) stated that for a single pressure sensitive spot, the Weber ratio appears to pass through a definite minimum of middle ranges of effective stimuli.

Fulton (1955) stated that Weber's Law applied only for a very limited range of intensities and this was assuming small continuous changes in the Just Noticeable Difference were ignored.

Barlow (1957) holds that Weber's Law is valid for long, large stimuli, especially at high intensities but the upper and l lower limits of the curves deviate.

The third major proposition (the first being Weber's Law, and the second being Fechner's Law) in the field was developed by Stevens (1957) but foreshadowed by Guilford in 1932. Guilford (1932) developed a psychophysical power equation $dS=Ks^n$. (in Weber's Law n is 1.) This equation is expressed verbally as, "the just noticeable increment in a stimulus is equal to a constant times the n^{th} power of the stimulus."

However, it was Stevens who perfected the power equation as $dS=Kl^x$. He stated a principle that equal stimulus ratios tend to produce equal sensation ratios. He related direct assessments of subjective magnitude to the stimulus by a power function. Stevens believed the fact that the Just Noticeable Difference sensory scale is a logarithmic function of the stimulus scale (when the scales are compared the JND's are not equal) invalidates Fechner's assumption.

Kawamura (1959 and 1966) as discussed earlier in this review, found that the Weber Ratio for natural dentition wire discrimination was 0.1 and that the periodontal ligament was necessary for judging the size variation of the smaller wires, but not the larger ones. (Denture patients could discriminate these as accurately.) This indicated to him a role of the temporal mandibular joint and oral muscle receptors.

Wilke, in 1964, found (using a spring aesthesiometer) that the mean axial threshold for maxillary and mandibular central incisors was .52/.44gm. He felt there was evidence of a direct relationship between axial and radial thresholds.

In 1965, Grossman, et al, found that certain areas in the oral cavity varied in tactile sensitivity and this was a direct reflection on the regional distribution of the nerve supply. He especially cited the upper lip then the lower lip and tongue for their tactile sensitivity.

Bowman and Nakfoor (1968) worked with forces on central incisors of children. He determined the Weber Ratio to be ten to fifteen per cent of the standard applied force values used. They felt the Stevens equation was more applicable for their work than Weber or Fechner's Law.

Soltis (1968) compared two groups of orthodontic patients one group requiring extraction of teeth; the other not requiring extraction and found no significant difference in proprioceptive abilities of maxillary anterior periodontal ligament function. He noted that both groups had a lessening of proprioceptive discrimination when orthodontic forces were applied to these teeth, but that this ability slowly returned as the forces of orthodontic appliances were lessened.

2. REVIEW OF MUSCULAR ASPECTS

Kawamura, in a dissertation on occlusion, states, "Without physiologic contraction of the jaw muscles and without normal movements of the temporo mandibular joint, even a subject with a morphologically normal occlusion is unable to occlude the teeth properly." New literature tends to include anterior dimensional proprioception in this muscle temporal mandibular joint relationship. He then suggests that the voluntary mandibular movements are controlled by a minimum of two different areas of the brain, the "cortical jaw motor area" and the "amygaloid hypothalmic area."

In 1937, it was revealed that the jaw motor area occupied a large portion of the motor cortex suggesting such movements to be well provided for by numerous cortical cells permitting refined and skilled maneuverings. As early as 1934, experiments on cats showed that mammalian motor cortex stimulations excited jaw openers and relaxed jaw closer muscles. Kawamura recently demonstrated on rabbits that the cortical motor area was concerned primarily with jaw opening and the amygdaloid-hypothalmic area with closing. Later, he raised the question of a functional imbalance between these two brain structures (e.g. emotional stress or abnormal sensory input) may interfere with the proper physiologic movement of the mandible. It seems possible to this author that such factors reacting on certain areas of the brain could have a deliterious effect on oral dimensional proprioception and certainly on the path of mandibular arc of incision. A further question is, does the different archial pattern demonstrate for Class I, II, and III occlusions result in altered ability for such dimensional proprioception.

Kawamura describes physiologic rest position of the mandible as that position where all jaw muscles are without active contraction, and the mandible is only tonically suspended against gravity. He then states that somatic sensory data from stomatognathic structures are transmitted to the V sensory nuclei in the nedulla and from the proprioceptors of jaw muscles to the midbrain trigeminol nucleus. Sherrington defines proprioceptors as receptors giving data concerning movements and position of the mandible in space and discharging when changes (i.e. in the muscle of mastications) occur. These mechanics are not under conscious control.

By 1943, such men as Szentagotha, et al, had shown the midbrain trigemina nucleus cells to be unipolar to the motor neurons of V with one synapse (i.e. monosynaptic) and then to the muscles of mastication. Stating the process reflexly, the muscle proprioceptors transmit through the midbrain nucleus to the trigeminal neurons in the pons. Kawamura states, "Even slight tensional changes of the jaw muscle induce a response in both the midbrain nucleus and the motor nucleus of the trigeminal nerve."

Finally speaking of the temporal mandibular joint, they (Kawamura, et al) have found many modified Golgi - Mazzoni End Organs in the fibrous joint capsule of the cat temporal mandibular joint. They state whenever the condyle moves, sensory information from the joint capsule is transmitted to the trigeminal motor nucleus which innervates the jaw muscles.

Sirila, et al, have demonstrated the ability of incisors to perceive the presence of sheets of tin foil as then as 10 microns to 30 microns. They attempted to relate this periodontal proprioception to the oral stereognosis and motor ability work of Berry and Manhood (in which subjects were asked to identify various geometric shapes of ten 1mm thick tabs of acrylic, while the motor ability test involved fitting together a series of sets of two pair of blocks). They found no conformity between periodontal sensory appreciation and either the oral stereognosis or moter ability tests. Quite the converse was noted, however, in the clear correlation between the results of the oral sterognosis and motor ability tests. From this comparative experiment, they concluded that "Evidently, it is the tip of the tongue that is the most important feeler of objects entering the mouth. The teeth serve only as supports against which the tongue presses each piece it feels out. Speaking of the teeth, their "unexpectedly high" perceptive sensitivity was noted and it was stated "their (teeth) most important function is to determine the thickness of objects coming between them."

Eloma recently (1960) noted some significant factors in this comparative threshold work on permanent teeth and age. Using medium frequency alternating current pulses and monophasic direct current pulses of 5m sec duration, he found that threshold excitation is independent of body weight and sex and decreases at the final stage of root development and age. He postulates the cause as due to the "Growth and degeneration phenomenon of the nervous receptors of the dental pulp." Further, a daily minor variation in threshold was noted.

Hollstein measured the least perceptible thickness of testing wires but failed to include the Weber Ratio or indicate the perceptible difference between two thicknesses of wire.

Manly, et al, (1952) compared thickness between two wires of varying materials. The wires, however, were quite thick and few in number.

The most closely related work to this thesis is that of Kawamura who in 1959 related a study covering a total of six (3 natural dentition, 1 complete denture, 1 maxillary denture, 1 mandibular crown) with all other natural teeth subjects and wires gradiated at 10%, 20%, 30% to standards of 1, 2, 3, 4, 5mm. His results noted that the order in which the testing was carried out effected the Weber Ratio. He used thicker first; next, he tried the thinner first, and finally a mixture at random. The first resulted in 10% discrimination (for 2.00mm vs. 1.9mm). The second way (thin then thick) resulted in 30% discrimination, and the random resulted in 80% discrimination.

Speed testing was not a factor in accuracy; therefore, he assumes that the discriminative ability of these teeth is "not effected by physic or other bodily conditions." In the cases where dentures replaced upper or lower dentition efficiency of this dimension judgement was strongly reduced. However, the discrimination of the post crown patient was nearly equal to that found in natural dention subjects. From his data, Kawamura states that persons with natural dentition can discriminate with 100% accuracy between two wires with a diameter difference of 10% (Weber Ratio=0.1.) Since this same ratio was shown for both the incisors and molars (even though molars show less tactile sensation than do incisors) the results are attributed to the degree of difference of overbite between the molar and incisor. Thus, he assumes that the pattern of pressure against the tactile receptor is to be changed in the incisor "when the testing wire is thicker and the degrees of opening for bite go beyond the normal overbite level." Since a complete denture patient without a periodontal ligament could still discriminate between two comparatively thick wires as well as the natural dentition subjects, he assumes that "when the mouth is opened beyond a certain degree, the senses of the mandibular joint might come into action strongly."

Since amount of opening and mandibular position seem to bring into play various muscle and joint receptors (other than those in the periodontal ligament), some aspects of mandibular position and muscle tone will now be reviewed.

Jacobs, studying effect of muscle tone on mandibular position, states that, "there is no random activity of motor units in a resting muscle to afford an 'active tonus." These electromyographic studies indicate that "considerable movements may be performed without releasing reflex activity in the muscle itself." He then closes by denying the old assumption that muscle stretch and stretch reflex are adequate stimulus to maintain an active tonic condition.

Along similar studies, Ahlgren noted that "during active lowering of the mandible, no action potentials were recorded from the elevator muscle." He noted, however, that in elevation the action potentials appeared in the antagonists near the beginning of that movement.

Concerning maximal jaw openings, a survey of 436 adults with a normal functioning masticatory system demonstrated the mean maximal opening to be 50.23mm (Lingell 1967).

Trapozzano, et al, in speaking of the terminal rotational position of the condyles, says, "Rotation will also take place if there is one point of contact between a moveable extension and a fixed surface. It is this type of movement which may account for the finding of multiple hinge axis points." This shows the extreme number of mandibular positions possible, and, therefore, the multitude of different stimulation patterns possible for dimensional proprioception.

Finally, Kawamura (1963) in a study of the Temporal Mandibular joints sensory mechanism of the cat states that histologically many golgi - mazonni end organs are in the fibrous joint capsule especially at the frontal and posterior parts. He also notes a rapid bulbar and spinal trigeminal sensory nuclei response to condylar movements. From this result, he assumes that muscle proprioceptive mechanisms and possibly also proprioception from the temporal mandibular joint strongly participate to control the muscle activities of the jaw.

Brill (1957) states that the function of muscular activity is based to a degree on nervous impulses originating in the proprioceptive system and this system's nerve endings or receptor organs are found in muscles as spindles. He further states that in periodontal ligaments and joint capsules a great number of similar functioning receptor organs are also found. A muscle consists of motor units which, in turn, are made up of a group of muscle cells and a nerve fiber. These cells which belong to the same motor unit are distributed throughout the muscle. Thus, muscle cells respond at the same time and with the equal force. However, some motor units possess more cells and require greater stimulation to fire than others. He states muscular activity originates in the smallest units of the lowest threshold values. He concluded that consciousness merely is used to initiate and/or terminate inherent reflexes patterns.

3. ANATOMY OF THE MUSCLE SPINDLE

Great quantities of information are transmitted from the muscle and tendons to the spinal cord and the cerebellum (Guyton, 1961). They cause reflexes associated with equilibrium, posture, and damping. There are two varieties of muscle-tendon sensory organs: the muscle spindle and the Golgi tendon apparatus. The muscle spindle is built around three to ten very minute intrafusal muscle fibers which, in turn, attach to nearby skeletal muscle fibers. Each intrafusal fiber has a middle zone heavily nucleated and without cross striations. This portion cannot contract but rather is stretched when the ends of the intrafusals are contracted. The annulospinal nerve ending is entwined around the center. From this ending goes "large type A nerve fiber" (16 microns or greater). On either side of the nucleated area are flower spray nerve endings. They are connected to a smaller nerve fiber (8 microns). A far more severe stretching of the spindle is required to excite these.

The nerve supply of the intrafusal fibers, per se, is small gamma motor nerve fibers. If these are stimulated, they cause the spindle to contract. The central nervous system is able consequently to regulate the muscle spindles by regulating the gamma efferents. The muscle spindle can be stimulated in two ways, (1) stretch of the entire muscle belly (This stretches the muscle spindles) or (2) by contraction of the intrafusal fibers of the spindles. Either results in a stretch of the center of the intrafusal fibers. It is this stretch which excited the muscle spindle. The amount of stretch is important since excitation of the anulospinal endings (small amount of stretch) excites the homonymous muscle while excitation of the flower spray (only great stretch excites) inhibits (by reflex) the muscle.

The receptor functions as opposed to the spinal cord and cerebellar reflex functions of the muscle spindle are detection of muscle length and rate of change in the muscle length. Thus, the spindle responds instantly to phasic changes in the muscle length but in a few seconds it adapts and then the set or static length of the muscle determines the degree of stimulation.

The central nervous system is able to regulate the muscle spindle response through the gamma efferents.

The tendon areas are supplied with a specialized nerve ending the Golgi tendon apparatus. It lies between tendon fibers and is stimulated only by tension on the tendon. It differs from the spindle in that it detects muscle load. It, too, is connected with a large (16 micron) nerve fiber and when stimulated initiates an inhibitory reflex in the muscle to prevent damage from overload.

Most of the muscle spindle - Golgi tendon organ information is not transmitted into the conscious portion of the brain, but rather to the spinal cord and to the spino-cerebellar tracts and into the cerebellum. However, those sensations that are transmitted into the conscious part of the brain give a subject continual knowledge of the force with which he is contracting his muscles. Thus, he can determine the magnitude of weights he is lifting or force he is applying. This is "muscle sensation." It is thought that the large sensory fiber to the muscle spindle does not transmit sensory information directly into the conscious areas of the brain but rather goes to the spinal cord and cerebellum as the afferent arm of reflex reactions. It is the intermediate sized fiber (8 microns) with its flower ending that transmits into the conscious area and, thus, much of our so called muscle sense comes from the flower spray endings.

Granit (1962) contends that as far as is now known, gamma fiber activity is not regulated by muscle length except for extreme lengths. He believes that single fiber work is not always applicable to general situations because one is using pars pro toto, and there is a kind of overlap of efferent innervations and, thus, spindles do some averaging of efferent net effect.

In the same year, McIntyre stated that although not definitely settled, the balance of evidence indicates that most muscle spindle signals do not reach cortical levels, and the stretch receptors probably play little significant part in conscious proprioception. He further states that probably most of the cortical representation is to signal injury. The sense of movement and position being served by receptors mostly outside the muscle. He gives pacinian corpuscles joint, subcutaneous and cutaneous receptors as examples of such receptors.

Shimazu, et al, (1962) suggests three kinds of central nervous system controls: 1. a diffuse activating pathway probably maintaining muscle tone through the Gamma Loop; 2. a reciprocally modulating pathway for smooth and reciprocating movement; 3. some muscle spindle Group II fibers appear to receive special efferent CNS control.

Boyd, et al, (1962) speaks on groups of origin in the nerves to skeletal muscle of gamma one and two fusimotor fibers and suggests that thickly and thinly myelinated gamma fibers are representative subdivisions of the traditional gamma group into two components which are, perhaps, the stem fibers of the gamma 1 and gamma 2 motor fibers found at the spindles respectively.

Baker (1962) in an article on the structure and distribution of muscle receptors states that the muscle spindle of the cat (rectus femorus muscle) has a complex afferent innervation consisting of one primary and two secondary endings to an intrafusal muscle bundle which has one large nuclear bag fiber, one intermediate fiber and three small nuclear chain fibers. The secondary ending next to the primary is chiefly rings and spirals and the other chiefly sprays.

Baker, et al, (1962) the same year speaking on the innervation of individual intrafusal muscle fibers reports the presence of a number of very fine nerve fibers in spindles which innervate the intrafusal muscle fibers in the equatorial area. They branch and end as free epilemmal terminals in the area of sensory innervation. They conclude that they are probably sympathetic fibers and cause significant changes in the threshold of spindle receptors applied to stretch as per Hunt (1960). Further, Cooper (1962), writing on the behavior of spindle receptors during muscle stretch states that the marked responses of the primary endings to any form of movement of the muscle are enhanced and controlled when the spindle motor is intact.

Paintal (1962) in a discussion on responses and pressure pain receptors of mammalian muscles concludes that if one is searching for pressure pain endings one has merely to find endings connected to fibers with a diameter of about 1 to 3 microns near their termination and the majority of these should be pressure pain receptors.

Cooper, writing in 1953 on proprioception in the tongue confirmed histologically, the presence of a goodly supply of muscle spindles in the intrinsic muscles of the human tongue, also in the monkey but failed to see them in the tongue of the cat and lamb. The pathway for these organs is believed to lie in the hypoglossal nerve and unrelated to the sensory type ganglion cells in the tongue. Cooper further notes that through the lingual nerve the tongue has very rich afferent connections with the trigeminal nerve complex and, perhaps, as suggested by Baron (1936) some tongue proprioceptors send messages to the brainstem by this nerve. She further emphasizes that other endings may act as low threshold stretch receptors, for example, stretching a cat extraocular muscle stimulates the third nerve even though in spite of the absence of muscle spindles (Cooper and Fillens - 1952).

Ursula (1959) in his work on morphological observations on the living neuromuscular spindle, isolated spindles from a living frog. He noted that (in contradiction to fixed preparations) most spindles occupied only a part of the total length of the muscle. In virtually all of the fifty spindles examined, each intrafusal muscle bundle contained only one primary irregular annulo spiral structure.

Further, no equatorial zone of interruption of cross striation common to all the intrafusal fibers in a bundle was noted.

Robertson (1960) states that stretch on the whole muscle or stimulation of the efferent nerves to the intrafusals both result in an increase in afferent impulses from the spindles. He further states that each intrafusal fiber is a continuous structure running from tendon to tendon in the muscle. He describes spindles as areas in which the number of myofibrils is greatly reduced, the area of muscle membrane greatly increased in folds. He visualizes a cup-like extension of muscle tissue around a spindle axon. Upon contraction of this muscle the molecules of the axon membrane could be separated resulting in depolarization and an action potential.

Kennedy, in a recent article (1968) on the innervation of the human muscle spindle describes it as a dense innervation in comparison to extra fusal muscle. In his study, he used human intercostal spindles strained by silver impregnation. He noted most spindles had between ten and eighteen nerve fibers, the largest going to the nuclear bag and nuclear chain area. It then branches and these give off short extensions which coil around muscle fibers and terminate as tufts. Further, most spindles also have secondary nerve endings, and some intermediate fibers also enter the spindle. These latter are presumed to be motor and have bulb, sphere, and spray ends. Finally, a fourth group of fibers is observed to enter the spindle. These are very thin and have simple endings. It is not certain if these endings are placed on intrafusal muscle or connective tissue.

4. THE ROLE OF THE PERIODONTAL LIGAMENT AND PROPRIOCEPTION

The following cross section of data on the periodontal ligament, for the most part, demonstrates the maxillary and mandibular branches of the trigeminal (v) nerve as its source of innervation. Nerve fibers are found to come from surrounding alveolar bone and from the apical region.

Peaslee (1957) believed sensory nerve supply for the tooth was derived from pulpal origin. He was also one of the earlier men to write of the sense of locality (or ability) of the dentition to pinpoint locations. Black (1924) believed so strongly in the innervation of the periodontal ligament and its being the source of proprioception for the tooth that he felt that this sensation would remain intact even if both gingival and apical ends of the ligament were disected away. A few years prior, Noyes (1921) spoke of end organs or at least free nerve endings in the ligament. He felt they were beaded in shape. In his assessment he limited the sensory function of the ligament to touch only.

Bradlaw, some fifteen years later (1936), described the nerve endings as terminal coils. He also discovered that the periodontal nerve fibers on occasion arrive at the ligament by way of the interdental septum. That is, they enter the septum and then travel through it before entering the ligament.

Van der Sprenkel in the same year described three distinct endings for the mylineated nerve fibers. 1. Especially in the central portion of the ligament he found axons devoid of their myelid sheath. 2. Close to the bony reticulum he discovered certain small end rings. He felt their function was for pressure proprioception. Finally 3. Surrounding the various nuclei of the connective tissue of the ligament were terminal reticula.

Again in 1936, Brashear noted that large nerve fibers are found in the periodontal ligament but not in the dental pulp. He felt this showed the selective nature of the distribution of dental sensations.

Lewinsky and Stewart (1937) carefully traced and described the ligament fibers that originated from the apical area of the tooth. They noted these went toward the gingiva and were seen with blood vessels in longitudinal bundles. There appeared two main types of fibers, thick and thin. The thick were noted to have two varieties of special endings end organs. These were a knobby swelling and fine branching organs. These end organs were linked with dental tactile and pressure sensations.

Dealing with forces, Pfaffman (1939) demonstrated that a force against a tooth (from one direction only) stimulated a single fiber preparation; whereas, when a full nerve trunk was used, force applied to the tooth from any direction gave a neural response. From this, he concluded that with the tactile endings in the periodontal ligament only one of deformation of the particular receptor aorgan is effective.

In 1940, Corbin and Harrison working on the mesencephalic root of the cat demonstrated that dental proprioceptive impulses were directed through the lower caudal half of the root.

Ness (1954) working with the rabbit's central incisor discovered responses were related linearly to the log of the magnitude of the stimuli if the force was less than 100 grams. Further, he noted that the end organs showed directionality and believed this was possibly a property of the orientation of the individual receptors.

A year later, Lowenstein and Rothkamp (1955) compared vital and non-vital teeth and their sensitivity to a spring aesthiometer. The vital teeth were found to be more sensitive and they postulated the presence of intradental receptors (pulpal) in addition to the ligament end organs. He gave 2.5 gm as the average threshold for teeth (which he felt classified teeth as organs of high sensorial sensitivity.) He held that thresholds increased significantly from incisor (.9gm) to first molar (4.5gm). Further, he held a fifty-seven per cent rise in threshold of pulpless teeth. The work concluded evidence exists for existence of intradental as well as periodontal pressoreceptors.

Rapp, et al, in 1957 noted throughout the periodontal ligament, highly organized encapsulated neural terminations. They were described as consisting of intertwining fine neurofibrils. The general shape of the structure was ovoid.

In 1959, Bernick described two varieties of nerve endings according to the type of fiber. Medulated fibers and ends devoid of the myelin sheath and the unmyelinated fibers were drawn into spindle like endings. The non-modulated fibers formed branchings (arborations) and free nerve endings came from these.

Kruger and Michael (1962) working in a similar vein to Pfaffman (1939) told of it usually being necessary to check the particular surface of a canine of a decerebrate cat to give a response to a particular precise tactile stimulus. Further, they felt the dental end organs to be fast adapting.

A year later, Jerge reported two general groups of innervation patterns for dental pressoreceptors for the cat. The first group involved a response when a single tooth was stimulated. The second seemed to supply (innervate) a group of teeth and even adjacent soft tissue. (Perhaps the tissue remnants of group two are responsible for some of the discriminative ability of denture patients by Kawamura in 1967.)

Kizior, et al, (1968) demonstrated that sensitivity to force application was greater along the long axis of the cat canine than other axis. They used identical forces and applied them to various areas and at various angles to the canines.

They explained this on the basis that the encapsulated oval end organs innervated by large nerve fibers were observed only in the apical 1/3 of the periodontal ligament. They felt these receptors would be more distorted from a long axis force than a lateral axis force.

Bowman and Nakfoor (1967) noted no directional sensitivity in human maxillary incisors. They demonstrated almost identical equations for expressing the psychophysical law with forces applied the long axis ($dS\ \ .231^{.861}$) and forces applied 90° to the long axis ($dS\ \ .241$). Nakfoor (1967) noted in orthodontic patients that following four days of light orthodontic forces (applied to central incisors) a change in the ability of the patients to differentiate difference in forces applied to these teeth. Furthermore, after four days, the pain threshold was markedly lowered.

CHAPTER III

INSTRUMENTATION AND METHODS

1. Introduction

Twenty-two subjects were used in this study. They consisted of normal and various types of malocclusions. Five were Angle Class I malocclusions. Six were Angle Class I or normal molar relationship with all dentition within normal parameters of positioning. Normal molars - malaligned anteriors. Six were Class II malocclusion with the mandibular first molar either in end to end or disto version to the maxillary first molar. Five were Angle Class III molar relationship. In this study all patients were unbanded.

The subjects were analyzed in two respects. First, demensional proprioceptive discrimination abilities, and secondly in the path of their arc of incision. A correlation was then produced between the aforementioned Angle classes.

2. The Dimensional Proprioceptive Testing Instruments

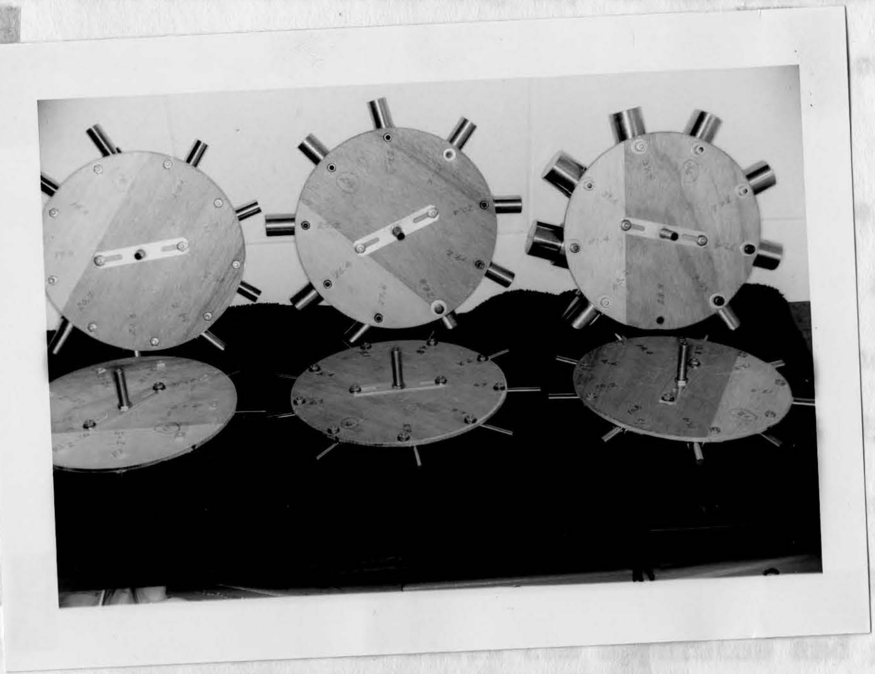
These materials consisted of gradiated bar stocks turned to an accuracy of 0.01 of a millimeter. Their surfaces were satin finish steel. Their shape, cylindrical. A series of such bar stocks were standardized at five per cent intervals for four increments above and below the standard. There were five sets of standards.

Gradiated Standards as Follows:

standard plus	20%	2.4	7.2	14.4	21.6	28.8
" "	15%	2.3	6.9	13.8	20.7	27.6
" "	10%	2.2	6.6	13.2	19.8	26.4
" "	5%	2.1	6.3	12.6	18.9	25.2
standard		2.0	6.0	12.0	18.0	24.0
standard less	5%	1.9	5.7	11.4	17.1	22.8
" "	10%	1.8	5.4	10.8	16.2	21.6
" "	15%	1.7	5.1	10.2	15.3	20.4
" "	20%	1.6	4.8	9.6	14.4	19.2

Each set of nine bar stocks was mounted on an identical rotating disc. The larger stocks were hollow ground to reduce the weight. However, the end in contact with the subject was not open. Each set of stocks (eight plus the standard) were mounted from the underside with Allen bolts exactly the same distance apart. The center of the disc contained a gasket into which the tip of the mounting arm fit. This enabled a smooth, easy turning of the mounted disc in either a reverse or a forward position.

figure 1



SERIES OF GRADIATED BAR STOCKS
MOUNTED ON ROTATING DISCS

The mounting arm consisted of heavy gauge stainless steel flexible conduit with the disc receiving tip on the top and a "C" clamp devise on the bottom which attached to a horizontal arm of the testing chair. (See figure 1.)

The chair was a typical dental chair with a comfortable padded back and seat. A thirty-six inch horizontal chrome arm extended from a hinge on the left arm rest to a latch on the right arm rest. From this horizontal bar was mounted the disc holding arm by its "C" clamp. The patient was seated comfortably in the chair, the horizontal bar locked and a disc placed upon the mounting arm. The subject was shown the apparatus and given a trial run first between a standard and 10% increment above and then 10% increment below. (See figure 2.) He was instructed to incise upon the bar stock (hereafter referred to as "wire") with his maxillary and mandibular centrals only. Lip and tongue contact were to be avoided. The wire to be tested was rotated in front of the subject's mouth and then by use of the flexible arm carefully brought up to his incisors. He incised on a first and then a second wire in the above mentioned manner. After the second wire was contacted, the subject was asked to tell which was the larger, the first or the second wire. The subject was always to say merely "first" or "second," whichever he felt was larger.

figure 2

SPECIALIZED DENTAL CHAIR AND DISC MOUNTING ARM

After this introduction, the subject was blindfolded and the tests carried out. (Kawamura in his related work used six subjects, three with full natural dentition and perceived a dimensional proprioception discrimination 100% of the time for a .10 or 10% thickness difference for a limited range of standards)

In our initial trials, we choose to use a 70% accuracy (7 correct evaluations out of 10) for a particular pair of wires as a satisfactory demonstration of ability to discriminate between the two particular thicknesses. Using this parameter, it became apparent that many of the subjects could achieve 70% accuracy between 5% thickness gradiation to the standard, particularly for the 6, 12, and 18 standards. Therefore, the individual wires in a series were compared to each other to obtain a percentage less than 5% thickness difference. The following, demonstrating less than 5% dimensional difference, were used. (See complete chart next page.)

	4.3%	**4.3%**	**4.3%**	**4.3%**	**4.3%**
Ratio used to obtain less than 5% difference	2.3:2.4	6.9:7.2	13.8:14.4	20.7:21.6	27.6:28.8
standard	2	6	12	18	24

From this trial, the dimensional proprioception could be tested below 5% difference and this data where applicable was correlated with the total results.

PAIRED INDIVIDUAL DIMENSIONAL COMPARISONS

	2.4		7.2		14.4		21.6		28.8	
9.1%		4.3%		4.3%		4.3%		4.3%		4.3%
	2.3		6.9		13.8		20.7		27.6	
9.5%		4.5%		4.5%		4.5%		4.5%		4.5%
	2.2		6.6		13.2		19.8		26.4	
10.0%		4.7%		4.7%		4.8%		4.8%		4.8%
	2.1		6.3		12.6		18.9		25.2	
		5.0%		5.0%		5.0%		5.0%		5.0%
	2.0		6.0		12.0		18.0		24.0	
		5.0%		5.0%		5.0%		5.0%		5.0%
	1.9		5.7		11.4		17.1		22.8	
11.1%		5.3%		5.3%		5.3%		5.3%		5.3%
	1.8		5.4		10.8		16.2		21.6	
11.8%		5.6%		5.6%		5.6%		5.6%		5.6%
	1.7		5.1		10.2		15.3		20.4	
12.5%		5.9%		5.9%		5.9%		5.9%		5.9%
	1.6		4.8		9.6		14.4		19.2	

3. Arc of Closure Testing Instruments and Materials

The archial correlation for Angle Class I normal and for Class I, II and III malocclusions was carried out by use of a series of seven superimposed lateral head plates. These were kept with the patient's permanent records to be used for future orthodontic diagnosis. The Wehmer cephlostadt was used and identical positions of the patient were secured by use of height adjustment of the cephlostadt and placement of porion rods at the same height for an entire series. Also the infra orbital pointer and a nasion locator were used. The casette was positioned at a constant 15mm from the subject.

The seven lateral headplates consisted of:

1. centric relation
2. centrals incising and holding the 2mm standard
3. centrals incising and holding the 6mm standard
4. centrals incising and holding the 12mm standard
5. centrals incising and holding the 18mm standard
6. centrals incising and holding the 24mm standard
7. mandible wide open

The serial radiographs were then orientated and related to themselves by means of superimposition of the following for each series.

1. center of Sella Tursica

2. Nasion

3. The anterior cranial base

4. The maxillary central incisor

The arc of incision tracing was plotted on acetate paper at the tip of the mandibular central incisor and a parallel arc was also traced at pogonion.

The seven points thus gave one continuous arch for each subject from centric to wide open. Upon completion of this, an average was established between these parameters for the normal Angle class I and Angle class I, II and III malocclusions.

A line from the center of sella tursica to nasion ("SN" line) was traced for each head plate. Lines parallel to this and running through each of the seven points were constructed. A second line was drawn from the center of sella tursica directly to each of the seven points. The angles formed by these two lines were measured and analyzed to compare with the data gathered in the dimensional proprioception portion of this experiment.

In conclusion, the average arcs of incision for Angle Class I normal, and Class I, II and III malocclusions are compared. Finally it is hoped that a continuation study after orthodontic treatment will be taken on these same subjects by some future investigator.

CHAPTER IV

RESULTS

The standard dimension values used in this study are those listed under "Methods and Materials." The extreme dimensional value at the upper limit (ie 36mm series) is intended as a measurement at maximal opening range and not necessarily one which will fall within optimal range of the psycho-physical law.

Each facet of data was entered in terms of actual difference in dimension (diameter) discernable and also in terms of percent of the standard dimension values used (see appendices). The Weber Ratios were changed to percent values to aid in the statistical analysis of the data with the independent form of the studentized "t" test.

Table I shows a comparison of the mean Weber Ratios and standard deviations for the dimensional values for each series (ie 2 - 6 - 12 - 18 - 24 - 36mm) and how they compare for Class I normal, Class I malocclusion, and Class II and Class III. Each mean value is the average for all the members of the particular occlusal classification. All proprioception data for each patient was acquired at one appointment and the cephlometric data at another to avoid fatique. It should be stated that the largest bars of the 36mm standard (41.4mm vs 43.2mm) were not used on all subjects due to the subject's inability to open

TABLE I

Mean Weber Ratios for Incisal Acuity of Dimensional Proprioception

Bar Thickness	Class I Normal Occlusion 6 subjects	Class I Malocclusion 5 subjects	Class II 6 subjects	Class III 5 subjects
2mm bars	.0663 ± .0258*	.0726 ± .0315	.0605 ± .0395	.0620 ± .0284
6mm bars	.0453 ± .0035	.0836 ± .0424	.0717 ± .0246	.0774 ± .0244
12mm bars	.0548 ± .0204	.1064 ± .0222	.0548 ± .0183	.0614 ± .0286
18mm bars	.0565 ± .0177	.0730 ± .0300	.0550 ± .0185	.0656 ± .0229
24mm bars	.0572 ± .00136	.0594 ± .0260	.0617 ± .0261	.0736 ± .0276
36mm bars	.0777 ± .0401	.0746 ± .0304	.0688 ± .0225	.0806 ± .0202

* ± standard deviation

sufficiently to receive them.

In comparing the six standards of measurement, the Weber Ratios, in general, are smaller and closer numerically in the 12, 18, and 24mm series. The 2 and 6 mm series are slightly larger but still near those of the 12, 18, and 24mm series. This suggests that the optimal range of the psycho-physical law for dimensional proprioception lies in the area of the 12, 18, and 24mm series. The 2mm and 6mm series then would represent possibly the lower limit of the optimal functioning range. The 36mm series is larger and more distant numerically, indicating the upper limit of the optimal range. It is noteworthy, however, that the 36mm series is nearly of the same magnitude as those in the optimal range.

Table 2 shows the means for orientated angles (sella nasios to mandibular central's incisal surface) cephlometric study of the arc of closure. Seven lateral headplates in centric, biting on the 2, 6, 12, 18, and 24mm bars, and maximum opening were used. Table two lists means for Class I normal occlusion, Class I malocclusion, Class II, and Class III.

In comparing the six standards, the mean angles in all instances grow smaller the wider the jaws are opened. With the exception of the wide open position, Class I normal and Class III mean angles grow progressively smaller in intervals of two to

TABLE 2

Means for Orientated Angles in Cephlometric

Study of Arc of Closure

Bar Thickness	Class I Normal Occlusion 6 subjects	Class I Malocclusion 5 subjects	Class II 5 subjects	Class III 5 subjects
CENTRIC	128.5 ± .96*	124.8 ± 3.48	129.4 ± 3.61	128.8 ± 2.40
2mm bar	124.3 ± .94	124.0 ± 3.03	127.4 ± 4.49	127.2 ± 1.94
6mm bar	124.3 ± 1.25	123.0 ± 2.83	125.0 ± 4.43	125.6 ± 1.50
12mm bar	121.8 ± 1.07	119.0 ± 3.63	121.4 ± 3.56	122.6 ± 2.15
18mm bar	118.7 ± 1.105	116.4 ± 4.18	118.4 ± 4.54	120.4 ± 2.25
24mm bar	116.17± 1.34	112.2 ± 3.87	115.0 ± 4.69	117.6 ± 2.06
wide open	109.0 ± 2.75	102.8 ± 2.93	107.0 ± 5.08	110.2 ± 4.70
wide open	mean maxillary opening = 43mm	mean maxillary opening = 44.4mm	mean maxillary opening = 44mm	mean maxillary opening = 45.4mm

three degrees. Class I malocclusion is much more irregular, with virtually no decrease in angulation between centric, 2mm and 6mm and then a sudden drop of four degrees to the 12mm level. Also, Class I malocclusion angulation is approximately four degrees smaller than any of the other groups. Class II is quite regular in its decreasing increments with the exception of the 4mm drop between the 6mm and 12mm levels. The orderly and regular progression of these angles corresponds to the rather uniform mean Weber Ratios for the acuity of dimensional proprioception for the 2, 6, 12, 18, and 24mm series.

The studentized "t" statistical comparisons between the various bar dimensions for Class I normal occlusion are presented in Table 3. The comparisons of this study show no significant difference between the various diameters. Tables 4, 5, and 6 represent the same "t" comparisons for Class I malocclusion, Class II, and Class III respectively. All statistics for these groups also have insignificant "t" values of 1.80, or less. This indicates that each of the various groups examined possessed a relatively uniform dimensional proprioceptive acuity for all of the series. The 36mm series is perhaps the lone exception. "t" values, although not significant, are greater than one in most cases.

Table 7 shows statistical "t" comparisons between Class I

TABLE 3

Statistical Comparison Between the Various Bar Dimensions for Class I Normal Occlusion *Six Subjects*

BAR DIAMETER	"t" values
2 millimeters vs. 6 millimeters	1.801
2 millimeters vs. 12 millimeters	.730
2 millimeters vs. 18 millimeters	.700
2 millimeters vs. 24 millimeters	539
2 millimeters vs. 36 millimeters	1.804
6 millimeters vs. 12 millimeters	.0759
6 millimeters vs. 18 millimeters	1.387
6 millimeters vs. 24 millimeters	.962
6 millimeters vs. 36 millimeters	1.800
12 millimeters vs. 18 millimeters	.0957
12 millimeters vs. 24 millimeters	.157
12 millimeters vs. 36 millimeters	1.137
18 millimeters vs. 24 millimeters	.0544
18 millimeters vs. 36 millimeters	1.39
24 millimeters vs. 36 millimeters	1.032

* P=<.05
** P=<.01

normal and Class I malocclusion for each bar dimension series. A significant difference ($P < .05$) is noted in the 6mm Class I normal vs Class I malocclusion series. A more significant difference "t" value ($P < .01$) is noted between both 12mm series. Roentrographically Table 8 represents statistical comparisons between Class I normal and Class I malocclusion for the orientated angles in the cephlometric study. There is a significant statistical "t" difference for the orientated angle size between the 24 vs 24mm series ($P < .05$) and between the wide open vs wide open positions ($P < .05$). The 18mm "t" value is perhaps a follow up expression of the significant 12mm proprioceptive "t" value seen in Table 5.

Table 9 demonstrates the statistical "t" comparisons between Class I normal and Class II. The 6mm vs 6mm series shows a significant "t" difference ($P < .05$).

Table 10 represents a statistical comparison for the cephlometrically orientated angles for these same two groups, and shows a correspondingly significant difference ($P < .05$) for the 6mm vs 6mm series. The Class II cases with their greater overjet are required to open to a slightly wider orientated angle at this level to compensate for the greater overjet.

Table 11 represents the statistical comparison between

TABLE 4

STATISTICAL COMPARISON BETWEEN THE VARIOUS BAR DIMENSIONS FOR CLASS I MAROCCLUSION * FIVE SUBJECTS *

BAR DIAMETER	"t" VALUES
2 millimeters vs 6 millimeters	.416
2 millimeters vs 12 millimeters	.0934
2 millimeters vs 18 millimeters	.0183
2 millimeters vs 24 millimeters	.6464
2 millimeters vs 36 millimeters	.0913
6 millimeters vs 12 millimeters	.3012
6 millimeters vs 18 millimeters	.408
6 millimeters vs 24 millimeters	.973
6 millimeters vs 36 millimeters	.109
12 millimeters vs 18 millimeters	1.793
12 millimeters vs 24 millimeters	.870
12 millimeters vs 36 millimeters	1.69
18 millimeters vs 24 millimeters	.686
18 millimeters vs 36 millimeters	.711
24 millimeters vs 36 millimeters	.760

*P= $<$ .05
**P= $<$ .01

TABLE 5

STATISTICAL COMPARISONS BETWEEN THE VARIOUS BAR DIMENSIONS FOR CLASS II * SIX SUBJECTS *

BAR DIAMETER	"t" VALUES
2 millimeters vs 6 millimeters	.908
2 millimeters vs 12 millimeters	.293
2 millimeters vs 18 millimeters	.282
2 millimeters vs 24 millimeters	.0567
2 millimeters vs 36 millimeters	.408
6 millimeters vs 12 millimeters	1.233
6 millimeters vs 18 millimeters	1.215
6 millimeters vs 24 millimeters	.624
6 millimeters vs 36 millimeters	.195
12 millimeters vs 18 millimeters	.0241
12 millimeters vs 24 millimeters	.468
12 millimeters vs 36 millimeters	1.08
18 millimeters vs 24 millimeters	.467
18 millimeters vs 36 millimeters	1.06
24 millimeters vs 36 millimeters	.0154

*P= .05
**P= .01

TABLE 6

STATISTICAL COMPARISONS BETWEEN THE VARIOUS BAR DIMENSIONS FOR CLASS III * FIVE SUBJECTS *

BAR DIAMETER	"t" VALUES
2 millimeters vs 6 millimeters	.351
2 millimeters vs 12 millimeters	.764
2 millimeters vs 18 millimeters	.0298
2 millimeters vs 24 millimeters	.198
2 millimeters vs 36 millimeters	1.067
6 millimeters vs 12 millimeters	.852
6 millimeters vs 18 millimeters	.223
6 millimeters vs 24 millimeters	.217
6 millimeters vs 36 millimeters	.0639
12 millimeters vs 18 millimeters	.229
12 millimeters vs 24 millimeters	1.070
12 millimeters vs 36 millimeters	.347
18 millimeters vs 24 millimeters	.983
18 millimeters vs 36 millimeters	.470
24 millimeters vs 36 millimeters	.433

*P= .05
**P= .01

TABLE 7

STATISTICAL COMPARISONS BETWEEN THE VARIOUS OCCLUSAL TYPES FOR EACH BAR DIMENSION SERIES

CLASS I NORMAL OCCLUSION vs CLASS I MALOCCLUSION

Class I Normal Bar Diameters six subjects	vs	Class I Malocclusion Bar Diameter five subjects	"t" Values
2 millimeters	vs	2 millimeters	0.330
6 millimeters	vs	6 millimeters	2.982
12 millimeters	vs	12 millimeters	3.631**
18 millimeters	vs	18 millimeters	1.0221
24 millimeters	vs	24 millimeters	0.129
36 millimeters	vs	36 millimeters	0.129

*P= $<$ .05
**P= $<$ .01

TABLE 8

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL TYPES FOR ORIENTATED ANGLES IN THE CEPHLOMETRIC STUDY

CLASS I NORMAL vs CLASS I MALOCCLUSION

Class I Normal Bar Diameters six subjects		Class I Malocclusion Bar Diameters five subjects	"t" Values
centric	vs	centric	.8575
2 millimeters	vs	2 millimeters	.200
6 millimeters	vs	6 millimeters	.819
12 millimeters	vs	12 millimeters	.174
18 millimeters	vs	18 millimeters	1.172
24 millimeters	vs	24 millimeters	2.964 *
wide open	vs	wide open	2.132 *

*P= < .05
**P= < .01

Class I normal and Class III for each bar dimension series. There is no significant difference between these two groups in the series. This is possibly explained by the fact that although all subjects listed as such were Class III molar relationship but in the anterior region all except one were either end to end or with a slight overjet compensated for by spacing in the maxillary segments.

Table 12, which demonstrates the statistical comparison for cephlometrically orientated angles of this same group also demonstrates no significant difference between any of the bar opening series.

Table 13 demonstrates the statistical comparison for each bar dimension series for Class I malocclusion vs Class II. There is one significant difference in this group and that is at the 12mm vs 12mm level. This factor appears as a distal horizontal shift on the cephlometric tracing for both groups. It is postulated that this is a compensatory neuromuscular shift to stabilize the mandible after translation has begun. It is seen in all occlusal groups but more accentuated in certain Class II subjects.

Table 14 covers the statistical comparison of cephlometrically orientated angles for these same groups. This demonstrates a significant difference only in ($P < .05$), the

TABLE 9

STATISTICAL COMPARISONS BETWEEN THE VARIOUS OCCLUSAL TYPES FOR EACH BAR DIMENSION SERIES

CLASS I NORMAL OCCLUSION vs CLASS II

Class I Normal Bar Diameters six subjects	vs	Class II Bar Diameters six subjects	"t" Values
2 millimeters	vs	2 millimeters	.275
6 millimeters	vs	6 millimeters	2.380 *
12 millimeters	vs	12 millimeters	0
18 millimeters	vs	18 millimeters	0
24 millimeters	vs	24 millimeters	.134
36 millimeters	vs	36 millimeters	.433

*P= $<$ .05
**P= $<$ .01

TABLE 10

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL TYPES FOR ORIENTATED ANGLES IN THE CEPHLOMETRIC STUDY

CLASS I NORMAL vs CLASS II

Class I Normal Bar Diameters six subjects	vs	Class II Bar Diameters five subjects	"t" Values
centric	vs	centric	.530
2 millimeters	vs	2 millimeters	.176
6 millimeters	vs	6 millimeters	2.09 *
12 millimeters	vs	12 millimeters	.237
18 millimeters	vs	18 millimeters	.141
24 millimeters	vs	24 millimeters	.540
wide open	vs	wide open	.638

*P= < .05
**P= < .01

TABLE 11

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL

TYPES FOR EACH BAR DIMENSION SERIES

CLASS I NORMAL OCCLUSION vs CLASS III

Class I Normal Bar Diameters six subjects	vs	Class III Bar Diameters five subjects	"t" Values
2 millimeters	vs	2 millimeters	.196
6 millimeters	vs	6 millimeters	.212
12 millimeters	vs	12 millimeters	.180
18 millimeters	vs	18 millimeters	.2570
24 millimeters	vs	24 millimeters	.253
36 millimeters	vs	36 millimeters	.133

*P= $< .05$
**P= $< .01$

TABLE 12

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL TYPES FOR ORIENTATED ANGLES IN THE CEPHLOMETRIC STUDY

CLASS I NORMAL vs CLASS III

Class I Normal Bar Diameters six subjects	vs	Class III Bar Diameters five subjects	"t" Values
centric	vs	centric	.169
2 millimeters	vs	2 millimeters	.909
6 millimeters	vs	6 millimeters	2.42 *
12 millimeters	vs	12 millimeters	.723
18 millimeters	vs	18 millimeters	.673
24 millimeters	vs	24 millimeters	1.225
wide open	vs	wide open	.674

*P = < .05
**P = < .01

TABLE 13

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL TYPES FOR EACH BAR DIMENSION SERIES

CLASS I MALOCCLUSION vs CLASS II

Class I Malocclusion Bar Diameters five subjects	vs	Class II Bar Diameters six subjects	"t" Values
2 millimeters	vs	2 millimeters	.525
6 millimeters	vs	6 millimeters	.174
12 millimeters	vs	12 millimeters	3.825 **
18 millimeters	vs	18 millimeters	1.157
24 millimeters	vs	24 millimeters	.132
36 millimeters	vs	36 millimeters	.328

*P= < .05
**P= < .01

TABLE 14

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL TYPES FOR ORIENTATED ANGLES IN THE CEPHLOMETRIC STUDY

CLASS I MALOCCLUSION vs CLASS II

Class I Malocclusion Bar Diameters <u>five subjects</u>	vs	Class II Bar Diameters <u>five subjects</u>	"t" Values
centric	vs	centric	1.833
2 millimeters	vs	2 millimeters	1.180
6 millimeters	vs	6 millimeters	.761
12 millimeters	vs	12 millimeters	.944
18 millimeters	vs	18 millimeters	.648
24 millimeters	vs	24 millimeters	.921
wide open	vs	wide open	2.048 *

*P= < .05

**P= < .01

TABLE 15

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL TYPES FOR EACH BAR DIMENSION SERIES

CLASS I MALOCCLUSION vs CLASS III

Class I Malocclusion Bar Diameters five subjects	vs	Class III Bar Diameters five subjects	"t" Values
2 millimeters	vs	2 millimeters	.158
6 millimeters	vs	6 millimeters	.253
12 millimeters	vs	12 millimeters	2.489 *
18 millimeters	vs	18 millimeters	.392
24 millimeters	vs	24 millimeters	.811
36 millimeters	vs	36 millimeters	.328

*P= $<$ .05
**P= $<$ .01

TABLE 16

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL TYPES FOR ORIENTATED ANGLES IN THE CEPHLOMETRIC STUDY

CLASS I MALOCCLUSION vs CLASS III

Class I Malocclusion Bar Diameters five subjects	vs	Class III Bar Diameters five subjects	"t" Values
centric	vs	centric	1.890
2 millimeters	vs	2 millimeters	1.888
6 millimeters	vs	6 millimeters	1.625
12 millimeters	vs	12 millimeters	1.705
18 millimeters	vs	18 millimeters	1.687
24 millimeters	vs	24 millimeters	2.465 *
wide open	vs	wide open	3.39 **

*P= < .05
**P= < .01

maximal opening. Thus, the horizontal slide follows for both groups. Being either proportionately smaller in size or in a more retarded position, it follows the centric and wide open angles should be larger for Class II. The other angles (2, 6, 12, 18, and 24mm bars) represent a reaching action to contact the bars for proprioception and could be expected to be more similar. The statistical comparison for each bar dimension series between Class I malocclusion and Class III is seen in Table 15. There is one significant difference ($P < .05$) at the 12mm vs 12mm level. It is postulated that this center series at the early part of translation has the least posterior horizontal neuro-muscular compensatory retraction due to the lesser amount of translation needed at this level in view of the greater length of the body of the mandible for Class III subjects.

Table 16 demonstrates the cephlometrically orientated angles for Class I malocclusion vs Class III. There are two levels of significant difference from this aspect between these two groups: 24mm vs 24mm ($P < .05$), and wide open vs wide open ($P < .01$). These are perhaps due to the forward position (due to increased length of the mandibular body in most instances) of the mandible.

Table 17 represents statistical comparisons between Class II and Class III for each bar dimension series. There are no significant differences between the various parameters in this group. Corresponding to this, Table 18 (statistical comparison between Class II and Class III for cephlometrically orientated angles) also demonstrates no significant difference between the various factors.

In conclusion to the data observation, it seems the greatest significant defferences evolve around Class I malocclusion which in virtually every case included rotated mandibular incisors. These differences are demonstrated both in the acuity of dimensional proprioception aspect and in the cephlometrically orientated angles in the arc of closure. This substantiates the postulate of the important role played by proprioceptive endings found in the normally positioned human incisors in both producing a precise level of proprioception and a smooth arc of closure in the incision process.

The mean Weber Ratios for incisal acuity of dimensional proprioception were plotted against the gradiated bar dimension series for each occlusal classification studied. These were graphic representations of the changes in the Weber Ratios as the dimensional thickness of the series increased and as the occlusal type of the subjects was varied. The Weber Ratios for incisal acuity of dimensional proprioception are presented in figures three to six. The corresponding plots of mean

TABLE 17

STATISTICAL COMPARISONS BETWEEN THE VARIOUS OCCLUSAL TYPES FOR EACH BAR DIMENSION SERIES

CLASS II vs CLASS III

Class II Bar Diameters six subjects	vs	Class III Bar Diameters five subjects	"t" Values
2 millimeters	vs	2 millimeters	.0641
6 millimeters	vs	6 millimeters	.349
12 millimeters	vs	12 millimeters	.3930
18 millimeters	vs	18 millimeters	1.157
24 millimeters	vs	24 millimeters	.663
36 millimeters	vs	36 millimeters	1.195

*P= < .05
**P= < .01

TABLE 13

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL

TYPES FOR ORIENTATED ANGLES IN THE CEPHLOMETRIC STUDY

CLASS II vs CLASS III

Class II Bar Diameters five subjects	vs	Class III Bar Diameters five subjects	"t" Values
centric	vs	centric	.277
2 millimeters	vs	2 millimeters	.0817
6 millimeters	vs	6 millimeters	.257
12 millimeters	vs	12 millimeters	.577
18 millimeters	vs	18 millimeters	.789
24 millimeters	vs	24 millimeters	1.051
wide open	vs	wide open	.982

*P= < .05
**P= < .01

TABLE 18

STATISTICAL COMPARISON BETWEEN THE VARIOUS OCCLUSAL

TYPES FOR ORIENTATED ANGLES IN THE CEPHLOMETRIC STUDY

CLASS II vs CLASS III

Class II Bar Diameters five subjects	vs	Class III Bar Diameters five subjects	"t" Values
centric	vs	centric	.277
2 millimeters	vs	2 millimeters	.0817
6 millimeters	vs	6 millimeters	.257
12 millimeters	vs	12 millimeters	.577
18 millimeters	vs	18 millimeters	.789
24 millimeters	vs	24 millimeters	1.051
wide open	vs	wide open	.982

*P= < .05
**P= < .01

cephlometrically orientated angles plotted against bar dimension series for a particular occlusal classification follows each mean Weber Ratio graph. These plottings are presented in figures three through eight.

Plots of the mean Weber Ratios for Class I normal are presented in figure three. The curve begins quite high and takes a sudden drop at the 6mm level. This high 2mm level is postulated as being a position of mixed rotary and translational movement with neuro-muscular forces seeking stabilization. Thus, the lessened acuity of dimensional proprioception is seen. The curve rises rather sharply toward the 12mm series and then attains relative stability until the sharp rise at the 36mm level.

The mean cephlometrically orientated angle plots (figure 4) for Class I normal group demonstrates a corresponding sharp drop for the 2mm series. This denotes a proportionately great increase in the orientated angle.

Figure five depicts the plots of the mean Weber Ratios for Class I malocclusion. This begins somewhat high for the 2mm series, then sharply swings upward demonstrating a phase of continuing less accurate proprioception for the 6mm and 12mm series. It is postulated that this represents poor periodontal proprioception (due to Class I malocclusion lower anterior rotations) in a mixed rotational-translational phase of the arc of closure.

CLASS I --- NORMAL

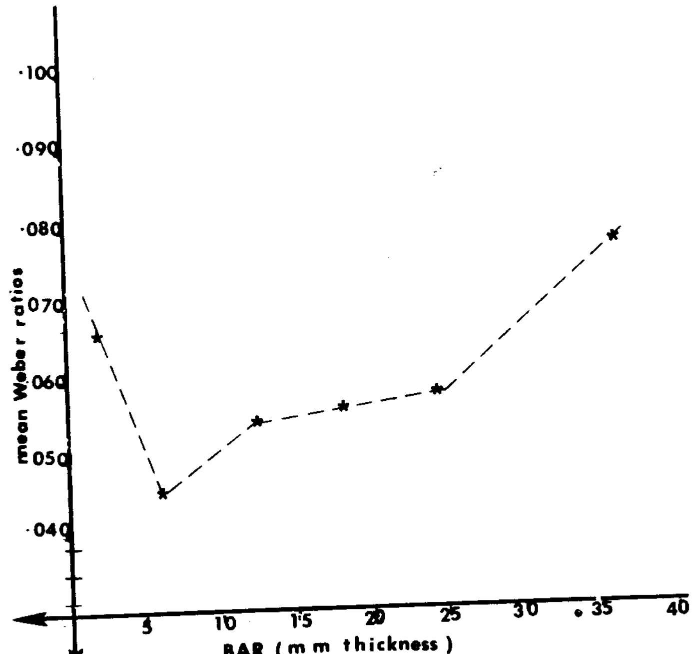


FIG 3

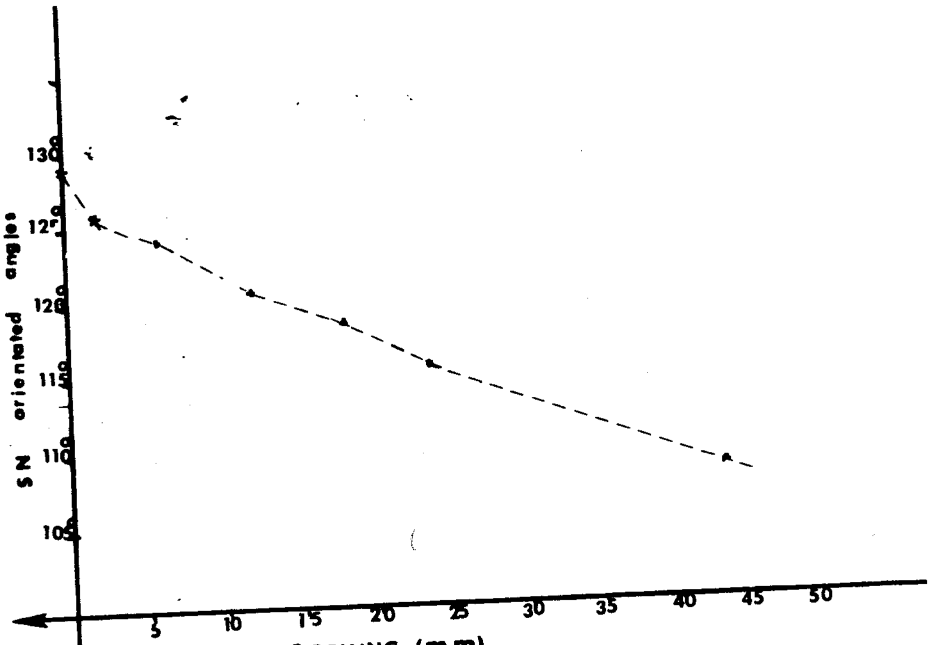


FIG 4

CLASS I — — — MALOCCLUSION

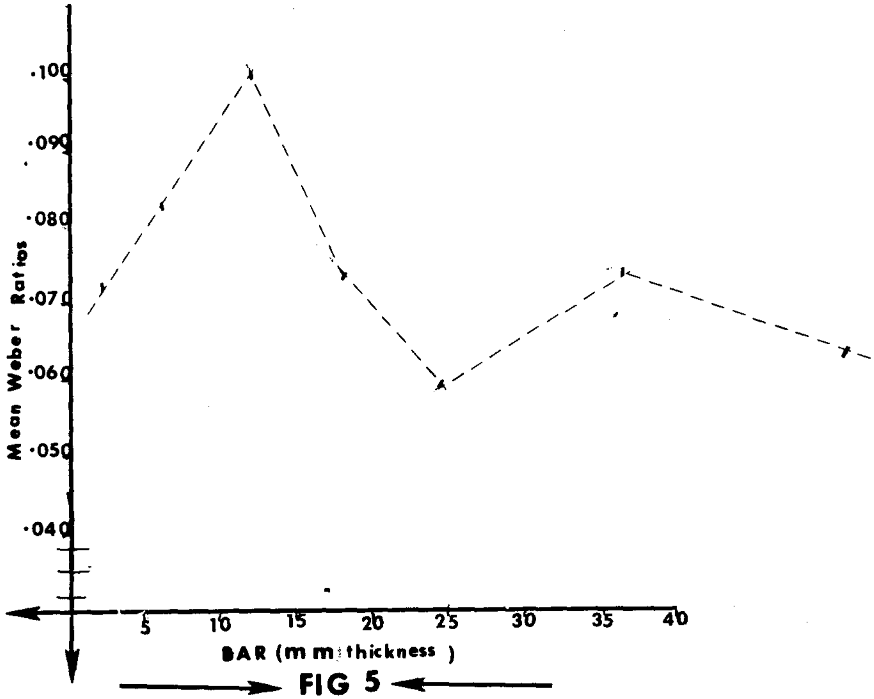


FIG 5

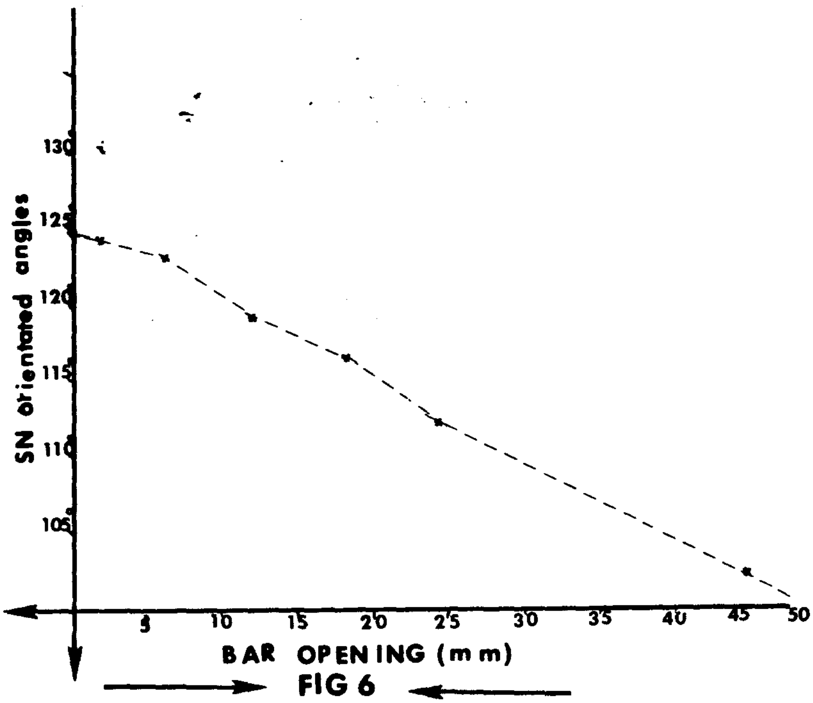


FIG 6

From the high of the 12mm level, the plot demonstrates an increasing return to proprioceptive accuracy through the 24mm series and then swings slightly upward again.

Figure 6, representing the Class I malocclusion cephlometrically orientated angles demonstrates a steady smooth plot with a slight dip in the 12mm area indicating a greater increase in orientated angle here. This is postulated to correspond to the increase in Weber Ratio demonstrated for the 12mm level in figure 5.

The Class II mean Weber Ratios are plotted in figure 7. The curve begins slightly above a middle range and then climbs sharply to the 6mm level. This graphically represents a sharp decline in acuity of dimensional proprioception at this level probably representing the beginning of translation and a neuromuscular attempt at stabilization. The curve then drops sharply to the 12mm level and continues rather evenly through the 24mm range and then increases rather sharply toward the 36mm area.

Figure 8 shows a somewhat sharp increase in orientated angle at the 2mm level. This is followed by a smooth regular decline.

Class III malocclusion mean Weber Ratios are graphically represented on figure 9. This curve corresponds quite closely to the Class II curve (figure 7) but on a level .010 higher. It

CLASS II

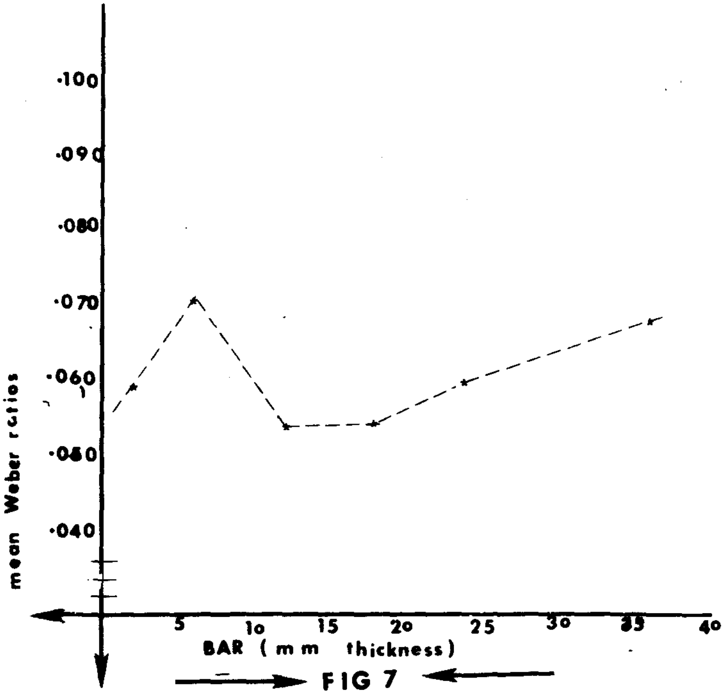


FIG 7

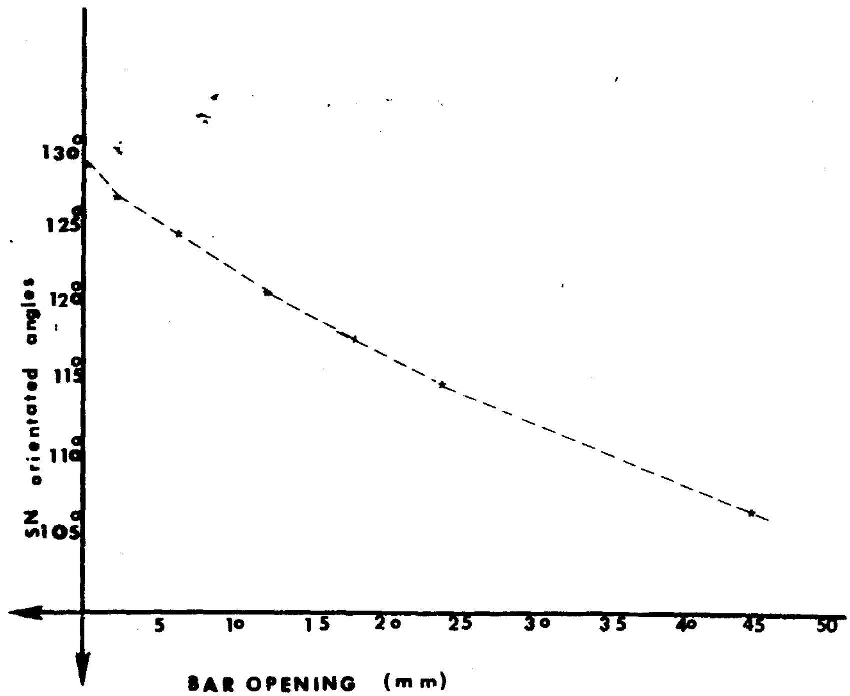


FIG 8

CLASS III

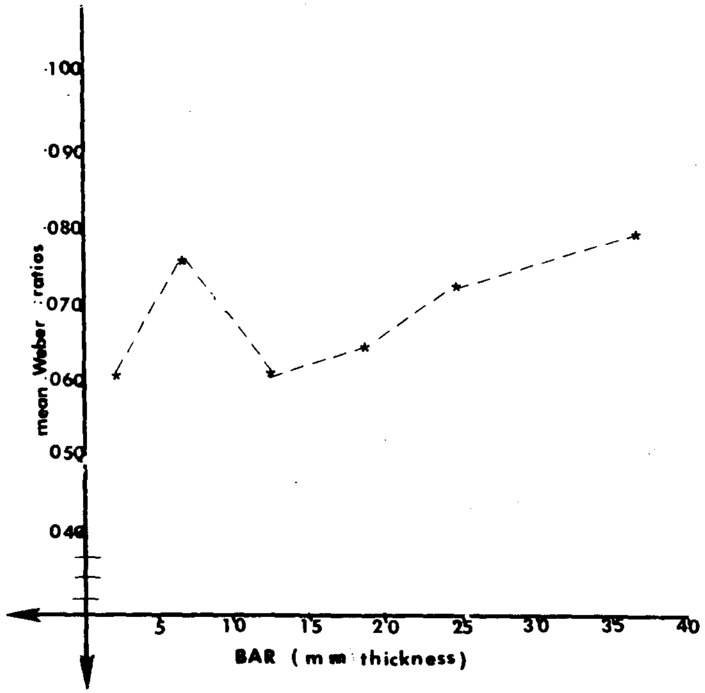


FIG 9

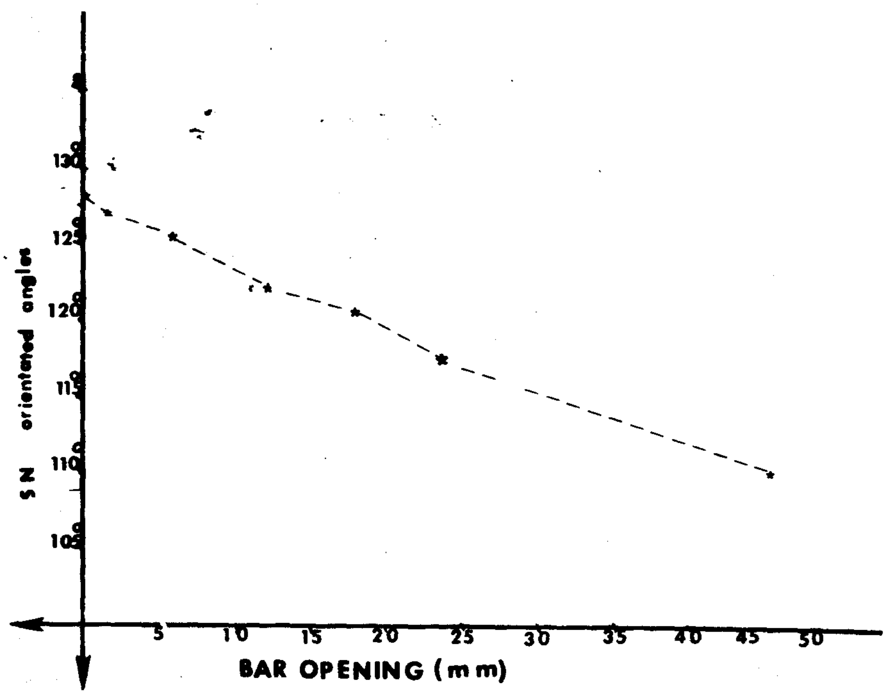


FIG 10

begins at a middle level and rises sharply to a high 6mm level and then drops rapidly back to the 12mm level with a gradual rise through the 24mm level.

Figure 10 demonstrates the plot for the mean cephlometrically orientated angles Class III. This is similar to the other groups. A slight drop is seen in the 2mm area and a smooth regular gradually declining curve follows.

CHAPTER V

DISCUSSION

The mean Weber Ratios reported in this study are quantative assessments of the various occlusal classes of individuals ability to consciously discriminate between similar thicknesses of bars placed between the maxillary and mandibular central incisors. These stimuli are conducted through the teeth to the sensory receptors located in the periodontal ligament and also through receptors in the temporal mandibular joint capsule and the muscles involved in the movement of the mandible. Comparing the mean Weber Ratio plottings for Class I normal, Class I malocclusion, Class II and Class III, it is postulated that the normal occlusion has a greater small-diameter acuity of dimensional proprioception with the translation phase beginning sooner and with less resultant loss of dimensional proprioception in this area. The vastly superior mean Weber Ratios in the 6mm area are perhaps due to smoother neuromuscular stabilization in early translation aided by more precise learned patterns resulting from the more accurately occluding dentition.

In all the malocclusion groups (Class I malocclusion, Class II, and Class III) a striking rise in Weber Ratios at the 6mm level is noted. This is a direct variance to the previously mentioned Class I normal parameter. The Class II and Class III

Weber means have a similar curve (with Class III being roughly .010 greater throughout). Accounting for the marked variance in the 6mm parameter through the neuromuscular occlusal function postulate, the remaining portions of the curves for Class I normal, Class II and Class III corresponds closely.

The Class I malocclusion mean Weber curve is sharply at variance with all the other occlusal groups between the 6mm and 12mm level. The substantial decrease in acuity of dimensional proprioception shown only in the Class I malocclusion curve at this level is correlated with the presence of anterior rotations in the lower incisor teeth of all subjects in this group. It is postulated that this rotation results in diminished normal function of the dimension proprioceptors thought to be in the periodontal ligament.

Tables 11, 13, 15, and 17, denote no significant difference between the various types of occlusion and tooth relationships for the 18, 25, or 36mm series. This is perhaps an indication of increased reliance on temporal mandibular joint receptors and on muscle proprioceptions for evaluating dimensional difference involving standards of 18mm and greater. Since all the subjects are of roughly the same young age group and in apparent good systemic health, the TMJ capsules, the mandibular musculature, and their nerve supplies might well be expected to fall within similar parameters of function.

In computation of data from the standards used, it is noted (see tables 3, 4, 5, and 6.) that the Weber Ratios do not significantly vary with diameter change within each of the individual occlusal groups (as stated, there are certain significant differences between the groups). Perhaps the 36mm series is an exception to this in that values here are generally higher. It is postulated that perhaps the 2mm series is at the lower border of the optimal range; and if this study were continued with a series of less than 2mm diameters, a dramatically increased Weber Ratio would be observed.

Kawamura, in his work with gradiated wires, found that the Weber Ratio for natural dentition acuity of dimensional proprioception was .10 and that the periodontal ligament was necessary for judging the size variation of the smaller wires but not the larger ones. The data obtained in this study demonstrates a much smaller Weber Ratio (see Table 2). This study uses approximately six times as many subjects. However, it used no artificial dentition subjects as Kawamura did. The results of this study definitely agree with his contention that the periodontal ligament is significant in discrimination in smaller diameter series and that the larger diameter (i.e. the 18, and 24mm results for all occlusal types) series are discriminated by all these sources of receptors but perhaps relatively more by temporal mandibular joint and mandibular musculature receptors.

Since it seems three separate sets of receptors come into play as the diameter of the proprioceptor testing series wires increases, it does not seem unreasonable to postulate that there need not be a definite optimal mean Weber Ratio and then a definite increase in Weber Ratio at the so called extremities of the dimensional series. Such a definite range was seen by Soltis and Bowman and Nakfoor (1968) in their work with applied forces. This seems logical since they were concerned primarily with one set of proprioception receptors; namely, those in the periodontal ligament, while this study was probably dependant also upon proprioceptors within the mandibular muscles and TMJ.

In deference to the experimental work of Grossman, et al, (1965) which noted both lips and the tongue as areas of great tactile sensitivity, the subjects were instructed to avoid all contact between these and the gradiated wire. Thus, in actual practice these tactile receptors could constitute a fourth group of dimensional determination receptors.

Finally, in a second work, Kawamura, et al, have noted many Golgi Mazzoni end organs in the fibrous joint capsule of the cat. They state, "Whenever the condyle moves, sensory information from the joint capsule is transmitted to the trigeminal motor nucleus which innervates the jaw muscles." It is this moving of the condyle in translation which perhaps stimulates the musculature to react so strongly in seeking mandibular stabilization as to mask sensory discrimination in the 6mm standard area.

The work of Sirhila, et al, (1967) has demonstrated the ability of incisors to perceive the presence of sheets of tin foil as thin as 10 microns to 30 microns. They conclude that the most important function of the teeth is "to determine the thickness of objects coming between them." This may help to explain why a standard series as thick as 2mm could still fall within the optimal functioning range for Weber Ratios.

CHAPTER VI

SUMMARY AND CONCLUSION

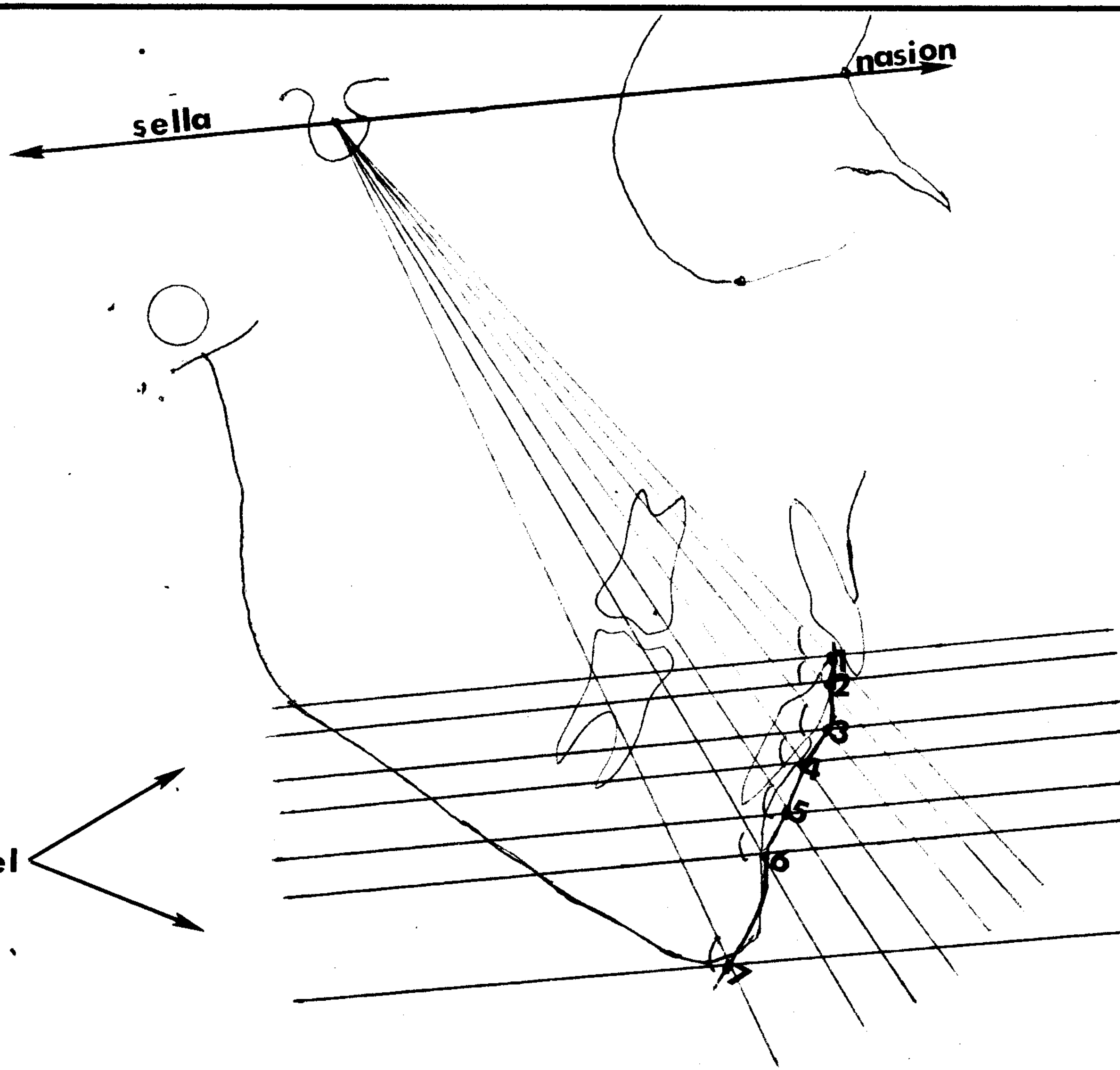
A clinical method of determining the acuity of dimensional proprioception involving the human periodontal ligament was described. This method was undertaken to determine the effect of the various types of occlusal relationships upon dimensional proprioception.

The conscious acuity of dimensional proprioception is significantly affected by the correct relationship of occlusal surfaces in that Class I normal showed better dimensional proprioception with opening around the 6mm standard than did the various malocclusions studied. The conscious acuity of dimensional proprioception is significantly affected by rotated position of mandibular anteriors (as exemplified by the Class I malocclusion group) in the area of the 12mm standard.

Twenty-two subjects were utilized in this study. Six subjects were Class I normal occlusion, and five were Class I malocclusion, six were Class II Division 1 with greater than normal overjet, and five were Class III. No significant difference was found between the four groups and their acuity of dimensional proprioception for the 18, 24, or the 36mm series. This suggested a greater dependence of temporal mandibular joint receptors for acuity of dimensional proprioception for standards of a diameter of 18mm or greater.

APPENDICES

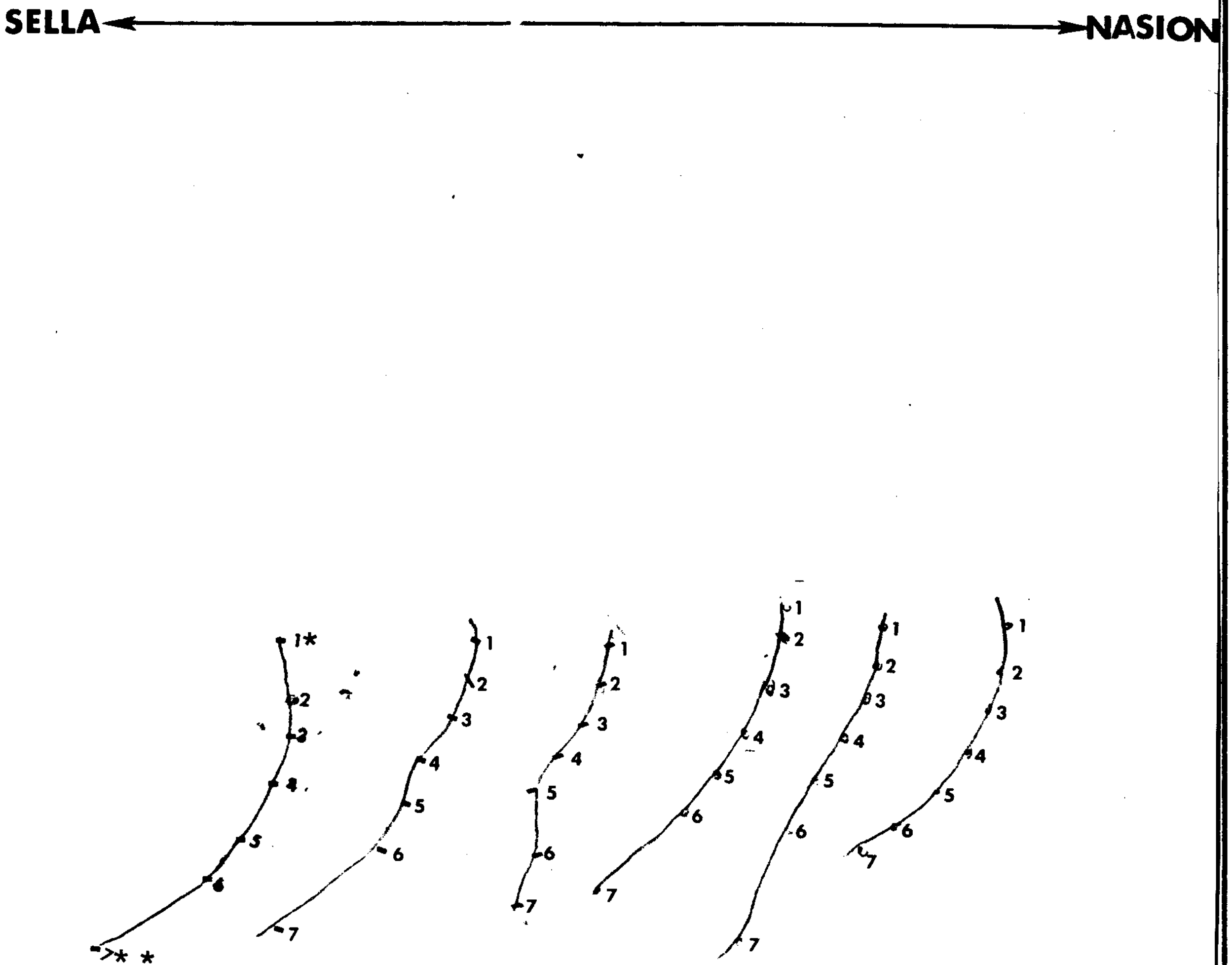
sample set of
cephlometrically
orientated angles



lines parallel
to sella—nasion

CLASS I --- NORMAL

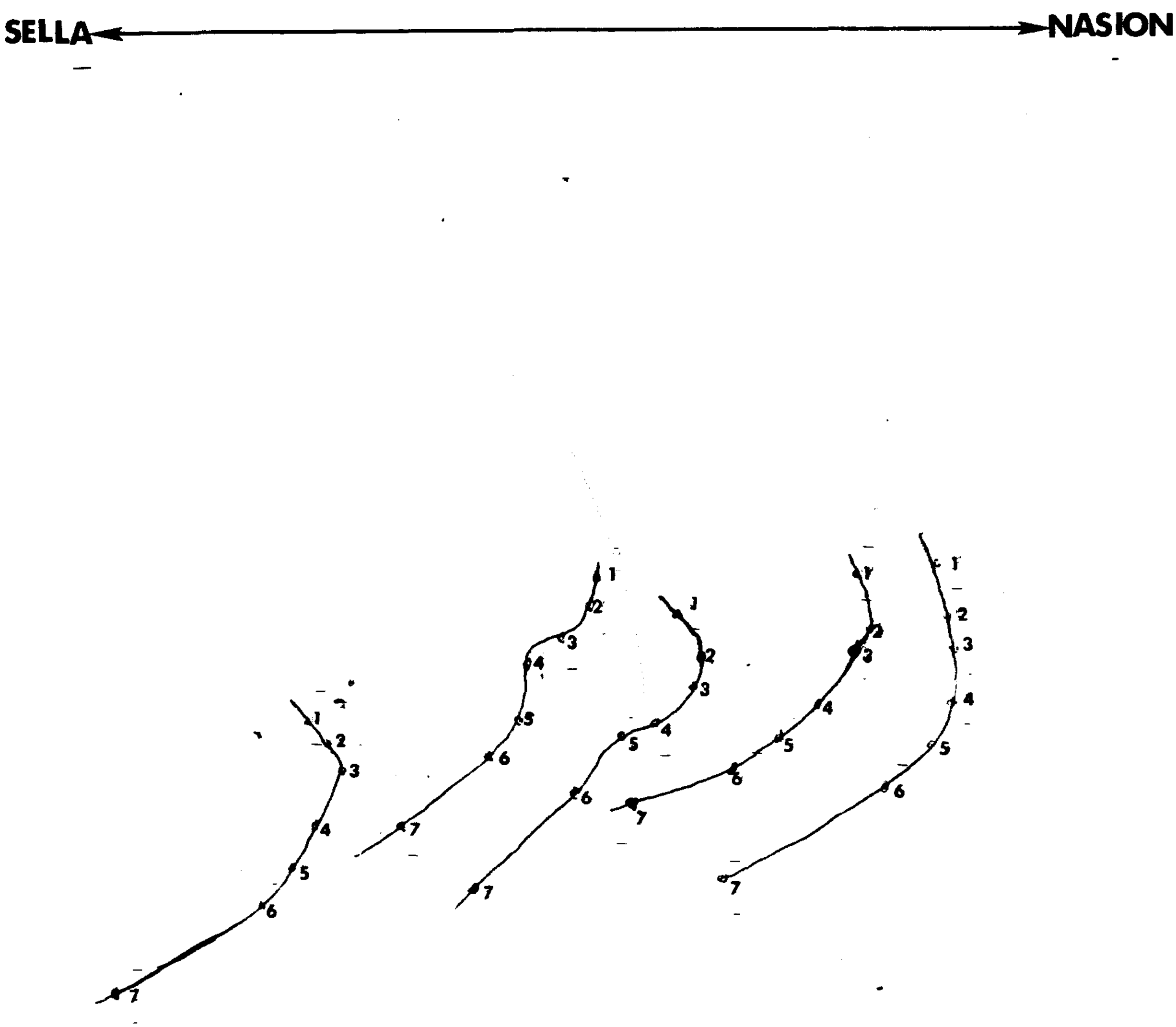
Arc of Closure



* centric
* * wide open

CLASS I MALOCCLUSION

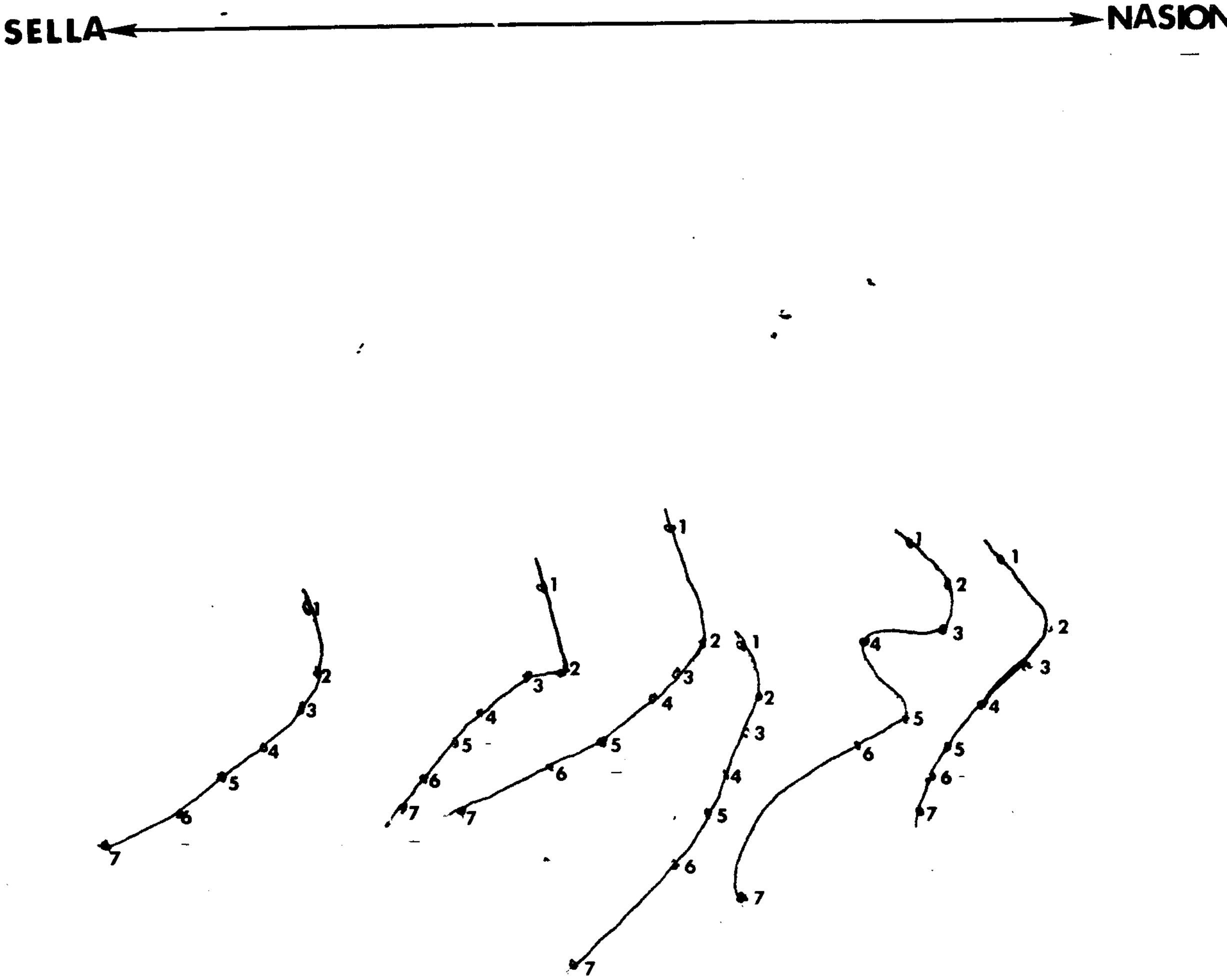
Arc of Closure



*centric
**wide open

CLASS II

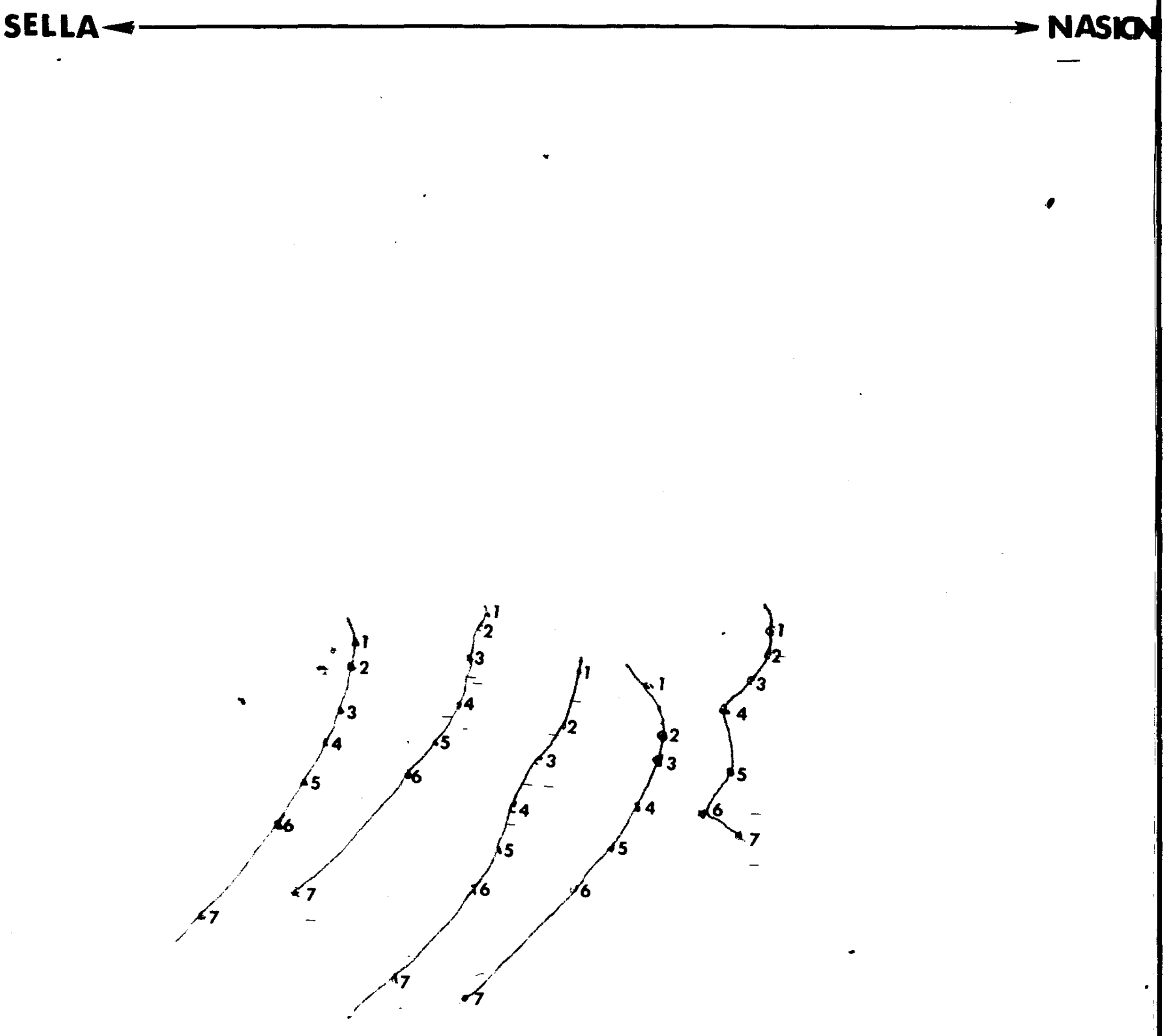
Arc of Closure



* centric
* * wide open

CLASS III

Arc of Closure



* centric

** wide open

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APPROVAL SHEET

The thesis submitted by Dr. David P. Stangl has been read and approved by members of the Department of Oral Biology.

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

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

May 13, 1969
Date

Douglas C. Bowman
Signature of Advisor