THE EFFECT OF INTERMAXILLARY ELASTIC FORCES ON THE TEMPOROMANDIBULAR ARTICULATION

by

GLENN CHARLES GOODRICH

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Department of Orthodontics

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Chairman

Sanford Nuger B.S. DDS MS

Philip Bormann DDS PhD

Date May 19, 1965

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INTRODUCTION

Since the beginning of Orthodontics as a science, the temporomandibular articulation has been of great interest and concern to the orthodontic practitioner. This articulation is the most complex of the body, exhibiting not only a hinge-like movement but, also, a sliding movement. Two separate articulations exist anatomically, one on either side of the head, working in synergistic action and acting in toto as one articulation because one side is directly connected to the other by the rigid mandible. Any study of this articulation is complicated by its position, inaccessibility to palpation, and obscurity to radiographic techniques.

Early orthodontics, out of necessity, were immediately concerned about this articulation, as it is the mode of connection between the lower teeth and denture to the upper teeth, denture, face, and cranium. Altering or attempting to alter the relationship of these elements is the orthodontist's most perplexing problem.

As techniques in orthodontics progressed (in the early years) two separate schools of thought appeared in the literature. One school, that of the labio-lingual technique, attempts to change the spatial relationship of the mandibular articular condyle to the temporal fossa of the temporal bone. This theory of treatment is extremely popular in European countries today. The opposite school is typified by those who feel that this spatial relationship is more stable, and controlled by the neuro-muscular mechanism.

Many of those who believe in repositioning the mandible utilize the occlusal guide plane as a "mechanical device having an established inclined plane which, when in use, causes a change in the occlusal relation of the maxillary and mandibular teeth and permits their movement to a normal position." (32) These practitioners state that the chief purpose of the occlusal guide plane is "that of aiding in the establishing of a correct anteroposterior relation of the teeth and arches and the occlusal and incisal plane." (32) These men feel that the occlusal guide plane can not be omitted from the technique where anteroposterior correction of teeth and arches must take place. This change takes place, they say, because the lower teeth and mandible shift, en masse, after which a normal physiologic change of surrounding tissue takes place due to the inclined plane and intercusp reaction from the stress brought about when the teeth are occluded.

The adherents to the latter school, feel the temporomandibular articulation is more stable and definitely under control of the neuro-muscular mechanism. They believe that any attempt to forceably alter the spatial relationship of these parts will not produce a stable result, and will only invite temporomandibular joint pathology. Ricketts, (39) in a study of pathologically involved and painful temporomandibular joints stated, "Two such cases encountered were treated orthodontic cases in which a guide had been employed to position the mandible forward. Attempts to heedlessly jump the bite are not consistent, therefore, with an appreciation of the health of the structures especially if no condyle growth remains to aid in the necessary adjustments of the muscles, teeth, and mandible."

It has been quite difficult, in the past, to show concrete evidence on either side of the argument. In recent years, however, numerous articles have been written on this subject, but a review of the literature reveals only a few articles in which controlled studies have been conducted. The greatest impediments to any valid study supporting either argument are the lack of any accurate means of measurement, the fact that this articulation is so complex, and the fact that the anatomic location makes any study difficult. Recent developments of improved roentgenographic techniques, however, enable us to observe the spatial relationship of the bony elements of the temporomandibular articulation and to accurately reproduce serial roentgenographs.

Ricketts has been one of our most active researchers in this field. He very aptly pointed out the importance of this problem to the orthodontist when he stated, "The responsibilities of the orthodontist lie in the establishment of correct function and the creation of a permanent result. In this regard, a consideration of the health of the temporomandibular joint is an absolute necessity. This is due to the fact that joint pathology, in a majority of cases, is directly or indicrectly the result of malocclusion. Therefore, the orthodontist is in a position to diagnose conditions in the child that may contribute to joint disease in the adult. It is up to you as orthodontists to prevent temporomandibular joint disease. Proper service can be rendered by harmonizing the denture with joint structures and muscles, so have respect for the joint. It can be more important than you think." (39)

All orthodontists, who employ intermaxillary elastics in their treatment, have occasionally observed after a very short period of time a dramatic change of a case from Class II to Class I, or Class I to Class III while treating with Class II elastics. Although, after removal of this elastic pull, the occlusion generally tends to revert to its original position, these cases would certainly appear to have undergone temporary alteration of the spatial relationship of the mandibular condyle to the articular fossa of the temporal bone. Thus, the questions remain: how frequently does the occlusion revert to its normal relationship, how soon, and why? Further, if we can alter this spatial relationship, and if the mandibular condyle is a primary growth site, can we, in so treating alter growth if Reisner is correct in stating that the temporomandibular joint is not completely developed until 25 years of age?

This paper can not begin to answer all these questions. It seems to the author that the logical approach to the problems posed by the above questions is to first determine the stability of the temporomandibular articulation. With recent developments in roentgenographic technique, such as the Updegrave T.M.J. board as modified by Baxt, one can reposition the patient and study changes with serial roentgenographs. Thus, one may hope to derive information from the application of intermaxillary elastic forces to the temporomandibular articulation, and attempt to reveal that the neuromuscular system controls the spatial relationship of the mandible, and that orthodontic appliances do not alter said relationships.

PURPOSE

The purpose of this study is:

1) To determine what effect intermaxillary elastic force, routinely used in orthodontic treatment, has on the spatial relationship of the articular condyle of the mandible in the glenoid fossa of the temporal bone.

2) To determine, if a spatial change does occur, whether this change is temporary or permanent and, if temporary, the time necessary for the condyle to return to its original position.

REVIEW OF THE LITERATURE

In reviewing the literature for this study, it is first necessary to have a thorough understanding of the history of roentgenology leading up to the various techniques available for temporomandibular articulation study.

Since its discovery in 1895, hundreds of uses and techniques of roentgenography have been developed. Most studies of the temporomandibular articulation before 1929, however, were based on gross anatomy. In 1929 Parma (30) attempted some short distance roentgenology.

Broadbent (9), in 1930, developed the Broadbent-Bolton cephalometer and a cephalometric x-ray technique which was a major step toward sound diagnosis and treatment. This seemed to reemphasize the value of roentgenography to the orthodontist. While this technique could not be used to study the temporomandibular articulation because the ear rods of the cephalometer masked this area, it served to illustrate the value of being able to reposition the patient for serial study.

In 1932, Humphreys (21) used an angulation technique which had no special directional device, but which directed the x-ray beam about ten degrees downward and ten degrees forward toward the opposite joint through the apex of an imaginary triangle.

An angulation technique was developed by Sproull (48) in which he used a 23° sinus board. The x-ray beam was directed perpendicular to the floor, three inches above the upper most part of the auricle of the ear.

In the middle thirties, many lateral oblique roentgen techniques were developed. The fact that so many techniques were developed made it quite obvious that investigators encountered considerable difficulty in radiographing this area. Gillis (15) cut the end of the x-ray cone so it could be placed against the head with the central rays directed at an angle of "about 15° downward and ... directed about 17° posteriorly" when the patient's head was tilted against the film cassette. Reisner (43) used a 15° angle board. The mid-sagittal plane of the head was parallel with the board and the central ray was directed two inches above and one-half inch in front of the external auditory meatus. Lindblom (27) placed the patient in an upright position so that the head would be in an unstrained position as previously advocated by Schwarz (47). The central ray angle was fixed at 15° downward from above onto the horizontal plane and 15° toward the frontal plane at a point first determined by a beam director indicator in 1933, and later in 1938, with a transferring bow.

Schier (45), in the early forties, made an extensive study on 200 human skulls, then presented a "new projection" technique in which he directed the central ray perpendicular to a plane through the zygoma, gonion, and union of the external oblique line and lower border of the mandible. This plane, which he called the "planar determinant", was located on the side being radiographed. The patient was seated upright and the film cassette was positioned contacting these three points. Higley (17, 18, 19) rotated the patient's head 20° on the vertical axis and tipped it four degrees to the horizontal axis. He used a cephalostat to position the patient. Higley based his angulation on his study of 250 skulls plus the 2000 skulls studied by Maves (28) at Western Reserve University.

In 1953, Craddock (11), having measured 26 mandibles and examining 100 patients, showed a standard 15° angulation would coincide with the condylar measurement 70% of the time, and give a fair angle 20% of the time. He utilized the upright position and Schier's planar determinant. Maves (28) measured 2000 skulls and attempted a technique with the lateral cephalometric head film. His findings are summarized as follows: "Hundreds of tracings of skulls have proved that the long axis (of the mandibular condyle) bisects the median sagittal plane at various angles and therefore no average angle can be accepted for accuracy." He did not describe his technique. Amer (1) and others measured human skulls attempting to determine the angulation of the mandibular condyle, but revealed variability from one skull to another and even between the right and left sides of the same skull.

All of these techniques used various angulations of the central ray through the articulation. Therefore, depending on the angle, some distortion occurred in the roentgenogram.

In 1936, the body section roentgenographic technique (laminagraphy) was developed, and application was made to the temporomandibular articulation by Kieffer (22). With this method, the x-ray source and the film cassette rotate in opposite directions around a common center while the exposures are being taken. At a calculated point between the two there is a center of no movement. Only structures in this plane are registered clearly on the roentgenogram; all others are blurred. Thus, a straight bicondylar horizontal exposure can be made and the petrous portion of the temporal bone, as well as other structures, will not completely mask the temporomandibular articulation.

In 1943, Kurz (24) recognized the need for an orientation device with this technique, and designed and constructed a head holding apparatus for successive laminagraphic exposures. His laminagraphic equipment necessitated positioning the patient's head on its side with the zygoma and superior external border of the bony orbit on the table.

It remained for Brader (5), however, to prove the value of laminagraphy for practical scientific investigation. In 1949, he added leaded scales which permitted correction of dimensions to within .5 of a millimeter.

In 1950 and 1952, Ricketts (34,35) described his roentgenographic technique. The patient's head was positioned on its side and an average "cut" of 3.5 centimeters was used. This depth projected the head of the condyle, the ramus, the outer rim of the orbit, the zygomatic ridge, the ear canal, glenoid fossa, petrotympanic fissure, post glenoid process, articular eminence, and an area just lateral to the buccal teeth. Ricketts showed in his study of 100 normal patients that: (1) there is no correlation between the size of the condyle and the size of the fossa; (2) the mean anterior joint gap is 1.5 millimeters; (3) the mean superior joint gap is 2.5 millimeters.

Hjortsjo (20), in 1954, demonstrated an upright body section technique which eliminated the somewhat controversial horizontal head position.

Several specialized techniques were also developed. One of the most classical was that of Norgaard (29), in 1947. Using the principle of arthrography, he injected radiopaque media into the joint cavities and radiographed the area; a quite distinct outline of the glenoid fossa and articular condyle could be observed.

In 1952, Lindblom (26) described an interesting stereoscopic method for three-dimensional study. Then, in 1962, Ricketts (41) developed and proposed the most specialized technique of all - he combined cephalometrics and laminagraphy to develop the Dome Sectograph.

Most of these more specialized techniques involved more or less complex equipment and cost became a limiting factor. The majority of investigators continued to make improvements in the lateral oblique technique. More and more stress was being placed on being able to reposition the subjects and reproducing roentgenograms accurately for serial study.

In 1950, Lawther (25) modified the head holding apparatus on the Broadbent-Bolton cephalometer so that the porionic axis was at an angle of 10° downward and $12\frac{1}{2}^{\circ}$ forward in relation to the central ray. The head was positioned via ear rods and a nasion rest, and accurate repositioning was assured. The longer target-film distance of the cephalometer, minimized enlargement and distortion of the image. In his study on 32 patients Lawther showed the average superior joint gap to be 2.61 millimeters in centric occlusion.

Updegrave (52) attempted to stimulate roentgenographic investigation by seeking a simplified method which would give consistently satisfactory results with regular dental office equipment and average dental roentgenographic skill. In 1950, he combined the 15° angle board with a post-auricular angulation technique. He added a lead diaphragm and aluminum filter to the x-ray head to best utilize the more penetrating central parallel rays and to eliminate the weaker non-parallel rays as well as secondary radiation. Because of this, the roentgenograms demonstrated better quality and showed less fogging. Updegrave also removed the plastic cone from the x-ray head. By doing this, he could get the radiation source closer to the head, making superimposition of intervening structures less apparent on the opposite temporomandibular articulation to be studied.

In 1951, Updegrave (53) modified the board by adding two vertical aligning arms and an adjustable protractor arrangement to record head angulation and nose height. With this improvement, he was able to reposition the patient in subsequent exposures for serial studies. The patient was positioned on the board according to his or her anatomy, as

Updegrave followed the thinking of Schier (45), who stated, after his study of two hundred human skulls, "if a flat plane is laid against the skull contacting the high point of the zygoma, the gonion, and the junction of the external oblique line and the lower border of the mandible, a line at right angles to this plane would run parallel to the transverse direction of the condyle head, or in the extreme, to the descending inclination of the superior surface."

Donovan (12) realized the need for repositioning apparatus when he stated, "For serial studies we must provide mechanics for repeated accurate repositioning of an individual so that accurately comparable roentgenograms can be obtained." In 1953, he designed an upright head holding apparatus which he attached to the back of a Broadbent-Bolton cephalometer. The radiation source and cassette are aligned in much the same manner as in the Lindblom technique - the central beam making a horizontal angle of 15^{o} and a vertical angle of 19^{o} with the hinge axis of the condyles. This method was designed to make positioning, film, and radiation source constant for accurate repositioning. Donovan concluded that a functional analysis is more valuable than a measurement of the various joint gaps in centric occlusion.

Ruskin (44) tested Donovan's method on ten dry skulls and showed that it permitted accurate serial roentgenographic reproduction. He found: (1) the junction of the lateral and middle thirds of the fossa formed the lower border of the fossa outline on the radiograph; (2) the Donovan orienting device permitted accurate duplication of temporomandibular joint radiographs; (3) it was not possible to measure the actual distances between points on condyle and fossa from only the radiograph; (4) the mediolateral distances between corresponding points on the condyle and fossa compared favorably with the thickness of the sections obtained by use of laminagraphy.

In 1953, Craddock (11), studying 60 joints of 30 normal adults, found the approximate dimensions of the interarticular space with the teeth in occlusion averaged 2.0 millimeters in the anterior joint gap, 3.0 millimeters in the superior joint gap, and 2.5 millimeters in the posterior joint gap.

This same year, 1953, Updegrave (54,55) wrote that the lateral oblique technique of temporomandibular joint radiography was of value for the following purposes: (1) demonstrating the condyle-fossa relationship in all excursions of the mandible, (2) outlining the contours of the condyle, fossa, and eminence which should be closely examined for erosion or calcific deposits, (3) checking the positioning of the condyle in the fossa during the alteration of the maxillomandibular relationship, (4) disclosing developmental defects, subluxations, luxations, ankylosis, fractures or other traumatic injuries.

In 1957, Updegrave (56), continuing his work on the temporomandibular joint, reemphasized the fact that no correlation of joint morphology and condyle function could be demonstrated, but that "it appears that muscular function, dictated largely by jaw and tooth relations, is the dominant factor, the joint being secondary."

Chays and Finkelstein (10), in a fairly extensive study in the Temporomandibular Joint Clinic at Columbia University, found the Updegrave technique to be one of the most useful. They modified the technique, however, as the horizontal head position made it difficult to position some elderly and arthritic patients. They used an upright head position and placed the ear plug on a sheet of plastic so that it was possible to see directly whether the ear was positioned correctly.

Zech (60), in 1959, compared the original Updegrave technique with a modification of the Law projection technique and the McQueen-Dell technique, as described by Ennis. He found the Updegrave technique most accurately demonstrated the correct relationship of the articular condyle, fossa and eminentia with good detail. He said, "This is a gratifying technique to use, for the results are uniformly good."

Baxt (2), at Western Reserve University in 1963, modified the Updegrave technique by placing two pointers on a ring which replaced the cone of the x-ray head and by adding an adjustable pointer which more accurately recorded nose height. He radiographed a series of ten dry skulls and showed that it was possible to make accurate measurements of the anterior, posterior, and superior joint gaps by measuring directly from the roentgenograms. The mean anterior joint gap was 1.6 millimeters; the posterior was 2.3 millimeters; and the superior was 3.1 millimeters. Baxt showed that it was possible to make accurate measurements of the joint gaps by measuring directly on the radiographs. His modified Updegrave technique compared favorably with the regular Updegrave technique, demonstrating more accuracy in portrayal (roentgenographically) of the anterior joint gap.

In 1964, Benson (3), also at Western Reserve University, made a study on human subjects, of the accuracy of repositioning with the Updegrave technique as compared to the same technique with Baxt's modifications. He used nine male students, with sufficient teeth to insure a stable centric occlusion. At three separate sittings, within a one month time period, he positioned and radiographed the subjects with each technique. Then he measured the joint gaps directly on the roentgenograms and compared them. Benson showed that the patients could be accurately repositioned and stated, "An interpretation of the evidence presented indicated accuracy within two-tenths of a millimeter in all positions, and accuracy within one-tenth of a millimeter in the modified Updegrave technique."

A review of the literature pertaining to changes in the temporomandibular articulation as a result of any force is quite brief. Very early in orthodontic literature, two schools of thought appeared concerning the alteration of the spatial relationship of the mandibular condyle in the articular fossa. Although much was written, most of the articles were based on clinical observations and very little was based on sound scientific research.

The theory supporting repositioning of the mandible is quite popular in Europe today. European orthodontists use primarily removable appliances; those in agreement in the United States use primarily fixed appliances. Korkhouse (23) writes, "German orthodontists took to using these removable appliances in large numbers after Hitler forbade the further use of alloys of precious metals for orthodontic purposes about 1935 ... In contrast to the fixed appliance, which is attached to the teeth and effects movement of the teeth as a result of the reaction of the periodontium, the removable plate exerts a direct influence upon the alveolar process and the jaws ... The activator demonstrates a particularly favorable effect in transposing the lower jaw into the correct occlusal position. This excellent quality is mainly due to the metamorphosis of the temporomandible the cartilage of which is, of course, known to be the center of growth of the mandible. The bite shift achieved with the aid of the activator takes place very rapidly and is often completed long before the accompanying movement of individual teeth." In the United States, the most popular method of attempting to reposition the mandible is that of the labio-lingual technique. The advocates of this technique use the fixed "occlusal guide plane" to force the patient to occlude in a position, which alters the spatial relationship of the mandible to the maxilla.

Breitner (7,8), in 1930, showed histologically a tissue transformation in the region of the temporomandibular joint in animal experiments under the influence of fixed orthodontic appliances. In his first study on Macacus rhesus monkeys, he built up the mandibular canines so that the mandible was compelled to go into protrusion on closing. At the end of 81 days the animal was sacrificed. He found bone deposition in the temporomandibular joint and at the gonial angle. Later, in 1940, Breitner did a study on Macacus rhesus monkeys in which he placed fixed appliances on upper and lower arches and subjected the temporomandibular joint to elastic pull. After approximately three months, the animals were sacrificed and bone changes were studied histologically. He found that under the influence of the Class II elastic forces, the mandibular teeth had moved mesially to such a great extent that the interdental septa were composed of entirely new bone. He also found mild evidence of distal movement of the maxillary teeth. The angle of the mandible showed marked resorption on the posterior border and deposition of bone on the anterior margin, with a tendency for becoming more obtuse. In the glenoid fossa new bone trabeculation was shown on the posterior surface and bone resorption was evident on the anterior surface. New bone formation was evident also on the distal surface of the ascending ramus. The precise opposite results were demonstrated with Class III mechanics.

Breitner (7,8) also showed, with the use of the biteplate, that the condyle could be shown to grow upward and backward while new bone was laid down in the glenoid fossa, causing it to become more shallow.

In this country, some orthodontists use the occlusal guide plane to alter the spatial relationship of the temporomandibular articulation. Oliver, Irish, and Wood (32), in their textbook The Labio-lingual Technique, state that the chief purpose of the occlusal guide plane is "that of aiding in the establishing of a correct anteroposterior relation of the teeth and arches and the occlusal and incisal plane." They feel that the occlusal guide plane can not be omitted from the technique when anteroposterior correction of teeth and arches must take place.

In 1962, Oliver and Oliver (33) wrote in Vistas in Orthodontics, in reference to the occlusal guide plane: "It is constructed to insure that the patient bites in a predetermined position of neutral occlusion ... There is an immediate forward repositioning of the mandible into a more desirable anteroposterior relation ... Clinical tests prove that there is a permanent establishment of a new occlusal relation ... Over a 30-year period, the author (Oliver and Oliver) has not encountered any indications of pathology in the temporomandibular joint. X-ray pictures of this joint, some 3 or 4 months after inception of treatment, indicate that the head of the condyle is in a normal relation in the glenoid fossa. This would lead one to believe that there is accelerated growth in the neck of the condyle in conjunction with the use of the occlusal guide plane. This, however, is very difficult to prove. There is at least an apparent forward repositioning of the mandible."

Angle, on the other hand, felt that the changes in tooth relationship were due solely to the periodontal tissue transformation.

Haas, (16) in 1953, wrote, "Prior to 1938, the functional concept of development was widely accepted, and it was fairly generally felt that expansion was successful and bone would grow to support the teeth if they were moved gently and in good function. At this time the Orthodontic Department of the University of Illinois published the findings of an x-ray appraisal of treated orthodontic cases stating, 'Actual bone changes accompanying orthodontic management seems to be restricted to the alveolar process.'"

Biederman (49), in commenting on an article by Tiegelkamp, stated, "In my opinion, forces exerted on the teeth would hardly be likely to cause permanent changes in a structure such as the temporomandibular joint unless there were changes in the musculature also."

In 1942, Thompson and Brodie (50), after completing a serial cephalometric x-ray study of relatively large size, postulated, "the position of the mandible in relation to the rest of the face and head is an integral part of the pattern of the individual and is just as unchangeable as its form."

Ricketts (36), in 1952, did a combined laminagraphic-cephalometric investigation on the results of treatment of fifty Class II malocclusion cases. In this study, he indicated that the relation of the mandibular condyle to the glenoid fossa in rest position did change. The mean supracondylar measurement prior to treatment was twice that of the control subjects in rest position. After treatment, however, the mean distance from the condyle to the roof of the fossa diminished to almost exactly that of the control. Several cases indicated that the rest position followed the movement of the maxillary incisors. Ricketts felt that the neuromuscular system made compensatory adjustments to establish a new equilibrium which becomes stable for the new condition. He stated, however, "it has often been stated that the wearing of Class II elastics leads to a forward movement of the mandible. In the light of the demonstration that the condyle is relatively more posterior at the end of treatment, this concept can hardly be sustained. True, there are cases in which the elastics seem to overcome the natural resistance in the joint with the result that a dual bite is established. Such cases, however, show little tendency for the condyle to assume its normal relation and they usually were found to relapse to the pretreatment state ... It would be regrettable if the findings here set forth should become the excuse for the undertaking of empirical procedures designed to reposition the mandible."

In 1955, continuing his studies of the temporomandibular joint, Ricketts (38), utilizing the same sample of the previous study (50 Class II patients), showed changes of the spatial relationship of the mandibular condyle to the articular fossa after treatment in the occluded position. No mention was made to the specific type of treatment. Thirteen percent of the condyles were observed to move downward and forward, twenty-seven percent moved distally, and sixty percent showed no appreciable change. Regarding the downward and forward movement of the condyles, he stated, "This was observed in relatively few instances and subsequent relapse was observed in some but not all, of these conditions." He did not mention the length of time these cases were observed after treatment. In this same study, Ricketts showed that posterior growth of the condyle contributed to a downward thrust of the chin. This contradicts the theory that a force pulling the mandible forward contributes to a backward growth of the condyle and results in forward movement of the chin.

In 1962, Ricketts (41) summarized his work on the temporomandibular articulation and indicated the following significant findings:

> 1) The rest position often changed with treatment correcting to normal position at rest.
>
> 2) The duration or direction of force of intermaxillary elastic traction did not seem to alter condylar growth.
>
> 3) At pubertal ages, condyles grew at a greater rate in the male than in the female.
>
> 4) The condyles grew in different directions even with similar treatment procedures.
>
> 5) The apparent mechanical effects of condylar growth on facial behavior were not consistent with previous concepts, i.e., a posterior direction of condylar growth led to an increase in height rather than an increase in depth.

In 1964, Thompson (51), writing in _The Temporomandibular Joint_, wrote, "Many treated cases may exhibit excellent anatomical occlusion but at the same time may be responsible for abnormal function of the temporomandibular joints and musculature."

Ricketts (42) also writing a chapter for _The Temporomandibular Joint_, stated, "Alterations of less than one millimeter in the relation of condyle to fossa will sometimes lead to clinical problems."

METHODS AND MATERIALS

This study was designed to study the stability of the spatial relationship of the mandible to the maxilla. Intermaxillary elastic traction was employed in treatment and changes in the position of the mandibular articular condyle in the glenoid fossa of the temporal bone were recorded.

Fifteen patients, who were receiving active treatment at the Western Reserve University Orthodontic Clinic, were selected for study. All subjects had complete upper and lower multi-banded orthodontic appliances in place. No consideration was rendered to sex, race, class of occlusion, or type of treatment; extraction or non-extraction. The patients ranged in age from 12 to 27 years. Cases were selected which would require intermaxillary elastic force as a prescribed part of their treatment.

The Updegrave (59) T. M. J. board, with the modifications added by Baxt, was chosen as the technique for radiographing the temporomandibular articulations of these patients. This technique was selected because of the simplicity of manipulation, and the fact that it had already been tested and proven accurate by previous orthodontic students at this University. The greatest objection to this technique stems from the fact that the central ray of the radiation source passes obliquely, from above and behind the ear, through the subject's head and articulation; because of this, a small amount of distortion is inevitable. However, since the patient can be repositioned accurately and all other tangibles held constant, any distortion of the x-ray image in serial study can be virtually disregarded because it is reproduced uniformly, and each patient is compared only to himself. The other objection to this technique is the fact that the patient's head is tipped to almost a horizontal position, resting on the 15° angle board. Some investigators feel this position is abnormal and that the normal postural position of the mandible, maintained when the head is upright, is altered. It is felt, however, that this would not affect the centric occlusion position, since the mandible is guided to its centric position by the teeth. In the rest position, which will also be tested in this study, the spatial relationship may be altered. Updegrave (52) states: "This assertion is questionable if the head is correctly positioned with the tissues external to the joint, zygoma, and the angle bearing the entire weight of the skull. It takes considerable force applied at the angle of the jaw to produce a lateral displacement, since the leverage at this point is markedly less than at the symphysis. Furthermore, if there is a slight discrepancy anteriorly, it would be indistinguishable on the temporomandibular radiograph." The amount of variation should remain relatively constant, since the patient is positioned in the same way each time.

The radiation source was a General Electric 90-II dental x-ray machine. The plastic cone was removed from the unit head, and replaced by the Updegrave diaphragm, as modified by Baxt. Kodak Blue Brand medium speed film was used in an 8 x 10 cassette with a single par speed intensifying screen. The exposure was made at 65 kilovolts and 10 milliamperes, for four-tenths of a second.

The subject was seated facing the T. M. J. board and the head was positioned with the external auditory meatus of the side to be examined directly on the ear positioner of the board. The head was positioned so that it was supported by the ear positioner, zygoma, and angle of the mandible. The tip of the patient's nose was aligned in the same horizontal plane as the side alignment rod. The head position was recorded by raising or lowering the protractor-rod assembly and aligning the tip of the pointer with the tip of the subject's nose. This gives a reading for the vertical height of the nose on a scale calibrated from one to ten. The moveable rod on the protractor assembly is then aligned with the mid-sagittal plane of the subject's head and recorded on a scale calibrated from A to H. The head of the x-ray machine is positioned so that the central ray is perpendicular to the floor (gently touching the subject's head). The two pointers, at 90^{o} to each other on the ring which replaces the plastic cone, are aligned with the vertical rods of the T. M. J. board.

A six exposure technique was used, in which it was possible to make three radiographic exposures on each side of the head with one film. For this technique the leaded rubber mask having a small rectangular opening is placed over the slide tunnel. The film cassette is placed in the slide tunnel on the extreme right side of the board. With the subject positioned, he is instructed to close his teeth together (maximum occlusion was verified by visual observation). In this position, the first exposure is made. Next, the subject is instructed not to move as the film cassette is centered in the slide tunnel. With the teeth separated comfortably, in rest position, a second exposure is made. Finally, the film cassette is slid to the extreme left of the board, as the subject once again remains positioned, and a third exposure is made with the teeth in maximum occlusion again. Thus, one side is complete and the film cassette is turned

180^{o}, repositioned, and registrations are recorded. The same exposure technique is followed as was previously followed on the opposite side.

The study was designed so that subjects would be radiographed at three-week intervals prior to and after any change in the use of elastic forces. For example, the subject was positioned, all the necessary registrations for repositioning were obtained, and the radiographs were taken. Before dismissing the subject Class II or Class III elastics were placed. The elastics were worn for three weeks; the subject was then repositioned with the previously recorded registrations and radiographed again. The three week time interval was chosen in an attempt to minimize the effects of growth, but still allow a reasonable amount of time for the elastic force to influence the position of the mandible.

The elastic pull was approximately four ounces, as measured with a Richmond gauge, in every case and was always removed for one hour prior to taking the radiographs. This was done so that the mandible would not be under the direct influence of the elastics when records were taken. It was felt that, if the mandible remained at or returned to the position it occupied prior to applying the elastic force in this one hour time period, one could state that the spatial relationship was stable. If, however, the mandible occupied a new position, one could state that the spatial relationship had changed and further investigation would be necessary to determine if this change was permanent.

To evaluate the spatial relationship of the mandible to the maxilla, three measurements were made of the position of the mandibular condyle in the articular fossa of the temporal bone. Measurements were made of the anterior, superior, and posterior joint gaps directly from the roentgenograms in tenths of a millimeter with dividers and a millimeter scale.

Bjork and Solow (4) in a study on Measurement of Radiographs concluded, "measurements on the films should be made without marking the reference points of lines. It was found that the marking introduced a systematic error that increased the correlation coefficient."

To standardize this technique of measuring the joint gaps, Craddock's (11) method was used in conjunction with the orientation lines of the Updegrave board. Line A (fig. 1), was drawn through the high point of the articular fossa parallel with the vertical orientation line and perpendicular to the horizontal orientation line. Line B was drawn at 45° to the horizontal orientation line, passing through the narrowest part of the anterior joint gap. Line C was also drawn at 45° to the horizontal orientation line, passing through the point of bisection of lines A and B and the posterior joint gap (fig. 1). This figure was made on Matt acetate tracing paper so that the same diagram could be used for measuring throughout the whole study.

Figure 1 - Method of Gap Measurement

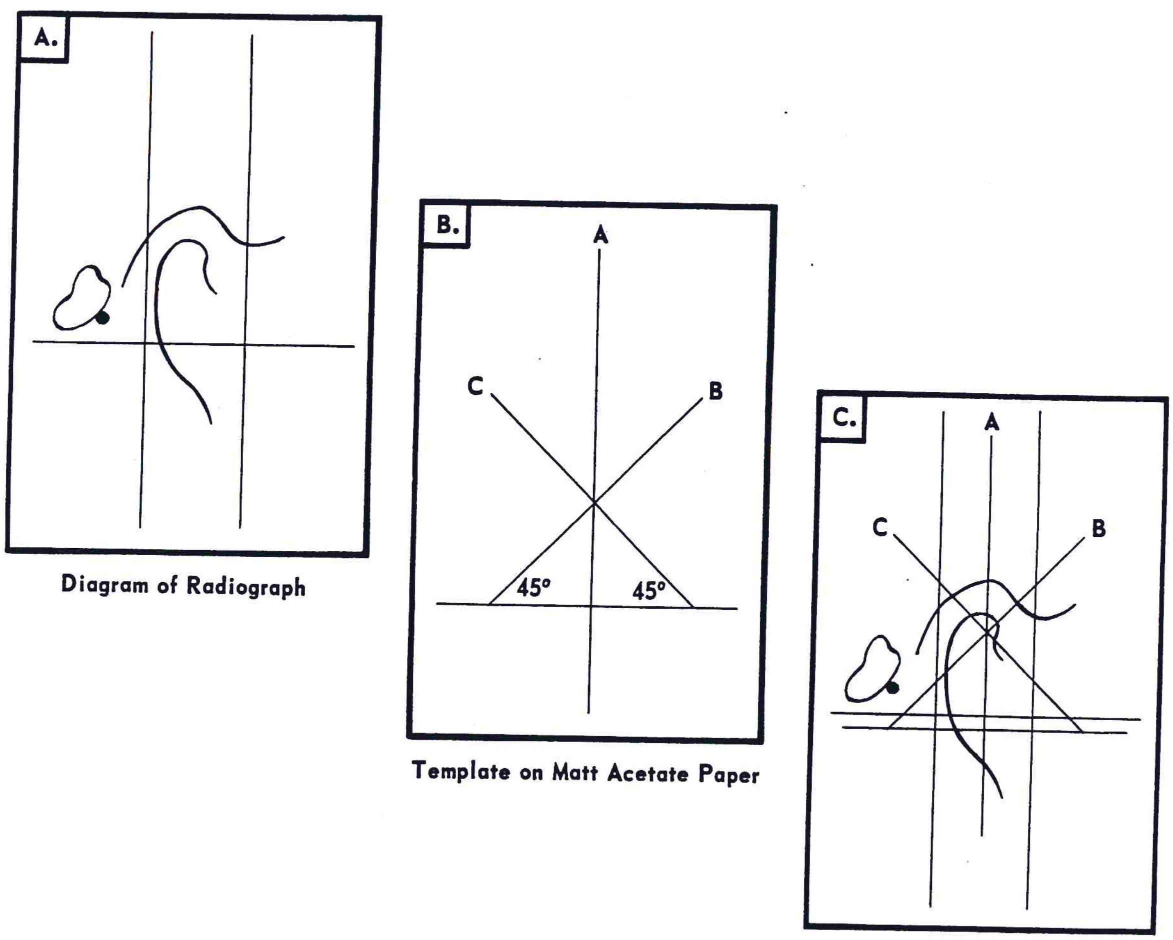


Diagram of Radiograph

Template on Matt Acetate Paper

Diagram with Template Superimposed

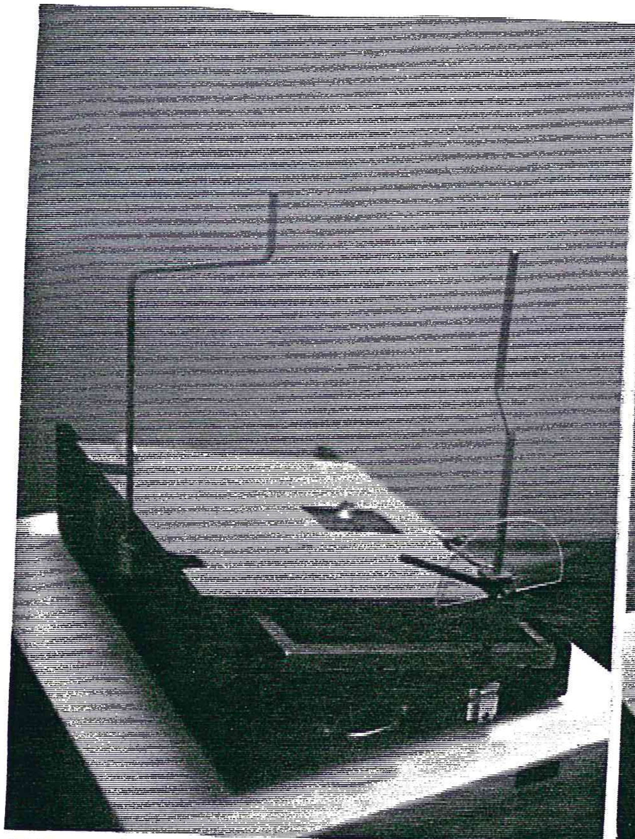


Fig. 2 The Updegrave board with Baxt's modification.

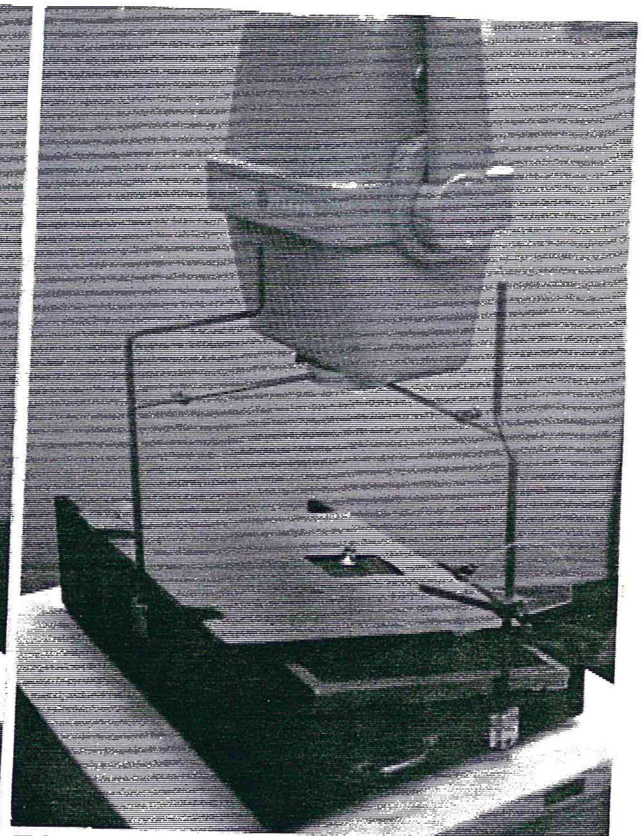


Fig. 3 X-ray head with ring and pointers positioned.

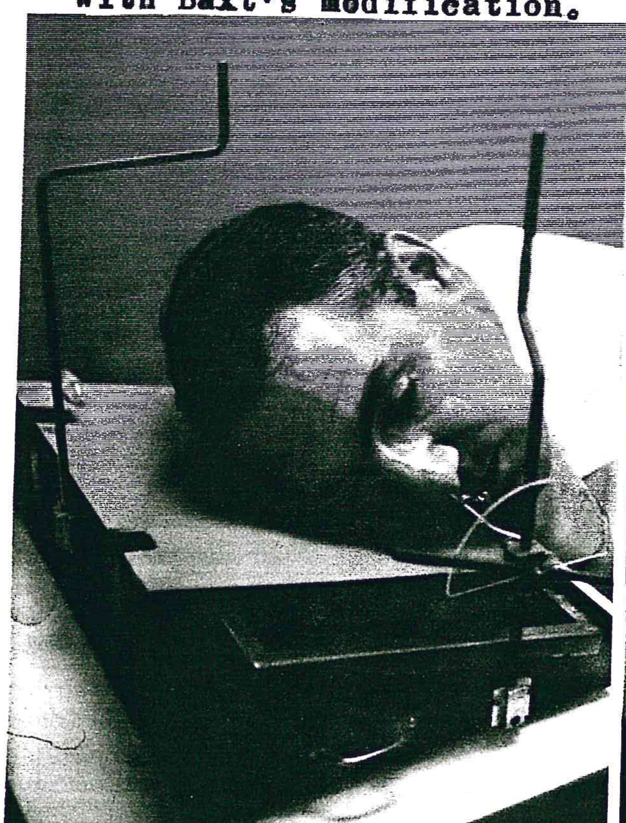
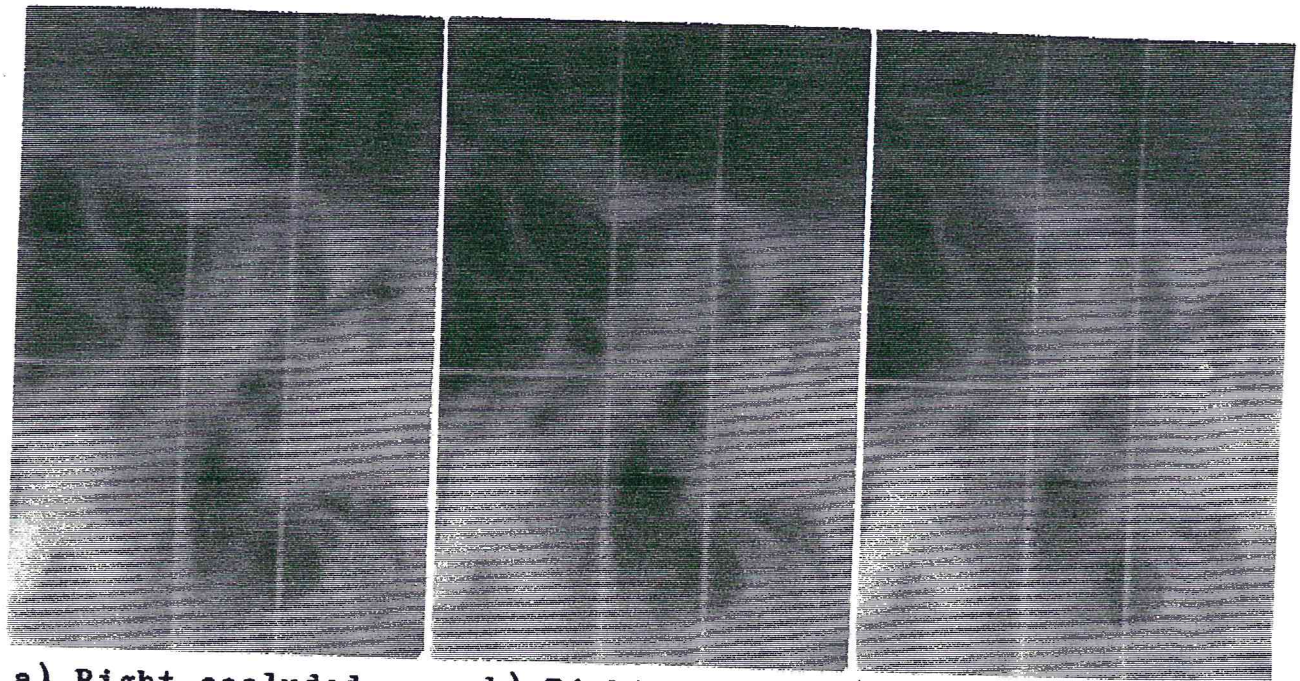


Fig. 4 Patient positioned with pretractor assembly aligned.

Fig. 5 Patient positioned with x-ray head and pointers aligned.

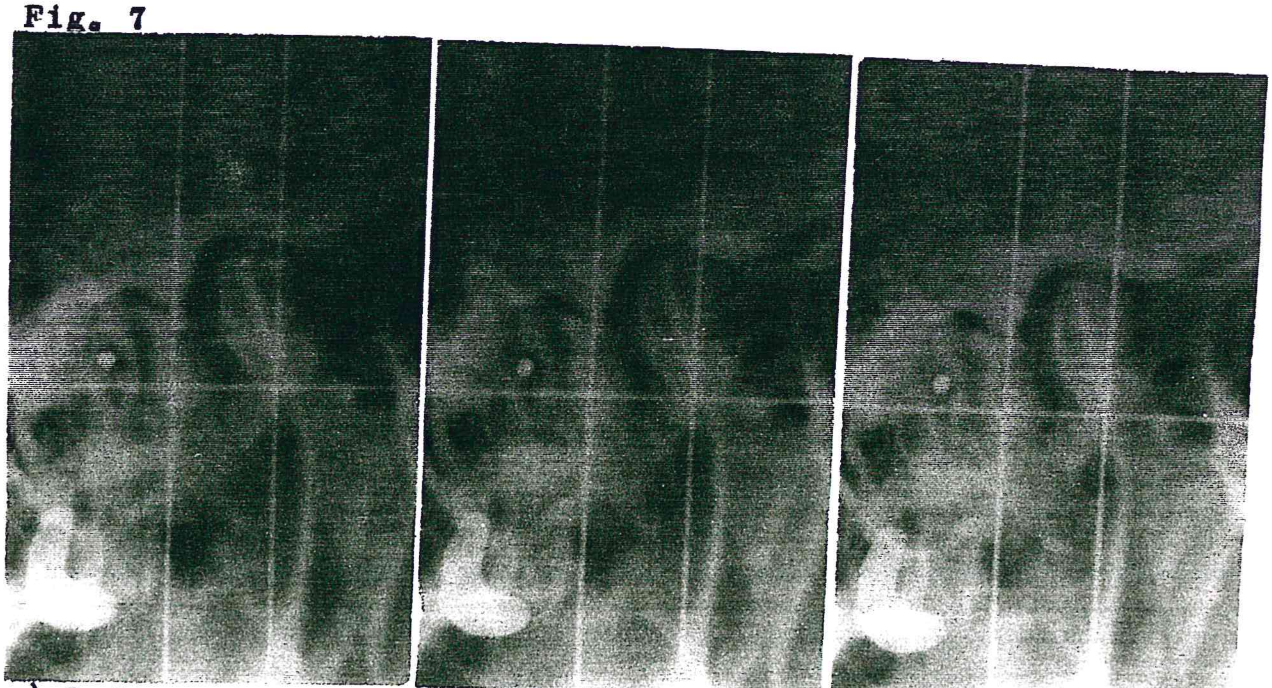
Typical Radiographs of Six Exposure Technique

Fig. 6



a) Right-occluded position   b) Right-rest position   c) Right-occluded position

Fig. 7



a) Left-occluded position   b) Left-rest position   c) Left-occluded position

FINDINGS AND DISCUSSION

In order to analyze the data in this study, it was necessary to work with several independent variables. Therefore, a "split plot" statistical model was constructed in order to split the error term. To facilitate manipulation of the model and plot, the variables were labeled as follows:

N-patient number (random sample)
S-side (two nested in each skull)
P-position (three; occluded, rest, occluded)
G-gap (anterior, superior, posterior)
V-visits or changes of the elastic force

The plot was GSN. To isolate G, it was necessary to treat SN as the plot.

In analysis of the data, all main effects and interactions not containing V reflect the parameters of the system as it exists (table 1). It is apparent that N is highly significant in all cases reflecting the gross differences in individual skulls. This was not surprising. Ricketts, studying the morphology of 100 normal subjects, showed the following variations; a) no harmony in size of condyle and fossa, b) little consistency of the form of articulating bodies, and c) variation in condyle position. Amer (1) made a similar observation about this same time and stated, "The right and left condyles in the same normal individual present a wealth of variations in size, width and length, and position." Donovan, Lawther, Schier, Updegrave, and many investigators not included in the Review of the Literature have shown that variation from person to person is the rule and not the exception.

In one instance G is significant (table 1). This indicates that for the 15 subjects in this study the gaps as individual classes are different. Of more importance is the fact that GN, variation of gaps within a specific skull, is highly significant in every case. GS(N), variation of gaps on one side of a specific skull as compared to the other side, is significant in all cases except one. Therefore these results support the validity of taking GSN as the plot in the design.

In designing this study, it was hoped that light might be shed on what effects the horizontal head position necessary with the technique used might have on mandibular rest position. When roentgenograms were taken, a set pattern of positions of the mandible was followed. The first was made with the teeth in occlusion, the second with the jaws at rest, and the third with the teeth in occlusion. When measurements were subjected to statistical analysis, there was no significant difference in measurements of the two different positions. These results coincide with Craddock's statement, "the

Table 1

TABULATED RESULTS OF SIGNIFICANT EFFECTS

S.V.	NONE-II	II-NONE	NONE-III	III-NONE	NONE-II-NONE
N	**	**	**	**	**
S(N)	**	**	**	--	**
P(SN)	----------	ERROR TERM	----------		
G	--	*	--	--	--
GN	**	**	**	**	**
GS(N)	**	**	--	**	**
GP(SN)	----------	ERROR TERM	----------		
V	--	--	--	--	--
VN	*	**	**	*	--
VS(N)	**	**	**	--	**
VP(SN)	----------	ERROR TERM	----------		
VG	--	--	--	--	*
VGN	*	**	**	**	--
VGS(N)	**	**	*	--	--
VGP(SN)	----------	ERROR TERM	----------		

**-.01 *-.05 Level of significance

Error term-the residual variance in the measurements.

S.V.-source of variance.

None-II-Data were gathered immediately before placing the subject on Class II elastics and three weeks after.

II-None-Data were gathered at time of removal of Class II elastics, after being off for one hour, and after three weeks of no elastics.

None-III-Data were gathered immediately before and three weeks after placing Class III elastics.

III-None-Data were gathered at time of removal of Class III elastics, after being off for one hour, and after three weeks of no elastics.

None-II-None-Data were gathered immediately before and three weeks after placing Class II elastics, as well as three weeks after their removal.

arc described by the incisors (moving from rest position to occlusion) is so small as to make the movement radiographically imperceptible at the condyle."

Analysis of the comparative data obtained before and after treatment with intermaxillary elastics (table 1) demonstrated that in no instance was a pure treatment effect observed. Thus, subjecting the mandible to an eight ounce force (a four ounce elastic force on each side) for three weeks in a given anterior or posterior direction does not cause a gross mono-directional change in the spatial position of the mandible. In most cases, however, an irregular treatment effect was observed. In every instance but one, when the roentgenograms of the 30 temporomandibular joints were studied individually, a significant effect of treatment was observed (table 1). This indicates that for some subjects treatment has a specific effect which differs from one side of the temporomandibular complex to the other side. This manifests itself in a twisting of the orientation of the mandible as related to the cranium, resulting in an increase in gap widths on one side and a decrease in gap widths on the other side. This twisting effect occurred in a vertical as well as horizontal direction. Thus, the mandible tended to rotate around to the left or right and one condyle tended to drop

Table 2

ERROR ANALYSIS AND TREATMENT RESULTS

		S.V.	σ^2	σ	% of σ^2 VGP(SN)
A. None-II					
		VGP(SN)	.028	.168	100
	Treatment	VGS(N)	.044	.21	156
B. II-None					
		VGP(SN)	.067	.26	100
	Treatment	VGS(N)	.131	.36	194
C. None-II-None					
		VGP(SN)	.033	.183	100
		VP(SN)	.154	.394	460
		VS(N)	.28	.53	840 (sides differ)
D. III-None					
		VGP(SN)	.084	.29	100
	Treatment	VGN	.052	.228	62
E. None-III					
		VGP(SN)	.007	.084	100
	Treatment	VGS(N)	.006	.078	85

S.V. - source of variance

σ^2 - the variance

σ - standard deviation

down out of the fossa or the other tended to move further up into the fossa.

When Class II elastics, which tend to pull the mandible mesially, were applied for three weeks, a change in magnitude of .21 millimeters (table 2) was observed in the position of the mandibular condyle in the glenoid fossa. This change appeared in random and unpredictable directions (from patient to patient and from one side of the mandible to the other of the same patient) and did not show any significant mono-directional movement.

When Class II elastics were removed (II-None in table 2) for three weeks prior to collecting of comparative data it was observed that the mandibular condyle moved .36 millimeters, again in random and unpredictable directions. This was apparently the result of the mandible returning to the position it occupied prior to being subjected to the mesial force of the Class II elastics.

When the data were studied on subjects who went from no treatment to Class II elastic force for three weeks to no treatment for three weeks (None-II-None in table 2), it was found that the spatial relationship of the mandibular condyle to the glenoid fossa was altered by the elastic force. However, it returned to its original position within three weeks after removal of the force.

When Class III elastic force, which tends to pull the mandible distally, was employed for three weeks in treatment the results were very similar to those found with Class II elastic force. A statistically significant change occurred in the spatial relationship of the mandibular condyle to the glenoid fossa of .078 millimeters (table 2, None-III). This spatial change took place in random and unpredictable directions irrespective of the direction of elastic pull. Three weeks after the removal of Class III elastics (None-III in table 2) further positional change was evident from the data. The position of the condyle in the fossa moved .228 millimeters in random directions. In this study, we were unable to follow a series of subjects from None-III-None. However, with the significant changes that did occur with "before" and "after" Class III elastics and realizing the stability that was observed with Class II elastics (None-II-None), it is assumed that the mandible reverts to its normal position after the use of Class III elastics with the amount of force (four ounces on a side) and time (three weeks) set up in this study.

It was possible to complete treatment on 10 of the 15 subjects used in this study and to observe them in retention for at least three months. An interesting observation worth noting was made on one Class II Division I malocclusion used in the study. This subject (N_{13} in table 10) had demonstrated considerably more change in the mandibular condyle in the glenoid fossa than any other when intermaxillary elastic forces were used. This same subject, upon retention, was the only one which tended to relapse, and it was necessary to re-band and to retreat.

SUMMARY AND CONCLUSIONS

Summary

In designing this study, we set out to determine what effect the application of intermaxillary elastic forces would have on the spatial relationship of the mandibular condyle in the glenoid fossa (which is controlled by the neuro-muscular mechanism) and to evaluate the stability of said relationship.

A fairly extensive Review of the Literature pertaining to various techniques available with which to radiograph the temporomandibular articulation was made. Many techniques had been developed and altered because of the difficulty encountered in radiographing this area. The difficulty encountered is due; 1) to the superimposition of the denser petrous portion of the temporal bone in a straight bicondylar exposure, 2) to the distortion encountered in angular exposures which attempt to by-pass the petrous element, 3) to the innate morphologic variability encountered in attempting to standardize human subjects, and 4) to the prohibitive cost of the more complex laminagraphic techniques. In this study we chose to use the Updegrave T. M. J. board as modified by Baxt because it has been shown to be accurate for serial study by Benson.

A Review of the Literature was also conducted on the effects of treatment on the temporomandibular articulation. Relatively few controlled studies have been done. Two separate and opposed philosophies of treatment were reviewed. Advocates of the first philosophy, primarily those of the labio-lingual technique and the European orthopedic technique, attempt to reposition the mandible and alter growth of the mandibular condyle. The followers of the second philosophy feel that the position of the mandible is stable and that growth occurs independent of treatment.

For this study 15 patients undergoing orthodontic treatment were selected. All patients were in various stages of treatment with upper and lower multi-banded appliances. Serial measurements were made of the anterior, superior, and posterior joint gaps of both right and left temporomandibular joints. Data were collected immediately prior to placing Class II or Class III elastics three weeks after the elastics were worn with a one hour rest period prior to radiographing and three weeks after elastics were removed. It was not possible to follow all patients through all of the three phases of treatment but in every case measurements were made of at least two phases.

The data were then analyzed and studied with the aid of the statistics department of Western Reserve University.

Conclusions

The result of this study should not be considered as conclusive even though 684 gap measurements were made with the maximum control of facilities presently available, for only 15 subjects (30 gaps) were used. This study should serve, however, as a stimulus for further study and give us an indication as to the direction of further study.

Within the parameters of this study, several conclusions can be made:

1) With the use of Class II elastics of approximately four ounces on a side as routinely used in orthodontic treatment, a change of .21 millimeters occurred in the position of the mandibular condyle in the glenoid fossa after three weeks. This change appeared in random and unpredictable directions irrespective of the direction of elastic pull.

2) Three weeks after the Class II elastics were removed, further change took place in the position of the mandibular condyle in the glenoid fossa. This change was of the magnitude of .36 millimeters and occurred in random and unpredictable directions.

3) In several subjects it was possible to collect data immediately prior to and three weeks after placement of Class II elastics; further data were collected three weeks after the elastics were discontinued. The mandibles underwent

spatial change as previously mentioned due to the Class II elastics but returned to their original positions within three weeks after removal of the elastic pull.

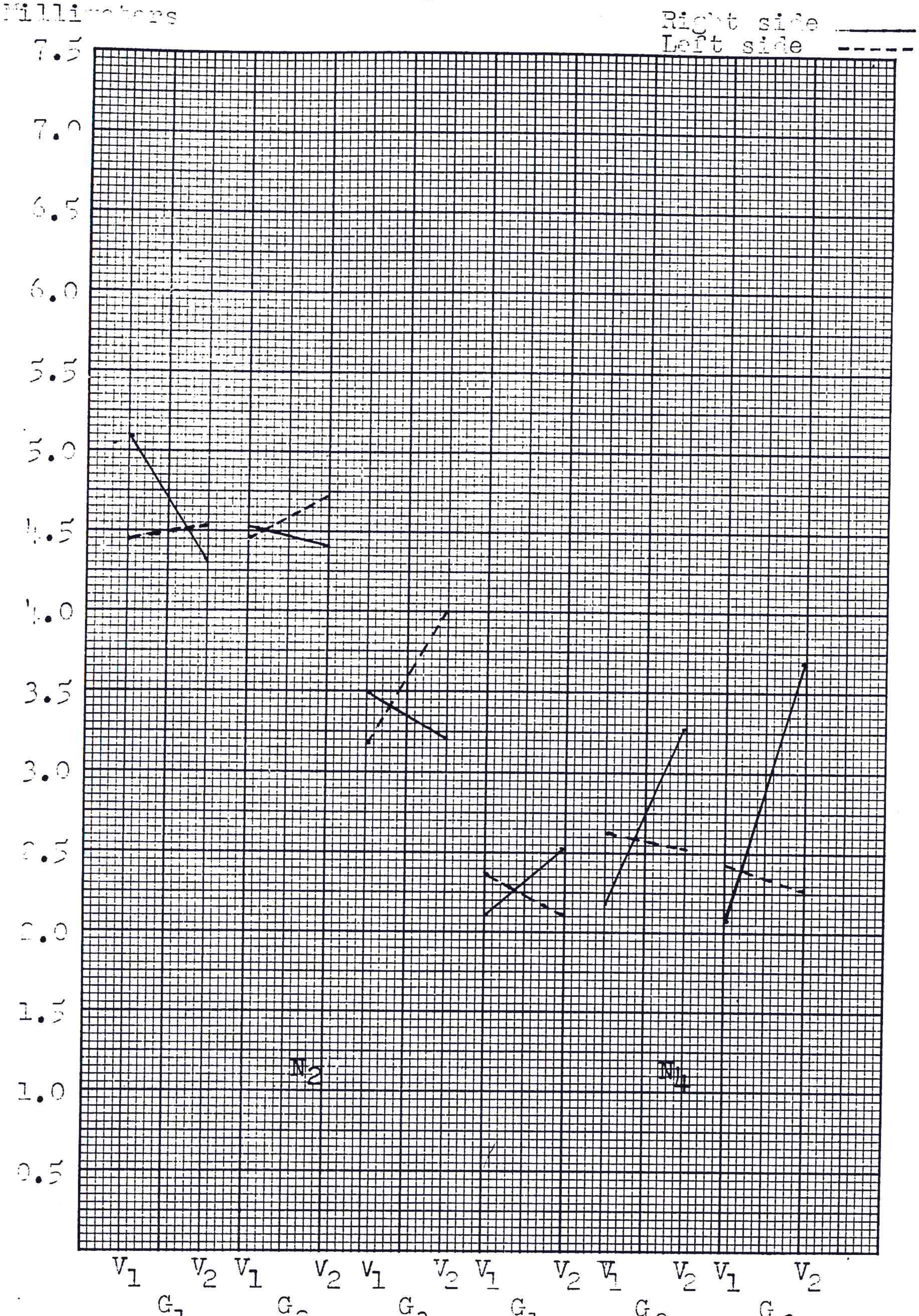
4) When Class III elastics were employed in treatment for three weeks a change quite similar to those observed with Class II elastics occurred in random and unpredictable directions irrespective of the direction of elastic pull. The mean magnitude of this change was .078 millimeters.

5) Within three weeks after the removal of the Class III elastics a change occurred, again following an unpredictable directional pattern. The mean spatial change was .228 millimeters. Even though it was not possible to follow a series of patients from None-III-None, on the basis of the None-II-None series, it is reasonable to assume that this change is a reversion of the mandible to its previous position; that occupied prior to any elastic force.

6) In nearly all cases, regardless of anterior or posterior direction of elastic pull, variation occurred from one side of the skull to the other in the direction of positional change of the mandibular condyle in the glenoid fossa. This resulted in a vertical as well as horizontal spatial change that manifested itself as a twisting (Figs. 8, 9 and 10) of the orientation of the mandible as related to the cranium. The vertical change resulted in a rotation or

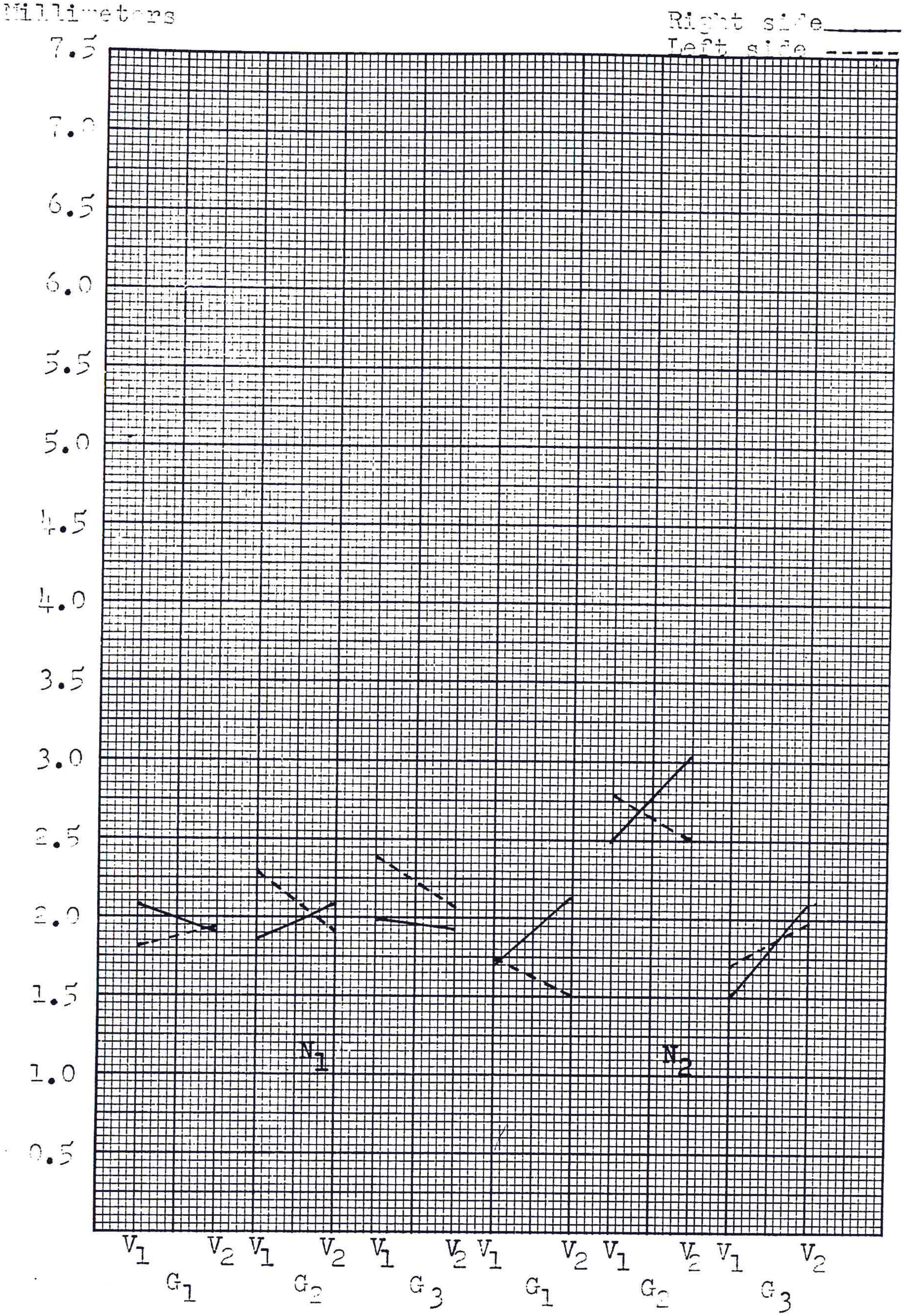
twisting of such a nature that one condyle tended to move further up into the fossa and the other tended to move down and further out of the fossa. The horizontal spatial change resulted in one condyle moving mesially and the other moving distally. Within the controls of this study, however, these changes were of a temporary nature and quickly returned to their original position in neuro-muscular stability.

Fig. 8



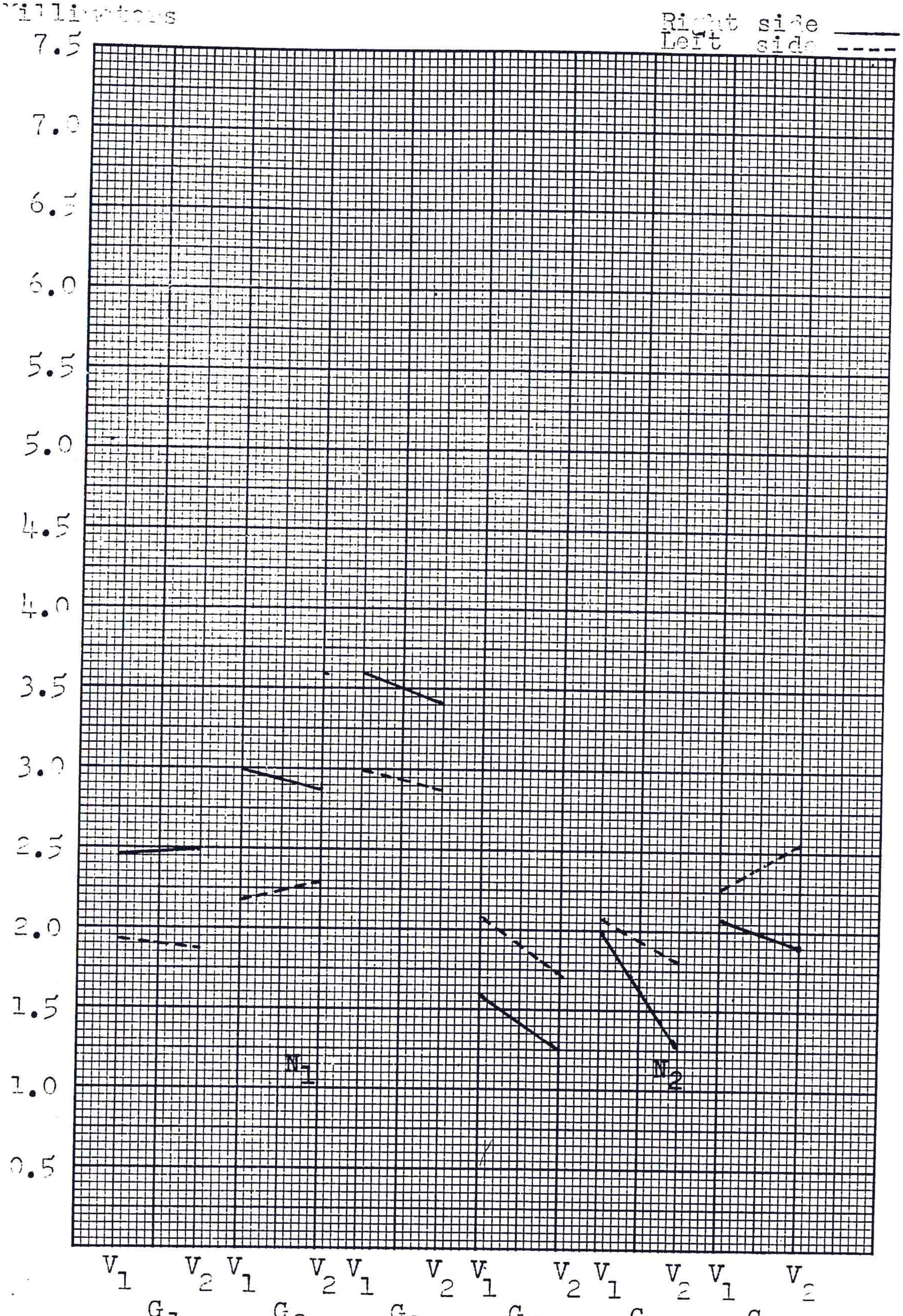
None-II Twisting Effect

Fig. 9



II-None Twisting Effect

Fig. 10



None-III Twisting Effect

Table 3

COMPONENTS OF VARIANCE

S.V.	N	S	P	G	V	Components
N	1	S	P	G	V	$\sigma^2 E^{III} + SPGV\sigma^2 N$
S(N)	1	O	P	G	V	$\sigma^2 E^{III} + PVG\sigma^2 SN$
P(SN)	1	1	1	1	1	$\sigma^2 E^{III}$
G	N	S	P	O	V	$\sigma^2 E^{II} + SPV\sigma^2 GN + NSPV\sigma^2 G$
GN	1	S	P	O	V	$\sigma^2 E^{II} + SPV\sigma^2 GN$
GS(N)	1	O	P	O	V	$\sigma^2 E^{II} + PV\sigma^2 GS(N)$
GP(SN)	1	1	1	1	1	$\sigma^2 E^{II}$
V	N	S	P	G	O	$\sigma^2 E^{I} + SPG\sigma^2 VS + NSPG\sigma^2 V$
VN	1	S	P	G	O	$\sigma^2 E^{I} + SPG\sigma^2 VN$
VS(N)	1	O	P	G	O	$\sigma^2 E^{I} + PG\sigma^2 VS(N)$
VP(SN)	1	1	1	1	1	$\sigma^2 E^{I}$
VG	N	S	P	O	O	$\sigma^2 E + SP\sigma^2 VGN + NSP\sigma^2 VG$
VGN	1	S	P	O	O	$\sigma^2 E + SP\sigma^2 VGN$
VGS(N)	1	O	P	O	O	$\sigma^2 E + P\sigma^2 VGS(N)$
VGP(SN)	1	1	1	1	1	$\sigma^2 E$

S.V. - source of variance

The model equation for statistical analysis was:

$$X=\mu+N+S(N)+P(SN)+G+GN+GS(N)+GP(SN)+V+VN+VS(N)+VP(SN)+VG+VGN+VGS(N)+VGP(SN)$$

(μ- an arbitrary average around which all other values fluctuate.)

Table 4

ANALYSIS OF VARIANCE

S.V.	S.S.	df	M.S.	F	F_c	Conc.
N	105.852	3	35.284	180.9	12.6	.001 sig.
P	.301	2	.1505	1	----	no sig.
PN	.774	6	.129	1	----	no sig.
V	.640	1	.640	3.28	4.96	no sig.
VN	1.171	3	.390	3.20	4.07	no sig.
VP(N)	.979	8	.122	----	----	----
G	4.427	2	2.214	1.58	5.79	no sig.
GN	8.433	6	1.406	27.6	6.02	.001 sig.
GP	.087	4	.022	1	----	no sig.
GPN	1.053	12	.088	1.72	2.28	no sig.
GV	.652	2	.326	6.36	5.85	.01 sig.
GVN	.489	6	.082	2.05	2.79	no sig.
GVP(N)	.639	16	.040	----	----	----
S	1.867	1	1.867	1	----	no sig.
SN	14.778	3	4.926	65.7	15.8	.001 sig.
SP	.222	2	.111	1.48	4.46	no sig.
SPN	.440	6	.073	1	----	no sig.
SV	.174	1	.174	1	----	no sig.
SVN	5.303	3	1.768	23.6	15.8	.001 sig.
SVP(N)	.603	8	.075	----	----	----
SG	.334	2	.167	1	----	no sig.
SGN	3.034	6	.506	31.6	7.09	.001 sig.
SGP	.024	4	.006	1	----	no sig.
SGPN	.841	12	.070	4.38	4.25	.005 sig.
SGV	.436	2	.218	1.55	5.14	no sig.
SGVN	.847	6	.141	8.8125	7.09	.001 sig.
SGVP(N)	.257	16	.0160	----	----	----

Table 5

NONE-II ANALYSIS OF VARIANCE

S.V.	S.S.	df	M.S.	F	F_c	Conc.
N	105.852	3	35.284	323	5.29	.01 sig.
S(N)	16.645	4	4.161	38.1	4.77	.01 sig.
P(SN)	1.737	16	.109	----	----	----
G	4.427	2	2.214	1.57	3.30	no sig.
GN	8.433	6	1.406	22.7	3.42	.01 sig.
GS(N)	3.368	8	.421	6.79	3.12	.01 sig.
GP(SN)	2.005	32	.062	----	----	----
V	.640	1	.640	1.64	10.13	no sig.
VN	1.171	3	.390	3.94	3.24	.05 sig.
VS(N)	5.477	4	1.369	13.8	4.77	.01 sig.
VP(SN)	1.582	16	.099	----	----	----
VG	.652	2	.326	3.98	5.14	no sig.
VGN	.489	6	.082	2.92	2.40	.05 sig.
VGS(N)	1.283	8	.160	5.71	3.12	.01 sig.
VGP(SN)	.896	32	.028	----	----	----

S.V. - source of variance
S.S. - sum of squares
df - degrees of freedom
M.S. - mean of squares
F. - F test
F_c - F critical

None-II - Those subjects on whom data were gathered immediately prior to and three weeks after the use of Class II elastics.

Table 6

II-NONE ANALYSIS OF VARIANCE

S.V.	S.S.	df	M.S.	F	F_c	Conc.
N	170.711	7	24.38	160	3.30	.01 sig.
S(N)	16.174	8	2.02	13.25	3.17	.01 sig.
P(SN)	4.881	32	.1525	----	----	----
G	24.181	2	12.09	3.96	3.74	.05 sig.
GN	42.735	14	3.05	44.5	2.35	.01 sig.
GS(N)	7.618	16	.476	6.95	2.35	.01 sig.
GP(SN)	4.379	64	.0685	----	----	----
V	1.293	1	1.293	1	----	no sig.
VN	15.387	7	2.19	8.42	3.30	.01 sig.
VS(N)	14.483	8	1.81	6.97	3.17	.01 sig.
VP(SN)	8.335	32	.260	----	----	----
VG	1.331	2	.666	1.53	3.74	no sig.
VGN	6.078	14	.435	6.45	2.35	.01 sig.
VGS(N)	7.360	16	.460	6.82	2.35	.01 sig.
VGP(SN)	4.318	64	.0675	----	----	----

S.V. - source of variance
S.S. - sum of squares
df - degrees of freedom
M.S. - mean of squares
F. - F test
F_c - F critical
Conc.- conclusion

II-None - Those subjects on whom data were gathered at the time Class II elastics were discontinued and three weeks after no elastics were worn.

Table 7

NONE-II-NONE ANALYSIS OF VARIANCE

S.V.	S.S.	df	M.S.	F	Fc	Conc.
N	113.855	2	56.9	202	6.93	.01 sig.
S(N)	10.661	3	3.56	12.7	5.95	.01 sig.
P(SN)	3.361	12	.280	----	----	----
G	3.597	2	1.79	1	----	no sig.
GN	10.115	4	2.53	41	4.22	.01 sig.
GS(N)	3.453	6	.575	9.3	3.67	.01 sig.
GP(SN)	1.482	24	.0618	----	----	----
V	.767	1	.767	3.65	4.60	no sig.
VN	1.095	2	.546	3.54	3.89	no sig.
VS(N)	7.969	3	2.65	17.3	5.95	.01 sig.
VP(SN)	1.848	12	.154	----	----	----
VG	.851	2	.426	7.6	6.94	.05 sig.
VGN	.224	4	.056	1.68	2.78	no sig.
VGS(N)	.489	6	.0815	2.44	2.51	no sig.
VGP(SN)	.802	24	.0334	----	----	----

S.V. - source of variance
S.S. - sum of squares
df - degrees of freedom
M.S. - mean of squares
F - F test
F_c - F critical
Conc.- conclusion

None-II-None - Those subjects on whom data were gathered immediately prior to and three weeks after the use of Class II elastics, we well as three weeks after no elastics were worn.

Table 8

NONE-III ANALYSIS OF VARIANCE

S.V.	S.S.	df	M.S.	F	F_c	Conc.
N	11.360	1	11.36	477	11.3	.01 sig.
S(N)	4.623	2	2.31	97	8.65	.01 sig.
P(SN)	.191	8	.0238	----	----	----
G	7.543	2	3.77	10.3	19.0	no sig.
GN	.734	2	.365	23.4	6.23	.01 sig.
GS(N)	.097	4	.025	1.6	3.01	no sig.
GP(SN)	.246	16	.0154	----	----	----
V	.435	1	.435	2.69	39.9	no sig.
VN	.161	1	.160	41	11.3	.01 sig.
VS(N)	.176	2	.088	22.7	8.65	.01 sig.
VP(SN)	.031	8	.0039	----	----	----
VG	.142	2	.071	1	----	no sig.
VGN	.329	2	.165	24	6.23	.01 sig.
VGS(N)	.104	4	.025	3.6	3.01	.05 sig.
VGP(SN)	.112	16	.007	----	----	----

S.V. - source of variance
S.S. - sum of squares
df - degrees of freedom
M.S. - mean of squares
F - F test
F_c - F critical
Conc.- conclusion

None-III - Those subjects on whom data were gathered immediately prior to and three weeks after the use of Class III elastics.

Table 9

III-NONE ANALYSIS OF VARIANCE

S.V.	S.S.	df	M.S.	F	F_c	Conc.
N	23.043	3	7.681	26.8	9.34	.001 sig.
S(N)	2.031	4	.508	1.77	3.06	no sig.
P(SN)	4.596	16	.287	----	----	----
G	11.304	2	5.652	1.74	5.14	no sig.
GN	19.485	6	3.248	29.5	5.12	.001 sig.
GS(N)	4.117	8	.515	4.68	4.58	.001 sig.
GP(SN)	3.527	32	.110	----	----	----
V	.680	1	.680	1	----	no sig.
VN	2.654	3	.885	3.88	3.29	.05 sig.
VS(N)	.759	4	.190	1	----	no sig.
PV(SN)	3.642	16	.228	----	----	----
VG	.612	2	.306	1	----	no sig.
VGN	2.395	6	.399	4.75	3.42	.01 sig.
VGS(N)	1.438	8	.180	2.14	2.27	no sig.
VGP(SN)	2.675	32	.084	----	----	----

S.V. - source of variance
S.S. - sum of squares
df - degrees of freedom
M.S. - mean of squares
F - F test
F_c - F critical
Conc.-conclusion

III-None - Those subjects on whom data were gathered at the time Class III elastics were discontinued and three weeks after no elastics were worn.

Table 10

ABSOLUTE GAP MEASUREMENTS

Number		Right Closed Ant.	Sup.	Post.	Right Rest Ant.	Sup.	Post.	Left Closed Ant.	Sup.	Post.	Left Rest Ant.	Sup.	Post.
N_1	Cl III	3.2	2.5	2.1	3.0	3.0	2.0	3.0	3.1	2.1	2.8	3.1	2.0
		3.2	3.0	2.5				3.0	3.0	2.1			
	None	3.3	2.5	2.2	3.3	3.4	1.7	2.2	3.0	1.7	2.5	3.3	1.8
		3.4	3.0	2.5				2.0	2.9	2.0			
	Cl II	3.0	3.0	2.0	3.0	2.9	2.0	2.9	3.1	2.0	2.6	3.3	2.2
		3.0	2.8	2.0				2.5	3.3	2.0			
N_2	None	2.1	2.0	2.1	1.8	2.0	1.9	3.0	3.0	2.0	3.2	3.0	2.0
		2.1	2.1	2.2				2.9	3.0	2.0			
	Cl II	2.6	2.0	2.1	2.0	1.9	2.0	3.0	3.0	2.0	2.9	2.7	1.8
		2.6	2.2	2.1				3.0	2.9	2.0			
N_3	Cl II	2.0	2.0	1.9	1.9	2.1	2.0	1.9	1.8	2.0	1.9	2.1	2.2
		1.8	2.0	1.9				2.0	1.9	2.0			
	None	2.1	1.6	1.7	2.0	2.1	2.3	1.8	1.6	2.1	2.0	3.3	3.0
		2.1	1.9	2.0				1.6	2.0	2.1			
N_4	Cl II	1.9	3.1	2.5	2.4	3.0	1.3	1.0	2.5	2.4	2.3	2.5	1.0
		2.1	3.0	2.5				1.2	2.5	2.5			
	None	1.8	2.2	1.4	1.5	3.0	1.6	1.5	2.5	1.1	2.2	3.4	2.4
		1.8	2.2	1.6				1.5	2.5	1.5			
N_5	None	4.2	4.4	3.4	4.6	4.5	2.6	4.6	4.5	4.1	4.5	4.8	3.9
		4.2	4.3	3.6				4.5	4.9	4.0			
	Cl II	4.6	4.5	3.3	6.0	4.6	4.0	4.1	4.5	3.2	4.6	4.5	3.1
		4.6	4.5	3.2				4.1	4.4	3.2			
	None	5.3	6.1	4.1	4.2	4.5	2.9	4.4	4.5	3.0	3.8	4.0	3.0
		5.6	6.0	4.3				4.5	4.5	2.9			
N_6	None	1.3	1.1	1.9	1.3	1.5	1.9	1.6	1.7	2.5	1.8	2.0	2.6
		1.2	1.3	1.9				1.8	1.6	2.5			
	Cl III	1.6	1.9	2.0	1.6	2.0	2.1	2.1	2.0	2.2	2.0	2.1	2.5
		1.6	2.1	2.0				2.0	2.0	2.2			
N_7	Cl II	4.5	3.9	2.1	4.5	4.0	2.7	3.7	3.6	2.1	3.9	3.8	2.0
		4.6	3.8	2.2				3.7	3.8	2.0			
	None	4.4	4.2	3.2	4.0	4.0	2.4	3.4	3.3	2.1	3.6	3.5	2.1
		4.2	4.2	3.2				3.4	3.3	2.3			
N_8	Cl III	1.7	3.5	1.6	1.7	5.6	5.5	2.6	4.0	3.7	2.0	4.0	4.1
		1.7	4.5	4.0				2.4	4.0	3.7			
	None	1.6	3.4	2.5	1.8	3.1	3.0	2.5	3.7	2.7	2.7	3.5	2.6
		1.8	3.3	2.5				2.6	3.8	2.6			

Table 10 - Continued

ABSOLUTE GAP MEASUREMENTS

		Right						Left					
		Closed			Rest			Closed			Rest		
Number		Ant.	Sup.	Post.	Ant.	Sup.	Post.	Ant.	Sup.	Post.	Ant.	Sup.	Post.
N_9	Cl II	3.1	2.2	1.6	2.9	2.1	1.6	2.9	2.6	2.2	3.0	3.0	2.5
		3.0	2.2	1.5				2.9	2.5	2.2			
	None	2.2	2.0	1.7	2.6	2.0	1.5	2.9	2.5	2.0	3.0	2.9	2.5
		2.6	2.1	1.3				2.8	2.6	2.3			
N_{10}	None	2.8	2.5	2.5	2.6	2.5	2.5	1.2	1.0	1.5	1.3	1.0	1.5
		3.5	3.0	2.2				1.3	1.0	1.5			
	Cl II	2.5	2.1	2.1	3.3	2.5	2.4	1.2	1.2	1.6	1.2	1.5	1.5
		2.5	2.1	2.1				1.2	1.4	1.5			
	None	2.5	1.7	1.1	2.5	2.0	1.4	1.3	1.2	1.5	1.3	1.2	1.5
		2.7	2.0	1.1				1.3	1.2	1.5			
N_{11}	None	2.6	2.9	3.4	2.4	2.8	3.5	1.8	2.5	2.9	1.9	2.1	2.9
		2.5	2.9	3.4				1.9	2.3	2.8			
	Cl III	2.5	3.0	3.5	2.5	3.0	3.6	2.0	2.5	3.0	1.9	2.0	3.0
		2.4	3.0	3.6				1.9	2.2	3.0			
N_{12}	None	2.4	3.0	3.5	2.8	3.6	3.9	2.1	2.6	2.4	2.0	2.8	2.4
		2.4	3.2	3.6				2.2	2.2	2.0			
	Cl II	2.1	1.8	1.8	2.1	2.7	2.5	2.3	2.7	2.4	2.1	2.7	2.5
		2.1	2.0	1.8				2.7	2.5	2.4			
	None	2.1	2.3	2.5	2.1	3.0	2.9	2.7	2.5	2.7	2.1	2.8	2.6
		2.0	2.4	2.5				2.6	2.5	2.1			
N_{13}	Cl II	1.6	2.5	.8	1.7	2.3	.8	2.0	3.9	1.8	2.3	4.2	2.2
		1.8	2.5	1.0				2.0	3.7	1.4			
	None	2.5	5.0	5.1	2.0	4.0	4.8	2.1	4.0	1.9	2.2	3.7	2.0
		2.0	5.8	5.7				2.5	4.4	1.9			
	Cl II	1.2	3.2	3.3	1.1	4.0	4.1	2.0	3.8	1.9	2.2	3.7	1.9
		1.0	3.2	3.5				2.0	3.8	1.7			
	None	1.1	5.0	5.0	1.0	4.7	4.5	1.6	2.0	1.9	1.6	2.5	1.7
		1.0	4.8	4.8				1.6	2.6	1.9			
N_{14}	Cl III	1.7	1.5	1.7	1.6	1.9	2.3	1.5	2.5	2.7	1.2	2.5	2.6
		2.1	1.7	1.6				1.3	2.5	2.5			
	None	1.5	2.0	2.1	1.5	2.3	2.1	1.5	2.1	2.0	1.6	2.5	2.8
		1.7	2.3	2.3				1.6	2.3	2.4			
N_{15}	Cl III	3.0	3.0	3.0	2.8	3.0	3.1	2.2	2.9	3.1	2.0	3.0	3.1
		2.8	3.0	3.1				2.1	2.8	3.1			
	None	3.0	3.0	3.1	3.0	3.0	3.1	2.2	2.7	3.0	3.0	3.0	4.0
		3.0	3.0	3.0				2.2	2.3	3.0			
	None	3.0	3.0	3.1	2.9	3.0	3.2	3.0	2.9	3.1	4.0	3.8	4.3
		3.0	3.0	3.1				3.0	2.9	3.1			
	Cl III	2.9	3.0	2.9	2.0	2.9	3.2	2.2	2.6	2.9	2.2	2.9	3.0
		3.1	3.0	3.0				2.2	2.7	2.9			

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