An Evaluation of Maximum Occlusal Force During the Initial Stages of Orthodontic Treatment

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AN EVALUATION
OF MAXIMUM OCCLUSAL FORCE DURING
THE INITIAL STAGES OF ORTHODONTIC TREATMENT

BY
THOMAS MALCOLM STEWART

A THESIS SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
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Warmest appreciation is expressed to my parents, without whose innumerable personal sacrifices I might not have attained an undergraduate education, and to Sharon and Susan whose, love, patience, and understanding have made it possible to realize the goals of a graduate education.
Thomas M. Stewart was born in Lebanon, Indiana, on February 19, 1939.

After graduation from Lebanon High School in 1957, he completed one year of pre-dental curriculum at Wabash College, Crawfordsville, Indiana, and two years of pre-dental studies at the Ohio State University, Columbus, Ohio. He enrolled in the Ohio State University College of Dentistry in 1960 and received the degree of Doctor of Dental Surgery in June, 1964.

Following two years service with the U.S. Navy Dental Corps, he entered general practice in Camarillo, California, for four years. In addition, he served as Assistant Clinical Professor in Operative Dentistry at the Center for the Health Sciences, University of California at Los Angeles, Los Angeles, California, from 1967 to 1970.

In 1970 he left general practice to pursue a two year residency in Orthodontics and full time graduate studies in Oral Biology at the School of Dentistry, Loyola (Chicago) University, Maywood, Illinois.
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INTRODUCTION AND STATEMENT OF THE PROBLEM

Since the turn of the century, a substantial number of studies have been performed concerning the ability of humans to exert maximum occlusive force (bite force). These investigations have been conducted on normal healthy, restored, and edentulous artificial dentitions. Recently, a few studies have related the function of the mandibular closing muscles to facial skeletal type.

Any orthodontic patient will attest to the fact that their ability to masticate is altered by their orthodontic treatment. No experiments have been conducted to measure the change that is clinically obvious in the patient's ability to exert masticatory force on his dentition, as previous studies were performed prior to any orthodontic treatment that may have been required.

The purpose of the present study is to evaluate the ability of orthodontic patients to exert maximum biting pressure and to detect any possible alterations in bite force that may occur after the initiation of orthodontic treatment.
REVIEW OF THE LITERATURE

1. Measurement of the force generated by the closing muscles of mastication.

Measurement of biting force was first reported in the literature of Borielli of Italy in 1681, but it was not until the late nineteenth century that any concerted effort was made to accurately determine the amount of force available to the human masticatory apparatus.

The instrument called a gnathodynometer was first constructed by Patrick and Dennis (1893), and was subsequently improved by G. V. Black. This particular instrument consisted of a small bite plate, a compressible spring with pointer, and a graduated scale.

G. V. Black (1895) utilized the gnathodynometer, as described above, to analyze the biting force of 50 patients, most of whom were adults over 20 years of age. He found a wide range of force values which were dependent on the age and physical development of the individuals studied. Black was one of the first to recognize that different values exist for incisors, premolars, and molars.

Klaffenbach (1936) stated that "The poundage that the teeth exert on any object or food is individual and
consequently cannot be standardized." He further reported, as did Black, that the force exerted by the teeth as recorded by a gnathodynamometer is a reflection of the power of resistance of the periodontal membrane, and is not indicative of the entire power of the muscles of mastication. Klaffenbach's study determined bite force in the molar region to be an average of 125 pounds, while Black's values averaged 171 pounds.

Brawley and Sedwick (1937) gave a comprehensive review of gnathodynametry prior to 1937. All the instruments to that date consisted of springs in various relationships to a lever system. Their instrument, similarly designed, was quite bulky and was only suitable for determining force values for entire dental arches.

Klatsky (1942) measured adult bite forces, and made a distinction between males and females plus right and left sides of the dental arches. His findings on males of an average age of 27.19 years with an average of 28.91 teeth were 119.58 pounds on the right side and 112.86 on the left. Females in the same study at 24.91 years of age with an average of 28.81 teeth provided values of 85.75 pounds on the right side and 83.91 pounds on the left. The author
concluded that unilateral chewers were capable of creating greater force on the side which performed the greater amount of mastication.

Howell and Manly (1948) designed a relatively accurate electronic gnathodynamometer with a narrow bite element suitable for use in all areas of the mouth. They utilized four male subjects ranging in age from 20 to 30 years. Average forces on teeth generated by a closing force on incisors, canines, premolars, and molars ranged from 24 to 198 pounds.

Measurement of stress during mastication by use of a strain gauge incorporated into a dental restoration in a molar tooth was accomplished by Anderson (1956). Mean maximum loads on three different types of food were calculated. Measurements reflected only the amount of force required to effectively masticate the given food sample, which, however, did not indicate the maximum bite force available.

Nyquist and Owall (1968) attempted to measure bite force by use of piezo-electric transducers mounted in restorations in molar teeth. While they found what they considered to be a fairly accurate measurement of vertical masticatory
Pressure, they could not determine the total force of mastication due to the oblique loading of force caused by the functional laterotrusion of the mandible.

2. Physiological phenomena associated with occlusive force.

Pfaffman (1939) demonstrated that pressure receptors are located in the periodontal membrane, and that great individual differences existed in response to pressure. He further stated that touch or pressures applied to the intact tooth gave rise to an intense discharge of impulses in the dental nerves. Force applied in one general direction stimulated the single nerve ending, and pressure rather than tension provided the adequate stimulus for the single ending.

Boos (1959) designed a spring-loaded instrument for measuring bite force on prosthetic patients at varying degrees of vertical dimension. Although his study was directed toward artificial dentition, an important physiological concept was brought forward. He asserted that the ability of a patient to exert maximum occlusal force varies with change in the vertical dimension. Boos concluded that for a muscle to function most efficiently, a normal physiological length from origin to insertion for that muscle must be attained.
Storey (1963) in a study on changing vertical dimension stated that there is a position of maximal closing force at an optimal vertical dimension for every individual. This position was characteristic of the muscle tissue itself. He found that submaximal closing forces remained the same and in some cases even increased as the optimal vertical dimension was exceeded. These forces were measured at the increased vertical dimensions of 1, 2, 5, 10, 12.5, and 17.5 millimeters. Electromyographical monitoring of the closing muscles of mastication was also performed, and a decrease in amplitude was observed as the vertical dimension increased even though the closing force remained the same. These concepts were related to the natural dentition by Atkinson and Shepard (1967). They concluded that during normal mastication, forces increase rapidly as the teeth approached maximal contact position in a healthy dentition.

Jerge (1963) proposed that two functional types of sensory nerve endings existed in the periodontal membrane. He classified these as dental pressoreceptors Type I and Type II. Type I responded to pressures of 1 to 3 grams on one tooth while Type II involved pressures of 2 to 6 grams
Kawamura (1967) showed that a stimulation of the periodontal pressoreceptors inhibits the motorneurons of the jaw closing muscles in the trigeminal motor nucleus. Griffin and Munro (1969) elaborated on inhibition of the elevators of the mandible as induced by tooth contact. The results of their research were in support of the earlier theories of Black (1895) and Klaffenbach (1936) that the amount of force applied to the teeth in mastication is regulated primarily by the periodontal membrane. This effect led them to assume that a protective reflex mechanism exists. They further observed that afferent impulses travel from periodontal receptors via the superior and inferior alveolar branches of the maxillary and mandibular divisions of the trigeminal nerve to the mesencephalic nucleus. A relay center in the nucleus supratrigeminalis was found to contain internuncial neurons which in turn could inhibit the motorneurons of the mandibular elevators.

3. Occlusal force and Orthodontics.

No studies were found that correlated a reduction in bite force to the initial stages of orthodontic treatment. However, a number of studies have been performed on
orthodontic patients prior to active treatment.

White (1967) correlated maximum biting force to the mandibular plane angle from a tracing of a lateral centric headfilm. He concluded that patients with higher values for this angle generally exerted less force occlusally than those with lower values.

Sassouni (1969) in an article on classification of skeletal types utilized a gnathodynamometer to measure the difference in bite force between patients of differing skeletal types. His results supported White's theory that persons with an open-bite facial type are able to generate substantially less occlusal force than an individual with a deep-bite skeletal type. He found that persons with open-bite facial types had a biting force of 50 to 80 pounds at the molar level, whereas persons with a deep-bite skeletal type could exert from 150 to 200 pounds of force.

Bonaguro, Dusza, and Bowman (1969) measured the ability of patients to discriminate differences in intensity of pressure applied to anterior teeth and first premolars. Their source of applied force was a torque wrench with which they measured a specific amount of pressure ranging from 100 grams to 2500 grams. They did not measure any form of
bite force, but were mainly concerned with the patients' ability to discriminate between forces of different intensity. Subsequently, Soltis, et al (1970) performed a similar series of tests, but concerned themselves only with the central incisor. This study concluded that proprioceptive discriminations dependent on the periodontal ligament are altered significantly with the application of light orthodontic force, and that 84% of the patients involved experienced a lowered pain threshold to pressure in a range of 500 to 1,000 grams of force. They also found that while this reduced pain threshold was evident immediately after insertion of orthodontic appliances (four days), the values at the end of one year of treatment were grossly the same as pretreatment values.

Yildirim and De Vincenzo (1971) measured the closing force of patients of diverse skeletal types, i.e. closed bite versus open bite groups. The gnathodynamometer utilized in their study is almost identical to the instrument used in this project. The instrument was compact, reasonably accurate (+ 1% error), and readily lent itself to measuring bite force at a constant vertical dimension in all areas of the mouth providing that the patient had no
anatomical abnormalities which prevented a normal range of opening. Their research demonstrated a considerable variation among individuals studied, with the mean closing force of the closed bite group significantly greater \( (p < .05) \) than the corresponding value for the open bite group. They concluded that a significant relationship exists between muscle force and skeletal type.

4. **Initial orthodontic tooth movement.**

Reitan (1951) in a study on the initial tissue reaction incident to orthodontic tooth movement reported that significant changes in the periodontium occurred with a force of 70 grams after a period of 48 hours. Dilation of capillaries on both the pressure and tension sides of the tooth did not occur, while compression of the capillaries was found on the pressure side only. He concluded that the compression led to a temporary ischemia of the periodontal ligament which subsequently led to increased capillary permeability and hyperemia with edema as the pressure was relieved by resorption of bone. There was no evidence that an inflammatory reaction was part of the histological picture created by initial tooth movement. The initial tissue reaction consisted of a deposition and widening of
osteoid tissue at the tension side, and bone resorption, rapidly increasing with time, at the pressure side. Concomitantly, there was an increase in the number of cells at the tension side and a decrease in cellular elements at the pressure side. A hyalinization of fibrous tissue was found along with the decreased cell number on the pressure side.

Graber (1967) further described the pressure side of the periodontal membrane as a cell-free area with occluded blood vessels. This area was small and was found to be relieved within a period of two weeks when resorption of bone was completed. On the tension side the fibers were usually not torn and there was no hemorrhage with a conventional continuous force in the range of 50 to 300 grams. However, the fibers of the periodontal membrane were stretched sufficiently to lead to the formation of osteoblasts.

Glickman (1958) contended that destruction of principal fibers and resultant discontinuity between cementum and bone diminished tooth support so that tooth mobility increased. He felt that an increased occlusive force is not an excessive force if the periodontium can accommodate it.
An ordinary physiologic force may become an excessive force if the adaptive capacity of the periodontium is impaired, thus inducing hypermobility of the involved tooth or teeth.

Thurow (1966) reported that pain during orthodontic treatment is created by increasing force of trauma to the periodontal membrane, or by increasing the area of the membrane to which force is applied. To derotate a tooth, the entire periodontal ligament is involved. There are few areas where pressure anesthesia can reduce pain response, thus adding to the discomfort of the patient. He further reported that tooth mobility is a normal physiologic response to stress in order to soften the blow of dental forces, and also to slow and to soothe the transfer of force to the fibers of the periodontal membrane. He added that an orthodontic force delivered to the crown of a tooth causes an increase in thickness of the periodontal space which results in an increase in the "looseness" or mobility of teeth.

Tweed (1966) described leveling as that stage of orthodontic treatment which entails the correction of all rotations and the establishment of good arch form. In this technique, all erupted teeth are banded, and the brackets
are of .022 x .028 inch in dimension. A series of wires is generally used which range in size from .016 round initially, to .018 round, then to .020 round to complete the procedure. This part of treatment can often be lengthy as it includes the breakdown of existing unfavorable anchorage in one or both arches prior to the beginning of the second step in treatment. (A mesially inclined mandibular molar is considered unfavorable anchorage as any Class II intermaxillary elastic traction would easily displace the molar in a mesial direction. This would permit the entire mandibular denture to be displaced forward - a result that would be most undesirable.) This rearranging of the axial inclination of one or of a group of teeth to reduce their resistance to mesial movement is one of the primary objectives that must be accomplished during the initial phase of treatment with the Tweed technique.
METHODS AND MATERIALS

Thirteen caucasian orthodontic patients ranging in age from 12 to 15 years were randomly selected prior to actual placement of orthodontic appliances. No separate control sample of individuals was selected, as all the patients served as their own controls. No distinction was made on the basis of sex or facial type of the sample. All patients were scheduled for extraction of four first premolar teeth.

The gnathodynamometer (an instrument used intraorally to measure biting force) obtained was identical to that used by Yildirim and De Vincenzo (1971) in their study on bite force generated by untreated orthodontic patients. It consisted of a steel baseplate and a steel lever arm. A steel housing between the baseplate and lever arm contained a gauge assembly which registered the amount of deflection of the lever arm when it was subjected to a compressive force.

Calibration in kilograms was performed with certified laboratory weights prior to the pilot study, before the actual experiment, and finally after all data had been collected. Each division on the gauge was found to register...
3.41 kilograms of compressive force, and this value remained constant throughout the experiment.

A pilot study was conducted on five adult males to test the reliability of the measurement technique and the consistency of the instrument. Results of this study in which two measurements were performed at an interval of 8 days showed no significant change in the values recorded.

The initial series of measurements was performed prior to placement of separators or bands. A maximum effort was made to explain the measurement procedure to the patient in order to minimize the amount of the anxiety reaction that a particular patient might exhibit. Each patient was instructed to practice some test bites to become acquainted with conditions of the actual test.

After allowing the patient a sufficient amount of time to become as relaxed as possible, a disposable paper pad 2 millimeters thick was placed on the bite table of the gnathodynamometer to prevent injury to the cusps of the teeth, and the bite table was placed in position in the region selected for measurement. Thickness of the instrument bite table plus the paper pads was 12 millimeters. The patient was instructed to close until teeth in both arches were
lightly touching the bite table in order to assure proper positioning of the instrument. When it was determined that the bite table was in proper position (Fig. 2), the patient was instructed to exert as much bite force as possible on the table. Extreme care was taken to position the instrument in the same antero-posterior region, and three separate measurements were performed for each area in order to assure reproducability of that particular measurement. These values were then averaged to determine a single value for the incisor region, the right and left canine, first and second premolar, and first and second molar regions respectfully. The patient was instructed to indicate any pain encountered at the cessation of each bite registration.

After the measurements prior to the onset of the orthodontic treatment, the patients were scheduled for extractions, separation, and banding. Eleven patients were banded for the Tweed technique with .022 x .028 inch brackets plus eyelets for correction of rotations. Two patients were banded for the Begg technique with conventional Begg brackets. Multiple loop .016 round archwires were placed in all patients for four to six weeks, and were later replaced by .016 inch round continuous
archwires for an additional four weeks. In a few of the edgewise cases, an .018 inch round archwire was placed in lieu of the .016 inch continuous wire, since leveling had sufficiently progressed to permit placement of the larger archwire.

When it was determined that the leveling procedure had been clinically completed and that arch form was acceptable, the second series of measurements was performed. These values were taken at least three to four weeks subsequent to any archwire change. The experimental procedure was identical to that of the first half of the study with the exception that it was not deemed necessary to allow the patient to handle the instrument.

When progress in treatment allowed, a third series of values was determined for 10 of the subjects. These patients were measured to evaluate the effect of an additional treatment interval involving a partial retraction of maxillary and mandibular canines.

Statistical method.

The data collected in the clinical phase of the experiment was statistically analyzed in three phases. First, the means and standard deviations of the gnathodynamometer measurements
in kilograms were calculated. Then paired-\( t \) tests were performed for the difference between the first and second, first and third, and second and third testing periods.

From the \( t \) values obtained, a table of probabilities was derived to indicate the level of significance of the statistical analysis.
Figure 1. The gnathodynamometer. Each division on the circular scale was equal to 3.41 kilograms.
Figure 2. Registration of bite force. In the canine region, the bite pads were centered over both the maxillary and mandibular canines.
RESULTS OF EXPERIMENTATION

The mean values for the three measurement periods are shown in Table I. A definite reduction in occlusive force was observed after the onset of orthodontic treatment when compared to the pretreatment measurements. The reduction was particularly noticeable in the tests on anterior teeth between the initial and the second measurement periods. The third series of measurements seemed to indicate a partial recovery of biting force, especially in the premolar and the molar regions. A further reduction of occlusive force for both the right and the left canine areas was observed.

The mean difference values in Table II which compare the three testing periods reinforce these original findings. The greatest decrease in occlusive force between the first and second measurement periods occurred in the left canine and left premolar regions, followed closely by the right canines, right molars, and the incisors. The smallest difference was observed in the right premolar area.

The greatest reduction of biting force between periods one and three occurred in the canine and the incisor regions. The posterior regions (premolars and molars) showed a
proportionate decrease in reduction of bite force when compared to period one versus period two, indicating a partial recovery of bite force posteriorly. Only slight recovery was experienced in the incisor region. Both canine regions exhibited a greater difference (reduction) in this comparison than in test one versus test two for those teeth.

Only a slight difference was found to occur during the interval between tests two and three. The canine regions exhibited a further decrease in biting force from the value obtained in measurement two, while all other areas tended toward recovery of occlusive force to some degree.

Table III reflects the level of significance of the mean differences as determined by the paired-t statistic. All the p values for the initial versus the second series of measurements are statistically significant (p< 0.01). Only in the right premolar region, as was true throughout the experiment, was the probability value not as low (p< 0.02). In support of the mean difference statistics, the most significant changes were observed between measurement periods one versus two and one versus three respect-fully.
The statistical analyses of the data indicate a marked decrease in occlusive force in test two with a slight recovery in test three for the incisors, a marked decrease in occlusive force in test two and a further decrease in test three for the canine regions, and a decrease in test two with a substantial recovery of occlusive force in test three for the premolar and molar regions.
TABLE I


<table>
<thead>
<tr>
<th></th>
<th>Period #1 (n=13)</th>
<th>Period #2 (n=13)</th>
<th>Period #3 (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCISORS</td>
<td>11.986 (+2.625)</td>
<td>4.723 (+3.621)</td>
<td>5.251 (+3.536)</td>
</tr>
<tr>
<td>R. CANINES</td>
<td>13.704 (+6.148)</td>
<td>5.797 (+3.580)</td>
<td>5.200 (+3.594)</td>
</tr>
<tr>
<td>L. CANINES</td>
<td>14.506 (+7.529)</td>
<td>6.032 (+3.621)</td>
<td>4.739 (+2.983)</td>
</tr>
<tr>
<td>R. PREMOLARS</td>
<td>22.035 (+6.687)</td>
<td>16.238 (+3.495)</td>
<td>19.300 (+4.576)</td>
</tr>
<tr>
<td>L. PREMOLARS</td>
<td>25.391 (+8.143)</td>
<td>16.999 (+7.580)</td>
<td>20.971 (+5.087)</td>
</tr>
<tr>
<td>L. MOLARS</td>
<td>33.943 (+6.891)</td>
<td>26.362 (+7.484)</td>
<td>29.394 (+6.874)</td>
</tr>
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</table>
### TABLE II

Means and Standard Deviations of Mean Differences in Occlusive Forces in Kilograms

<table>
<thead>
<tr>
<th></th>
<th>Test 1 vs. Test 2 (n=13)</th>
<th>Test 1 vs. Test 3 (n=10)</th>
<th>Test 2 vs. Test 3 (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCISORS</td>
<td>-7.267 (+3.182)</td>
<td>-7.263 (+2.158)</td>
<td>+0.222 (+0.457)</td>
</tr>
<tr>
<td>R. CANINES</td>
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<td>-8.883 (+5.531)</td>
<td>-0.529 (+3.645)</td>
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<tr>
<td>L. CANINES</td>
<td>-8.474 (+6.192)</td>
<td>-11.287 (+5.793)</td>
<td>-1.637 (+3.167)</td>
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<tr>
<td>R. PREMOLARS</td>
<td>-5.797 (+6.915)</td>
<td>-3.717 (+8.115)</td>
<td>+2.626 (+4.436)</td>
</tr>
<tr>
<td>L. PREMOLARS</td>
<td>-8.395 (+5.053)</td>
<td>-5.968 (+6.253)</td>
<td>+2.933 (+5.957)</td>
</tr>
<tr>
<td>R. MOLARS</td>
<td>-7.621 (+6.509)</td>
<td>-5.899 (+7.355)</td>
<td>+1.687 (+6.908)</td>
</tr>
<tr>
<td>L. MOLARS</td>
<td>-6.926 (+3.798)</td>
<td>-5.524 (+6.226)</td>
<td>+2.114 (+6.571)</td>
</tr>
</tbody>
</table>
TABLE III

Tests for Level of Significance for the Mean Differences in Bite Force as Determined by the Paired-\(t\) Test.

<table>
<thead>
<tr>
<th></th>
<th>Test 1 vs. Test 2</th>
<th>Test 1 vs. Test 3</th>
<th>Test 2 vs. Test 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=13)</td>
<td>(n=10)</td>
<td>(n=10)</td>
</tr>
<tr>
<td>INCISORS</td>
<td>(p&lt; 0.01)</td>
<td>(p&lt; 0.01)</td>
<td>0.10(&gt; p&gt; 0.50)</td>
</tr>
<tr>
<td>R. CANINES</td>
<td>(p&lt; 0.01)</td>
<td>(p&lt; 0.01)</td>
<td>(p&gt; 0.50)</td>
</tr>
<tr>
<td>L. CANINES</td>
<td>(p&lt; 0.01)</td>
<td>(p&lt; 0.01)</td>
<td>(0.10&gt; p&gt; 0.50)</td>
</tr>
<tr>
<td>R. PREMOLARS</td>
<td>0.02(&gt; p&gt; 0.01)</td>
<td>0.10(&gt; p&gt; 0.05)</td>
<td>0.05(&gt; p&gt; 0.10)</td>
</tr>
<tr>
<td>L. PREMOLARS</td>
<td>(p&lt; 0.01)</td>
<td>0.02(&gt; p&gt; 0.01)</td>
<td>0.10(&gt; p&gt; 0.50)</td>
</tr>
<tr>
<td>R. MOLARS</td>
<td>(p&lt; 0.01)</td>
<td>0.02(&gt; p&gt; 0.01)</td>
<td>0.10(&gt; p&gt; 0.50)</td>
</tr>
<tr>
<td>L. MOLARS</td>
<td>(p&lt; 0.01)</td>
<td>0.02(&gt; p&gt; 0.01)</td>
<td>0.10(&gt; p&gt; 0.50)</td>
</tr>
</tbody>
</table>
DISCUSSION

A common assumption made by clinical orthodontists has been that patients undergoing orthodontic therapy experience a loss of masticatory efficiency, a phenomenon partially due to a reduction in the patient's ability to exert occlusal force. This conclusion has been reached largely by clinical observation and by noting the patient's complaints of inadequate biting power.

The significance of this suggested reduction in masticatory power would logically appear to have an important ramification for the orthodontist in his selection of mechanical approach to treatment. If the orthodontic force system selected to perform a particular tooth movement contained an elongation component, e.g. a certain type of extra-oral appliance, the clinician would have to exercise judgement as to whether or not the force of occlusion would be sufficient to prevent an undesirable extrusion of the involved teeth. Conversely, if the occlusal force of the patient were significantly reduced, perhaps a resultant tooth movement could be achieved which previously would not have been attempted due to the assumed resistance of the
force of occlusion, e.g. distal movement of the maxillary first molar.

As has been previously stated, no definitive studies have been reported relating alteration of occlusal force to the initial stages of orthodontic treatment. The purpose of this research has been to measure the bite force of orthodontic patients prior to the onset of active treatment and during the early stages of tooth movement.

The pre-treatment measurements provided mean values for closing force that were in reasonable agreement with those values determined by Klaffenbach (1936), Klatsky (1942), and Yildirim and De Vincenzo (1971). The results were somewhat in agreement with those of Black (1895), since he determined that occlusal force for his adolescent subjects was in the range of 75 to 100 pounds (34 to 45 kilograms). Yildirim and De Vincenzo found a range of 45 to 48 kilograms, but their patients were of an older age group (15-18 years) than the present study. It would be logical to assume that a closer series of values should exist due to the similarity of instrumentation for the two experiments. No explanation for this difference in closing force in the untreated patient can be offered other than
sample variation and age. However, a possibility exists that the other investigators achieved a higher degree of rapport with their patients, thereby convincing the patients to exert more effort on the gnathodynometer. Apprehension on the part of the patients probably affected results, since this was a study involving the voluntary exertion of bite force by these patients. Also, the patients may have been inhibited by the anxiety of the impending orthodontic therapy.

The higher ranges of magnitude for the posterior teeth was also somewhat less than that reported by Howell and Manly (1948) and Sassouni (1969). The highest value of bite force obtained in this study was 51 kilograms, while the mean of approximately 34 kilograms was far below the range of 68 to 91 kilograms claimed by these other investigators. A possible explanation for this apparent discrepancy may be attributed to the amount of vertical dimension dictated by the gnathodynometer. As was pointed out by Boos (1959) and Storey (1963), a patient's ability to exert closing force on his dentition will decrease to a submaximal level if the established vertical dimension exceeds his normal physiological rest position. Since the
vertical dimension created by the bite table with paper pads in this study measured 12 millimeters in height, it would be reasonable to assume that the amount of opening required by the patients to accommodate the instrument exceeded physiological rest, thus promoting registration of a submaximal occlusive force. However, it was not the purpose of this study to quantitate absolute occlusive force, but rather to measure the alteration of this force subsequent to the onset of orthodontic treatment. Since the vertical dimension of the gnathodynamometer remained constant throughout the experiment and the patient served as his own control, the amount of difference in bite force between measurement periods should have been an accurate indicator of adaptive changes in the patient's masticatory apparatus. In addition, the same investigator made all measurements.

The gnathodynamometer utilized for this study proved to be a reliable instrument. It always returned to baseline after a measurement and generally yielded reproducible results. Three periods of calibration of the instrument yielded identical results. The greatest shortcoming was its bulk which necessitated a wider opening of the mandible of the subjects than was usually desireable. In addition,
placement of the bite table antero-posteriorly was most critical, since deviation from the procedure for instrument placement would have resulted in different force registrations for the same area of the mouth. For example, the bite tables were centered over the embrasure between the mandibular first and second molars for registration of force in the molar region. If the bite tables were positioned further distally (thus altering the vertical dimension), a smaller force value would be observed, thus affecting the reproducability of results for those teeth.

The statistics indicate a significant change in bite force for teeth during the first four to six weeks of treatment ($p<0.01$). Most notably affected were those teeth of relatively smaller root surface area, especially the incisors. A significant change was also reflected in the canine areas when those teeth became the primary focus of mechanical attention during the initial phases of canine retraction.

Although the premolar and molar regions showed a proportionate reduction in occlusive force during the first four to six weeks, these teeth showed a distinct partial recovery of bite force after the second measurement interval.
However, this result was not entirely unexpected since only a relatively minor amount of orthodontic force was directed toward these teeth during this stage of treatment. Based on the marked decrease in the occlusal force of the canines when canine retraction was begun, a logical assumption would be that the later stages of treatment which involve a more pronounced amount of orthodontic change in these posterior teeth would again decrease the ability of the patient to exert occlusal force in these regions.

The least consistent results in this study were those obtained for the right premolar region. Three of the patients involved had maxillary right canines crowded out of the dental arch, thereby producing a more severe malocclusion on the right side than on the left. A greater amount of orthodontic force was probably applied to that area resulting in a decreased occlusal force as compared to the left side. This could be attributed to a greater deflection of the initial archwires in order to obtain bracket engagement.

One other interesting facet of the results was that there appeared to be no difference in bite force due to treatment between the edgewise cases and the Begg cases.
This discovery is not totally unpredictable, since the same size archwire was utilized in all cases, and the early objectives of leveling are the same in both techniques. A further investigation into the later stages of orthodontic treatment of each respective technique is indicated before any firm conclusions concerning alteration of bite force due to technique can be made. A sound evaluation would include registrations taken during the final stages of treatment and into the retention phase, where less apprehension and pain would be encountered on the part of the patient.

Although the present investigation is an isolated project, some of the findings may be related to previous experiments along other guidelines. Yildirim and De Vincenzo claimed, that although their data suggested a relationship between a skeletal type and bite force \( p < 0.05 \), the relationship was not statistically high. They qualified this assertion by stating that higher levels of significance could probably have been attained by increasing the sample size. Their results were not nearly so dramatic as those of Sassouni who described a wide range of difference in bite force between open and closed bite skeletal types, although no statistical analysis was provided in that article.
The findings of the present study are in support of Yildirim and De Vincenzo, as there was a substantial overlapping of results obtained in respect to skeletal type. Of the thirteen patients in the sample group, three were visually determined to be brachycephalic, three were mesiocephalic and seven were dolichocephalic. The mandibular plane angles (GoGnSn) ranged from a low of 24 degrees to a high of 43 degrees with the average for the group being 35 degrees. The two highest recordings of bite force in the molar region occurred on patients having mandibular plane angles of 40 and 42 degrees respectively. The two lowest values were obtained on patients with angles of 32 and 34 degrees. Thus, the present investigation could also best be termed as inconclusive as far as the relationship of bite force to skeletal type is concerned.

Physiological explanations for the reduction of bite force during these initial stages of orthodontic treatment are rather subjective in nature. Increased mobility of teeth was felt to be a prime factor responsible for reducing occlusive forces. Extensive documentation exists that indicates that the increased thickness of the periodontal ligament with concomitant disorganization of the periodontal...
ligament fibers and loss of proprioception results in the increased mobility of teeth. Therefore, if a tooth is excessively mobile, as is the case during orthodontic treatment, then that tooth and its periodontium should not be capable of producing the same amount of force as was exerted in its "non-mobile" state.

Another evident factor during the experiment was the lowering of the pain threshold of some of the patients. Pain to occlusive pressure during orthodontic treatment may be attributed to trauma to the periodontal ligament with ensuing edema being responsible for the heightened sensitivity of nerve endings to that pressure. For this reason, no quantitations were made for at least four weeks subsequent to any archwire change or reactivation of mechanics. This interval of time allowed the edematous change to subside as much as possible in order to reduce the problem of lowered pain threshold to a minimum.

An additional problem which was impossible to quantitate was that of patient anxiety. Subjects who anticipate impending treatment usually anticipate pain, and part of this fear of treatment may have been transferred to the experimental procedure. Since this study was based on the
patient's voluntary cooperation, anxiety was regarded as a most undesirable reaction. However, this type of apprehension was much more evident in the pilot study on adults than on the adolescents in the actual experiment. Two of the adults openly admitted that they felt inhibited and apprehensive about exerting a maximum force on the gnathodynamometer. A slightly lower value in bite force for the second series of measurements substantiated this observation on their part.

No conscious anxiety reaction on the part of the subjects in the actual experiment was elicited. All the patients were questioned on at least two different occasions as to whether or not they felt any adversity toward the experimental procedure. No apparent expressions of apprehension or fear were forthcoming, and many of the subjects tended to look upon the experiment as a competitive exercise. Therefore, even though patient anxiety on a conscious level was not observed, no definite estimation of the possible effect of subconscious anxiety could be made.
SUMMARY AND CONCLUSIONS

Thirteen orthodontic patients were randomly selected for evaluation of occlusive force during the initial stages of orthodontic treatment. The following conclusions were reached following experimentation:

1. A significant reduction in the subjects' ability to exert maximum bite force on incisors, canines, premolars, and molars occurred subsequent to the onset of orthodontic treatment.

2. A partial recovery of bite force was shown on the premolars and molars after an additional interval of time when a third series of measurements was performed.

3. The canines exhibited a further reduction in bite force after canine retraction was begun.

4. Relationship of skeletal facial type to amount of bite force available was not established due to the small size of the sample and overlapping of results.
5. Since the data was collected on a voluntary basis from the subjects, apprehension and anxiety accompanying the orthodontic treatment probably affected the results to some degree. However, since the patients served as their own controls, any subconscious anxiety reactions were considered to be uniform throughout the experiment for any particular patient. Therefore, the differences found in occlusive force between intervals of measurement were considered an accurate reflection of change in the periodontium.


APPENDIX
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<th>PATIENT #</th>
<th>AGE</th>
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### TABLE II. Bite Registrations In Kilograms

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- No Measurements
APPROVAL SHEET

The thesis submitted by Dr. Thomas Malcolm Stewart has been read and approved by three members of the Oral Biology Department, Loyola University School of Dentistry, Chicago, Illinois.

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 17, 1972
DATE

SIGNATURE OF ADVISER