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The Effect of Orthodontic Forces on Gnathostatic Proprioception

Donald Richard Toso

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THE EFFECT OF ORTHODONTIC FORCES
ON GNATHOSTATIC PROPRIOCEPTION

BY

DONALD RICHARD TOSO

A THESIS SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF LOYOLA UNIVERSITY IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

JUNE

1969

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LIFE

Donald Richard Toso was born in New Orleans, Louisiana on January 23, 1942. After his graduation from De La Salle High School in June, 1959, he entered Loyola University in New Orleans. Upon completion of three years of pre-dental education, he entered the Loyola University School of Dentistry in New Orleans in September, 1962. He received the degree of Doctor of Dental Surgery in 1966.

Following graduation from dental school, he engaged in the private practice of dentistry.

He began graduate studies in oral biology at Loyola University in Chicago in June, 1967.
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I would like to extend my sincere appreciation to those who volunteered to participate in this study.

I would also like to thank Dr. Douglas C. Bowman, Professor of Physiology, Loyola University of Chicago, my advisor, who inspired this research and contributed invaluable advice and assistance in preparing this thesis.

I would also like to thank my parents and family who have guided and encouraged me in this and all previous endeavors.
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CHAPTER I
INTRODUCTION AND STATEMENT OF THE PROBLEM

Many investigations have been reported in the literature in which forces or other stimuli have been applied to the teeth in an effort to establish the existence of proprioceptive end organs in the periodontal ligament. Recent studies have evaluated the ability of subjects to discriminate between different intensities of forces applied to the teeth. Comparatively few investigations have been undertaken in which dimensional proprioception has been evaluated, that is, the ability to evaluate different-sized objects that are placed between incisal or occluding surfaces of natural dentition. It is thought that in such a situation additional proprioceptive receptors known to be present in the attached mandibular musculature and temporomandibular joint aid in dimensional discrimination.

This investigation will attempt to determine the acuity of dimensional proprioception between maxillary and mandibular incisors in subjects with an Angle Class II type malocclusion. This type of malocclusion is usually characterized by a moderate to severe anterior-posterior differential between the maxillary and mandibular incisal surfaces. When these patients incise or bring their anterior teeth end-to-end, the attached musculature must 'swing' the mandible forward.

The same subjects will be tested after light orthodontic forces are applied to the teeth to determine if proprioceptive function is altered.
All data collected will be subjected to the Weber–Fechner Law in a test of its validity for dental dimensional proprioception.
CHAPTER II

REVIEW OF THE LITERATURE

1. Measure of Discriminatory Ability as Formulated by Weber and Fechner

In comparing objects and observing the differences between them, Weber in 1850, reported that subjects did not, in reality, perceive the differences between them, but rather the ratio of this difference to the magnitude of the objects compared. As a result of these observations, he coined the phrase "just noticeable difference" relative to the change in stimulus perceived by the subjects, and found it to be a constant proportion when discerning small differences between weights, lengths, and tone pitch.

Fechner (1854) who had been thinking and working along similar lines, formulated a principle and derived a mathematical expression which became known as Weber's Law:

\[ C = \frac{\Delta I}{I} \]

where \( I \) is the stimulus, \( \Delta I \) is the change in intensity of the stimulus, and \( C \) is the constant. He further formulated the Psychophysical Law, which states that the magnitude of a sensation is proportional to the logarithm of the intensity of the stimulus,

\[ S = A \log(I + K) \]

where \( S \) is the intensity of the perceived stimulus, \( I \) is the intensity of the stimulus, and \( A \) and \( K \) are constants needed to relate to \( I \) and \( S \). Fechner thus sought to obtain both the absolute threshold and the differential threshold.
Practically from the outset the concepts formulated by Weber and Fechner were criticized and held to be limited in their application. James (1890) felt that the "just noticeable difference" could not be accurately determined unless a great number of sensations were computed, to which Van Leeuwan (1949) some years later agreed.

Exner (1879), Wundt (1900), and Hecht (1924) believed the Weber Ratio to be constant only within narrow limits. Hecht felt that sensory judgments were relative and not absolute, and agreed with Cowdrick (1917) that the Weber Ratio decreased steadily as the intensity increases.

Treisman (1964) reviewed the works of many investigators and concluded that the Weber Law could be applied only to the middle range of stimulus intensities with validity. The Weber Ratio increases as the stimulus is increased or decreased.

The Psychophysical Law of Fechner has not been accepted by some researchers from a psychological viewpoint. Plateau (1850), Brentano (1874), Grotenfelt (1888), Guilford (1932), and Stevens (1957) have all stated their belief that a power function exists between a stimulus and a perceptual response. Stevens has shown on twelve different continua of stimuli that the subject's perception grows as a power function of the stimulus intensity.

Urban (1933) did not believe that the psychic and physical entities could be related to one another consistently, while Brett (1962) objected to Fechner's Law for the following reasons: (1) the lack of experimental evidence; (2) the law has only physiologic value; (3) the mathematical expression of the law is incorrect; and, (4) mental processes were considered by Fechner to be mathematical rather than biological.
2. Proprioceptive Function of the Periodontal Ligament

Peaslee (1857) credited the pulpal region with the ability to localize and detect pressure, but Black (1887) stated that the periodontal ligament alone was the organ responsible, and again restated this belief in 1924. Noyes (1924), Bradlaw (1936), and Van der Sprenkel (1936) each described sensory nerve endings or organs in the periodontal ligament. Noyes described organs that were beaded in shape and said that they were sensitive to touch only. Bradlaw spoke of terminal coils in the monkey, while Van der Sprenkel discovered small end rings close to the bony reticulum in the mouse that were said to function as pressure proprioceptors.

Brashear (1936) found large nerve fibers in the periodontal ligament of the cat, but was unable to locate any in the dental pulp. He felt that the periodontal ligament was the organ of pressure proprioception, as well as other sensations, in the cat and human.

Lewinsky and Stewart (1936) described coarse and fine nerve fibers in the cat. The coarse or thick fibers terminated in knob-like swellings (tactile and pressure proprioception), and the fine or thin fibers ended in fine aborizations (pain).

Earlier, Stewart (1927) had applied measured light forces to human teeth and concluded that the periodontal ligament was responsible for pressure proprioception because of the negligible threshold difference between pulpless and innervated teeth.

In 1955, Lowenstein and Rathkamp used a spring aesthiometer to establish absolute thresholds for vital and non-vital teeth. They found the vital teeth to be more sensitive, and suggested that pulpal and periodontal pressoreceptors are present.
Pfaffman (1939) extirpated the dental pulp, fractured and removed all but a small portion of the tooth of a cat and still found the remaining portion to be responsive to pressure. He felt that many, if not most of the tactile or pressure receptors are located in the periodontal ligament.

Ness (1954) classified periodontal mechanoreceptors of the rabbit mandibular incisors as slow-adapting, fast-adapting, and spontaneously discharging. He found that end organs showed directionality and believed this might be a property of the orientation of the individual receptors.

Corbin and Harrison (1940) believed the fibers of the caudal half of the mesencephalic root of the trigeminal nerve mediated deep pressure impulses from the homolateral maxillary teeth, hard palate, and masticator muscles.

Jerge (1963) also found that receptors were directed to the caudal half of the mesencephalic root of the trigeminal nerve. He found one group of receptors to be involved when a single tooth was stimulated, and a different group of receptors involved when a group of teeth and adjacent soft tissue were stimulated.

Kruger and Michel (1962) discovered fast-adapting receptors in the cat that were sensitive to light touch. Only one surface of a tooth was found to be sensitive, showing the good directional sensitivity of these receptors.

Kizior, Cuozzo, and Bowman (1968), while recording electrical activity on the inferior alveolar nerve, applied identical forces in different directions to the mandibular canine of cats and found directional sensitivity to be greatest inciso-apically. They reasoned that if the receptors were uniformly distributed in the apical third, an incisal
tap would activate more receptors than a labially or lingually directed percussive tap.

Bowman and Nakfoor (1968) could demonstrate no directional sensitivity in human maxillary central incisor teeth. Identical forces were directed along the long axis and at 90° to the long axis of incisor teeth and the results were very similar. Nakfoor (1967) tested the same patients four days after light orthodontic forces were applied to the teeth. He found their discriminatory ability lessened and the pain threshold markedly lowered.

Soltis (1968) corroborated Nakfoor's findings relative to effect of orthodontic forces, and further demonstrated that as the forces of orthodontic appliances were diminished, discriminatory ability slowly returned.

Dusza (1968) applied forces to the maxillary canine tooth and found "... the ability of the subjects to discriminate between "similar" forces was significantly improved ..." four days subsequent to the application of light orthodontic forces.

3. Proprioceptive Function of the Muscle Spindle and Temporomandibular Joint

One of the first investigators who described the muscle spindle was Kuhne (1863 a and b). Because of its shape, he called it Muskelspindeln. Kuhne also claimed to have seen nerve fibers endings in the spindle, but it remained for Sherrington (1894) to demonstrate their existence conclusively. Sherrington sectioned ventral and dorsal spinal nerve roots in cats and monkeys, and found no degeneration of one-third to one-half of the myelinated nerve fibers in the nerves to muscles. Peripheral afferent fibers were connected with their dorsal root ganglion cells, but the motor nerve fibers were disconnected from their motoneurons and had degenerated. He traced many of these
afferent nerve fibers to muscle spindles and thus concluded that it was a 'sensorial' organ. At about the same time, Ruffini (1893, 1897, 1898) used gold chloride to stain the cat muscle and contributed many detailed drawings of nerve endings.

Matthews (1933) stimulated motor fibers to a muscle and recorded sensory discharge from the muscle nerve. During muscle contraction, he found a decreasing response, which he ascribed to spindle function; he also observed an increasing response, which he felt was produced by the stretch of tendon organs.

In 1948, Barker described two types of spindle sensory fibers: the larger fiber (12-20 microns) makes contact with the intrafusal bundle at its equatorial region through primary or annulospiral endings, and, the smaller fiber (4-12 microns) innervates the intrafusal bundle at regions adjacent to the primary endings through secondary or "flower-spray endings."

The equatorial region of the spindle is the central third and is defined by Matthews (1964) as being 80-200 microns wide, with the intrafusal fibers surrounded by fluid and contained in a capsule.

Boyd (1962) found that cat hindlimb muscle spindles contain two distinct types of intrafusal muscle fibers which differ in diameter, length, arrangement of nuclei, myofibril content, and sensory and motor innervation. The larger fibers (about 25 microns in diameter and 7-8 mm. long) attach to the perimysium of an extrafusal muscle fasciculus. These fibers are packed full of nuclei (Barker's nuclear bag, 1948), and contain many more myofibrils, but exhibit little branching. The smaller intrafusal fibrils (12 microns in diameter, and about 4mm. in length) which end on the surface of the large fibers, contain
a single chain of central nuclei (nuclear chain), contain few myofibrils, and sometime exhibit branching or joining. Primary or annulospiral endings are associated with both nuclear bag and nuclear chain intrafusal systems, while secondary or flower-spray endings are primarily associated with the nuclear chain systems.

Primary-ending fibers (Ia fibers) monosynaptically excite the homonymous and synergistic muscles, and inhibit antagonistic muscles (Eccles and Lundberg, 1958). Eccles and Lundberg (1959), Laporte and Bessou (1959), and others state that secondary-ending fibers (Group II fibers) generally synapse with motor neurons to the same muscle through two or more internuncial cells in the spinal cord and usually cause flexor excitation and extensor inhibition.

Eccles, et al (1963) believed that the afferent fibers from both primary and secondary endings have additional actions, and that in all probability act on the central terminations of other primary afferent fibers to diminish their synaptic action, and that they themselves may be similarly inhibited.

There is also the persistent belief that some fibers from secondary endings synapse in the dorsal cord and transmit sensations to the conscious portions of the brain (Guyton, 1966).

The motor neurons that are known to be activated by the secondary endings are designated as gamma\(_1\) and gamma\(_2\) (Boyd, 1962). Boyd has claimed that gamma\(_1\) innervates the nuclear bag and that gamma\(_2\) innervates the nuclear chain. Barker (1962) and Matthews (1964) have questioned this specific innervation, but have not challenged their existence. Feinstein, et al (1955), state they provide a second input from higher
centers to the spindle receptors. These efferent signals to the contractile portions of intrafusal fibers cause the latter's contraction. This in turn results in stretching of the central non-contractile portion of the spindle where the primary (annulospiral) endings are located, causing their receptors to discharge more rapidly.

Biancone and van der Meulen (1962), testing the sensitivity of spindle endings to fibration, found that the primary endings usually have a greater phasic or dynamic sensitivity than the secondary endings, which respond more to changes in tonus.

Matthews (1964) reasons that the primary ending's dynamic response is larger than that of the secondary ending because it lies in the relatively nonviscous region of intrafusal fibers.

Jansen and Matthews (1962 a) studied the effects of gamma efferents upon the static and dynamic sensitivities of spindle endings, and observed that there was no simple correlation between the changes in dynamic and static responses of primary endings when the level of gamma activity was altered. This suggests that the dynamic and static responses of primary endings are under relatively independent control.

Matthews (1962) had also observed that the two types of gamma fibers can be differentiated in the ventral root by their effects on the stretch responses in primary endings. One type increases both the static and dynamic responses, and the other increases the static and decreases the dynamic response.

Jansen and Matthews (1962 b) conclude that the primary (annulospiral) endings signal length and rate of change of length of muscle, while the secondary (flower-spray) endings signal mainly length. Renkin and Vallbo (1963) concur.
The idea of independent control of phasic and dynamic responses of primary endings is important when considering the stretch reflex, because the dynamic property of the stretch reflex counteracts the effects of the time delays, thus preventing oscillatory contractions. Higgins, et al, (1962) studied stretch responses to oscillatory stimuli in cats and concluded that the cerebellum modifies the myotatic stretch response so that the peak of tension tends to occur before the peak of extension. An intact gamma system seems necessary to prevent oscillatory contractions, or at least the tendency towards it.

Matthews (1964) believes that the primary function of muscle spindles is not conscious proprioception. He cites the investigations of Provins (1958) and Brindley and Merton (1960) as the basis for his reasoning. Provins anesthetized the finger joint of a man and found that the position sense of the joint was impaired despite the fact that the muscle spindles of the joint muscles were not interfered with. Brindley and Merton did similar work with human eye muscles and concluded that these muscle spindles did not contribute to conscious sensation.

Matthews (1964) concludes that the primary function of muscle spindles is "subconscious nervous control of muscular contraction, both during movement and during steady contraction."

Houk and Henneman (1968) state that the interaction between the alpha and the gamma systems of the muscle spindle results in a "positional control system," which controls the length of a set of muscles, thereby determining the position of a joint. Instructions come from control signals that impinge on alpha and gamma motor neurons.
Pairs of muscles throughout the body are the effectors in positional control systems. The output of positional control systems determine the actual position of a joint.

The role of the temporomandibular joint in proprioceptive transmission has not been widely investigated. Thilander (1964) has found free nerve endings in the human capsule. Kawamura and Majima (1964) located many modified Golgi-Mazzoni end organs in the cat joint capsule and found that sensory information is transmitted to the trigeminal motor nucleus and the medullar and spinal trigeminal sensory nuclei when the condyle is moved. The anterior and posterior portions of the capsule were the regions of heavy distribution of the Golgi-Mazzoni end-organs.

4. Investigations Related to This Study

Of particular interest to this investigation is the study of Kawamura and Watanabe (1960). Six subjects took part in their investigation: three persons with natural dentition and three persons with artificial dentition. Each was asked to ascertain the least perceptible difference in thickness of wires ranging in size between 2mm. and 5mm. when these wires were placed between the medial incisors and first molar teeth. In comparing the results obtained in testing the two groups, they concluded that the periodontal ligament of antagonistic teeth was essential in making the correct judgment of the size of materials. They also felt that the mandibular-joint receptors play an important role in dimensional proprioception beyond a certain degree of mouth opening.

Manly, et al (1952) in a similar study, state "... it is probable that the judgment of size is accomplished from proprioceptive sensations originating in the temporo-
mandibular joint and the muscles of mastication."

Langer and Michman (1968) investigated the ability of denture patients to discriminate differences in hardness of rubber sticks. They conclude that "... the proprioceptors of the muscles, tendons, and temporomandibular joints are capable to supply the necessary sensory information independently from the oral mucosa..." and that "... an integrated sensory interaction of all oral structures exists and that various types of receptors are functioning together."
CHAPTER III
METHODS AND MATERIALS

This study utilized fifteen patients who presented themselves for treatment in the Department of Orthodontics at Loyola University in Chicago. Their ages ranged from eight to eighteen.

Each subject had been previously examined and accepted as a good teaching case by the Loyola Orthodontic Department. Each patient exhibited an Angle Class II molar relationship. Initial records were taken on each patient before any experimental data were collected. These records consisted of a set of plaster casts, full mouth radiographs, a Panorex radiograph, an Orthopantomograph, three lateral and two posterior–anterior cephalometric radiographs, and color intraoral transparencies.

The first examination was made after initial records were taken and before treatment was begun. The second examination took place four days after orthodontic appliances were placed.

Previous to any subject being tested, a preliminary study was conducted on four orthodontic graduate students and five dental assistant students from the Loyola School of Dentistry. A range of dimensional discriminatory ability was defined and the examination procedure was established.
1. **Apparatus**

Six different dimensionally gradated series of rods were used in the investigation. Each series consisted of nine rods, the middle rod designated as the standard, with the other rods ground so as to be 5, 10, 15, and 20 percent smaller and 5, 10, 15, and 20 larger than the standard.

The rods in each series were given numerical designations -- the smallest rod designated #1, and the largest rod designated #9 (See Table One). In addition, each series was given a letter designation based on relative diameter -- the smallest was designated Series A, and the largest was designated Series F (See Table One).

Each series of rods was mounted on a circular wooden disc. The centers of the discs were drilled out and hollow metal tubes inserted therein. The six different standard rods used were 2mm. (Series A), 6mm. (Series B), 12mm. (Series C), 18mm. (Series D), 24mm. (Series E), and 36 mm. (Series F) in diameter.

The rods were ground so that the Weber Ratios were identical for each series. In each series the smallest Weber Ratio differential was .043. The next largest Weber Ratio Differential in each series was .045, the next largest .048, and so on. In other words, the relative gradations in each series were identical (See Table One).

2. **Experimental Procedure**

The examination room was a seven-foot square, well-lighted, and air-conditioned area. The subject was seated in a dental chair which had an adjustable head rest, a foot rest, an adjustable back, stationary arms, and a foot controlled hydraulic pump.
### TABLE I

**Rod Diameters and Rod Ratios**

<table>
<thead>
<tr>
<th>Rod Number</th>
<th>Diameter of Rods (millimeters) in Series</th>
<th>Successive Rod Ratio for All Series**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
<td>1.6</td>
<td>4.8</td>
</tr>
<tr>
<td>2</td>
<td>1.7</td>
<td>5.1</td>
</tr>
<tr>
<td>3</td>
<td>1.8</td>
<td>5.4</td>
</tr>
<tr>
<td>4</td>
<td>1.9</td>
<td>5.7</td>
</tr>
<tr>
<td>5*</td>
<td>2.0</td>
<td>6.0</td>
</tr>
<tr>
<td>6</td>
<td>2.1</td>
<td>6.3</td>
</tr>
<tr>
<td>7</td>
<td>2.2</td>
<td>6.6</td>
</tr>
<tr>
<td>8</td>
<td>2.3</td>
<td>6.9</td>
</tr>
<tr>
<td>9</td>
<td>2.4</td>
<td>7.2</td>
</tr>
</tbody>
</table>

* Standard

** Rod Ratio = \( \frac{(\text{Diameter of Larger Rod} - \text{Diameter of Smaller Rod})}{\text{Diameter of Larger Rod}} \)
addition, a metal bar was mounted on one arm of the chair which could be moved and attached to the other dental chair arm so that it would lie over the subject's lap when he was seated. A multi-directional flexible metal arm was clamped to this bar. A short prong extended from the end of the flexible arm. The circular wooden discs could then fit into this prong by means of the hollow metal tubing in the center of the discs. The different-sized rods could then be quickly rotated into position for biting without the necessity of the subject or the examiner holding the individual rod. Illustration #1 shows the rod-mounted discs. Illustration #2 shows one of the discs inserted on the multi-directional flexible arm and ready for use.

It was explained to each subject that two different rods would be placed between their front teeth, that they should bite or tap on these rods, and then designate which rod was thicker. The subjects were told that they could not use their lips or tongue in making these determinations. All subjects were blindfolded during the testing procedures.

The two rods for each test were placed between the teeth in random order, sometimes the larger diameter rod first, and sometimes second. However, testing in each series was begun by using the two rods in that series which had the smallest Weber Ratio (i.e. rods #8 and 9).

If a subject was unable to make the correct determination (the larger rod being correctly identified seven out of ten times), the two rods with the next larger Weber Ratio were then used (rods #7 and #8), and so on, until the correct determination was made. This was recorded before going to the next series. Subjects were cautioned to bite or tap gently at the beginning of each series. Because of the size differential in moving from
FIGURE 1

ROD-MOUNTED DISCS
FIGURE 2

ROD-MOUNTED DISC AND EXAMINATION CHAIR
one series to the next, it was felt that there might be a tendency towards biting too powerfully in the succeeding series and thereby cause trauma to the periodontal ligament which might thus impair discriminatory ability. This was avoided by reminding the subjects to bite gently.

The wires were always placed as closely to the maxillary teeth as possible. This allowed the head to remain in a fixed position (with the aid of a headrest), and the mandible to be brought into position for biting by the head and neck musculature. Attempts were thus made to strive for consistency, to eliminate the possible distracting effect of up and down head movement, and to make use of the proprioceptive nerve endings in the muscle and temporomandibular joint.

When all data were compiled, statistical comparisons were made between each series of rods. The mean Weber Ratio and standard deviations were calculated for each series during the first testing, and then for the second testing. The mean Weber Ratio for one series in the first testing was compared with the mean Weber Ratio of each of the other series. For example, the mean Weber Ratio of Series A was compared with the mean Weber Ratio of Series B, C, D, E, and F. The mean Weber Ratio of Series B was then compared with those of Series C, D, E, and F. The same procedure was followed with Series C, and then, with series D, E, and F, until all mean Weber Ratios for each series were related to the mean Weber Ratios of the other series. The data from each series of the second testing were similarly evaluated.
Additional statistical evaluations were then made between the mean Weber Ratios of each series of the first testing to the mean Weber Ratios of the corresponding series of the second testing.
CHAPTER IV

FINDINGS

A preliminary study was undertaken in order to approximate Weber Ratios anticipated in this study. It further indicated the expected range over which the Psychophysical Law, for a subject, would be valid. The following table presents the mean Weber Ratios for each series of wires used in the preliminary study.

TABLE II

Mean Weber Ratios for Dimensional Proprioception in the Preliminary Study

<table>
<thead>
<tr>
<th>Series</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Weber Ratio</td>
<td>0.066</td>
<td>0.065</td>
<td>0.060</td>
<td>0.061</td>
<td>0.065</td>
<td>0.065</td>
</tr>
</tbody>
</table>

These results confirmed the belief that the testing in each series should begin with the two wires in that series, which had the smallest Weber Ratio. It was decided, however, not to follow this procedure for the largest series of wires. The large diameter of the wires in this series made the testing procedure cumbersome and awkward. Testing in this series was therefore begun with the two rods that could be inserted between the opposing dentition without necessitating extreme mouth opening or causing apprehension in the subject.

The preliminary study also enabled the examiner to become more familiar with the equipment being used, and an examination procedure was easily established.
The subjects were then tested and the results recorded. The mean Weber Ratios and standard deviations in each series were then calculated and are given in Table Three.

The smallest Weber Ratio in any or all of the different series was .043. Two-thirds of the subjects gave a reading of .043 in one or more series. The smallest Weber Ratio was obtained in every series except the largest -- F Series -- where the smallest Weber Ratio obtained was .050. The largest Weber Ratio determined in any series was .125 (Series A and Series B -- same patient).

The second testing, four days subsequent to the placement of orthodontic appliances, produced almost identical results. In only six instances did the subjects differ from discrimination the first trial. In four instances, their dimensional acuity was not as good, but in two instances, their judgment was better. Statistical comparisons, in the form of "t" tests, confirm the lack of significant difference between the two testings (See Table Four).

Statistical comparisons were also made between each different series of rods. The "t" values for the first and second testings are given in Table Five.
**TABLE III**

Mean Weber Ratios* for Dimensional Proprioception Prior to Treatment
And Four Days After Placement of Appliances

<table>
<thead>
<tr>
<th>Weber Ratios</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<tr>
<td></td>
<td>± 0.0231</td>
<td>± 0.0250</td>
<td>± 0.0300</td>
<td>± 0.0222</td>
<td>± 0.0194</td>
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</tr>
<tr>
<td>Placement of Appliances</td>
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<td>± 0.0249</td>
<td>± 0.0202</td>
<td>± 0.0222</td>
<td>± 0.0194</td>
<td>± 0.0198</td>
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</tbody>
</table>

* Any variation is indicated by the standard deviation from the mean.

** Sample = 15 Subjects
TABLE IV

*Statistical Evaluation of First Measurement (Prior to Treatment) Versus the Second Measurement (Four Days After Placement of Appliances

<table>
<thead>
<tr>
<th>Series</th>
<th>A</th>
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<th>D</th>
<th>E</th>
<th>F</th>
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<td>.067</td>
<td>.011</td>
<td>.053</td>
<td>difference</td>
<td>difference</td>
<td>0.23</td>
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* Sample in both testings = 15 subjects
### TABLE V

**Statistical Evaluations Between Each Different Series of Rods**

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<th>Four Days After Placement of Appliances</th>
<th>Series</th>
<th>t</th>
<th>p</th>
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<td>A vs E</td>
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<tr>
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<td>D vs E</td>
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<td>E vs F</td>
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CHAPTER V
DISCUSSION

The Weber Ratios reported in this study are quantitative assessments of the individual's ability to evaluate small changes in the diameter of rods placed between the anterior teeth. The validity of the Weber Ratio being expressed as an absolute has been repeatedly questioned. Further, many investigators believe that the Weber Ratio is constant only over the midrange of intensity, and that it does not hold true for either the lower or higher ranges of stimulus intensity.

There was no significant difference in mean Weber Ratios between any of the different-sized series of rods tested. In the "t" tests comparing the subject's ability to discriminate differences in thicknesses of the rods of one series to those in other series, for both the first and second testings, the largest "t" value recorded was 1.322 (B vs E series). This is not considered statistically significant. It should be noted, however, that the series with the smallest mean Weber Ratios were those in the middle range of this study -- Series D (.0594) and Series E (.0578). In addition, the calculated Weber Ratios did not change from the first to the second testings in these two series. Thus, the middle range series of rods produced more consistent results in that they were the same in both testings, and had lower mean Weber Ratios, though the "t" tests show no significance.

The only previous investigation with which this study might be related in approach was that of Kawamura and Wanatabe. Three subjects were used in their study, and the
largest diameter rod used was 5.0mm. They established a Weber Ratio for dimensional proprioception in human teeth as 0.1 for 100 percent discrimination. In the present study, 70 percent discrimination was required. Since the subject in Kawamura and Wanatabe's study with upper and lower dentures could not discriminate as well as the natural dentition patients, they concluded that the periodontal ligament receptors were essential in making size judgment. It was mentioned in the discussion, however, that "when the mouth is opened beyond a certain degree the senses of the mandibular joint might come into action strongly."

Manly (1952), et al, used boilable lucite rods between 5.0mm. and 5.75mm. in thickness in testing size discrimination in natural dentition and denture patients. They found that similar judgments were made by the two groups.

In contrast to the results herein reported, Nakfoor (1967) found that light continuous orthodontic forces significantly altered the ability of subjects to discriminate forces applied to the teeth. The magnitude of the orthodontic forces in the present study, as well as in the investigations of Nakfoor (1967) and Soltis (1968) were dependent upon the intrinsic and extrinsic forces used. The forces derived from orthodontic wire are intrinsic forces. The magnitude of these intrinsic forces is dependent upon the configuration, modulus of elasticity, deflection and cross-sectional area of the orthodontic wire used. The extrinsic forces are classified as forces applied to a tooth or a group of teeth. These forces are most commonly developed by orthodontic rubber bands and elastic ligature. The magnitude of the range of forces used in this study were similar to those of both Nakfoor and Soltis.
Nakfoor felt that the reason for the loss of discriminatory ability in orthodontic patients was due to the impingement of the tooth roots against the pressoreceptors of the periodontal ligament. He felt that normal discrimination would return during orthodontic treatment as a result of physiologic adaptation. This was confirmed in Soltis' (1968) work.

In the present study of dimensional proprioceptive acuity, there is input to the higher centers from the temporomandibular joint receptors, the numerous muscle spindles in the muscles of mastication, as well as the pressoreceptors of the periodontal ligament. Sustained orthodontic forces had little effect on the subject's ability to differentiate small differences in rod diameter when these rods were placed between the anterior teeth. Since it has been shown that initial orthodontic forces had a disruptive effect on the proprioceptive function of the periodontal ligament, it is then reasonable to assume that the periodontal receptors play a minor role in this dimensional proprioception. The input from the temporomandibular joint receptors and the input from muscle spindles would then appear to be the more significant factors or elements needed for this dimensional proprioception. The type of subject selected for this study may also be significant. The malocclusion present in these subjects was the type in which the mandible had to "swing" forward in order for the anterior teeth to incise. This produced a greater muscle stretch and joint movement than in most "normal" occlusions, and perhaps resulted in more dependence upon temporomandibular joint and muscle receptors than one might find in a Class I occlusion.
CHAPTER VI
SUMMARY AND CONCLUSIONS

A method of testing oral dimensional proprioceptive discrimination was described. This method consisted of having the subjects evaluate minimal discernible differences between rods of varying thickness placed between opposing incisor teeth. Another objective was to determine if the initial phase of orthodontic treatment altered the ability of patients to make these proprioceptive discriminations.

Fifteen subjects were utilized in this study. All had Angle Class II malocclusions. Six series of identically dimensionally graduated rods were used. Nine rods were included in each series, making a total of 54 rods that could be utilized. The smallest diameter rod used was 1.6mm and the largest rod used was 43.2mm in diameter. The Weber Ratios obtained were generally similar throughout the different series of rods tested, with the middle range showing slightly lower Weber Ratios.

There was little difference between the results of the first and second testings. It has been shown that initial orthodontic forces disrupt input to the central nervous system from the pressoreceptors of the periodontal ligament. This investigation gives support to the idea or opinion that size discrimination is more dependent on the proprioceptive endings in the temporomandibular joint and the muscles of mastication than the receptors in the periodontal ligament.
# APPENDIX

Weber Ratios Obtained In Each Subject In First And Second Testings In Each Series Of Rods

<table>
<thead>
<tr>
<th>Series</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
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* First Testing
** Second Testing
BIBLIOGRAPHY


The thesis submitted by Dr. Donald Richard Toso 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.

Date: 5/23/69

Signature of Advisor: [Signature]