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THE CHANGES IN ANGULATION OF THE PALATAL, MANDIBULAR AND OCCLUSAL PLANES ACCOMPANYING AND FOLLOWING BEGG ORTHODONTIC TREATMENT

by

CARL PHILIP DIETRICH, JR.

Submitted in partial fulfillment of the requirements

for the Degree of Master of Science

Department of Orthodontics

WESTERN RESERVE UNIVERSITY

June 1966

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I would like to express my sincere thanks to Dr. Sanford Neuger, Research Director, Dr. Philip Burwasser, Director of Graduate Education, and Dr. Richard Beatty, Chairman of the Orthodontic Department of the School of Dentistry of Western Reserve University, for their generous assistance and criticism during the preparation of this thesis.

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INTRODUCTION

In 1956 Dr. P. R. Begg, an orthodontist from Adelaide, South Australia, introduced to this country his orthodontic technique in which light differential forces are employed (5). Since 1956 there have been many articles explaining his theory and technique (2-7, 11, 25, 40, 41, 44), which has attained a high degree of acceptance and has stimulated a great deal of controversy.

Dr. Begg's technique of light differential forces involves the use of very light, continuous elastic forces of 60-70 grams to obtain maximum anterior tooth movement. Would this technique, which uses such light forces, cause as much orthopedic tipping of the palatal, occlusal, and mandibular planes as the conventional edgewise technique and headgear therapy? An answer to this question could be of great aid to the clinician when evaluating this technique.

This investigation represents an effort to analyze the changes that occur in the palatal, occlusal, and mandibular planes in patients treated by the Begg orthodontic technique. More specifically, the purpose of this investigation is as follows:

1. To analyze the changes that occur in the angulation of the palatal, occlusal, and mandibular planes in patients treated by the Begg orthodontic technique.

2. To analyze the angular changes that occur in these anatomic planes after the completion of Begg orthodontic treatment.

3. To analyze statistically these angular changes and determine their significance.

4. To determine if there is a significant difference in the treatment response of males and females.

5. To determine if there is a significant difference in the treatment response of Angle's Class I and II malocclusions.

REVIEW OF THE LITERATURE

The orthodontic literature is replete with articles on growth and development, cephalometrics, treatment, and techniques. This review will be confined to growth and orthodontic treatment as they relate to the three anatomical planes used in this study. The review will be divided into three sections:

1. Growth changes without orthodontic treatment.
2. Growth changes with orthodontic treatment.
3. Factors to be considered in changing the occlusal and mandibular planes.

Growth Changes Without Orthodontic Treatment

Dr. B. Holly Broadbent, Sr., presented the composite mean pattern of facial growth in "The Face of the Normal Child" (12). He presented the concept that the facial pattern has no marked changes in its proportions after the completion of the deciduous dentition. This concept of consistency of facial proportions was carried further by A. G. Brodie (13) in his cephalometric roentgenographic study of the growth pattern of the human head on 21 males from three months to eight years of age.

Brodie discovered that the morphogenetic pattern of the head was established by the third postnatal month, or even earlier, and

when established it did not change. The growth of the facial complex was so integrated and proportional that the nasal floor, occlusal plane, and mandibular plane maintained a stable angular relationship during growth.

In 1953 Brodie (14) published the late growth changes of 19 individuals from eight to seventeen years of age. Here he did not find the rigid stability that his 1941 thesis showed. The hard palate - anterior nasal spine (A.N.S.) and posterior nasal spine (P.N.S.) - maintained a constant angular relationship to the anterior cranial base (S.N.) in only 10 out of 19 cases. One case had a decrease in the angulation of the hard palate; thus becoming more parallel with the cranial base. Eight individuals had an increase in angulation to S.N. Therefore, A.N.S. tended to drop more than P.N.S. The greatest angular change was 5^{o}. The occlusal plane did not change in angulation to S.N. in 9 cases, but these individuals did not correspond to the changes in the palatal plane. Two individuals had an increase in angulation and eight showed a decrease in the occlusal plane ranging from 2^{o} to 9^{o}. Thus the over-all change was that the occlusal plane tends to decrease its angulation to the cranial base with age.

The mandibular plane showed similar variations. Ten out of 19 had no change in the mandibular plane angle with the cranial base. One individual had an angular increase of 3^{o}. Eight cases had a decrease in the mandibular plane angle of 3^{o} to 7^{o}.

Bjork (9) did a cross-section study comparing the facial prognathism of 322 twelve-year old Swedish boys with 281 Swedish conscripts. He found that there was an increase in prognathism during growth, with a greater increase in the mandible than the maxilla. This mandibular increase straightened the profile and decreased the overjet, causing an uprighting of the incisors. He also found that the occlusal plane (drawn from the maxillary incisal point to the distal cusp of the maxillary first molar) had a decrease in its angulation to the cranial base of 2.82 ± 0.34^{o}. The mandibular plane changed less than 1^{o} in relation to the cranial base:

Conscripts	55.01 ± 0.39^{o}
Boys	55.19 ± 0.29^{o}

The palatal plane also changed less than 1^{o} in relation to the cranial base:

Conscripts	26.30 ± 0.20^{o}
Boys	25.98 ± 0.16^{o}

The mandibular-occlusal plane angle increased 2.89^{o}.

In 1952 Lande (28) found in a mixed longitudinal and cross-section study of 34 males from three years to eighteen years of age that there was an increase in mandibular prognathism, which generally occurred after seven years of age. He also found a decrease in the mandibular plane angle to S.N., which was associated with the increase in prognathism. This angular change was a decrease of 2.2^{o} between the ages of twelve to eighteen years.

Cohen (17) did a serial lateral cephalometric roentgenographic study of 47 Caucasians - 25 males and 22 females - who had no orthodontic treatment. He obtained two roentgenograms on each person - one at 8 years $\pm$ one year, the second age 16 years $\pm$ one year. Cohen also found variations of growth. For boys he found the mean change in the mandibular plane angle to be -3.3^{o} with a standard deviation of 3.14 and a range of -8.0 to +4.0. The girls had a change in angulation of -4.1^{o} and a standard deviation of 2.16 with a range of -8.0 to 0.6^{o}.

Downs (19) studied the growth patterns of untreated patients with normal occlusions and untreated Class II, Division 1, malocclusions. His sample was "small but carefully selected".

The normal occlusion group included 10 patients with an average age of seven years eleven months at the start of the study and sixteen years one month at the end. From this sample he found the following changes in the Frankfort horizontal-mandibular plane angle:

7 yrs. 11 mos.	26.0^{o}
16 yrs. 1 mo.	$\underline{21.8^{o}}$
Mean change	-4.2^{o}

The range in angulation was from -1.0^{o} to -9.0^{o}.

The untreated Class II, Division 1, sample included 8 patients with an average age at the start of the study of six years five months and thirteen years at the end. Here he found the following changes in the Frankfort horizontal-mandibular plane angle:

6 yrs. 5 mos.	27.7°
13 yrs.	27.5°
Mean change	-0.019°

The range of angular changes was from +3.5° to a -3.5°.

From Downs' sample one can easily see differences in the growth patterns of normal occlusions with those of Class II, Division 1 malocclusions.

Ricketts (33) studied a sample of untreated malocclusions for a 30-month period. He divided this sample into two groups:

Group I — 50 patients with Class I malocclusions and an average age of 8.1 years.

Group II — 50 patients with Class II malocclusions and an average age of 8.1 years; 24 were Class II, Division 1, and 26 were Class II, Division 2.

In studying the mandibular plane, he reported both groups had a slight decrease in angulation during this 30-month period of .5° and .6° respectively.

The palatal plane in the Class I group had no change in angulation, but the Class II group had an increase of 0.2°. Thus, the A.N.S. dropped more than the P.N.S.

The occlusal plane in both groups had a decrease in its angulation to the cranial base during growth.

Silverstein (39) did not find any difference in the growth trends of untreated Class II, Division 1 malocclusions compared with those of untreated normals. The variations that exist are not of statistical significance, but are due to normal variations of the same population. In both groups he found that the mandibular plane angle decreased with age.

In summary, variations in the palatal, occlusal, and mandibular planes are evident with growth. The palatal plane tends to drop faster at A.N.S. than at P.N.S., but this change in angulation is very small. The occlusal plane angle also tends to decrease with growth, but this change is also very slight. The decrease in angulation of the mandibular plane has greater variation: from -0.6^{o} to -4.2^{o}. From these samples one must agree with Silverstein that the mandibular plane decreases with age, but the amount of decrease depends on individual variation.

Growth Changes With Orthodontic Treatment

Brodie, Downs, Goldstein, and Myer (15) presented the first cephalometric appraisals of orthodontic results. They found that in all cases where Class II elastics were worn the angle formed by the occlusal plane to the Bolton plane opened; where Class III elastics were worn this angle closed. The change in the angulation of the occlusal plane was due to the elongation of the teeth at both ends of the elastic

traction, and the rotation of the mandible. The amount of change in angulation seemed most dependent upon the amount of time the elastics were worn. They also found that the occlusal plane had a tendency to return to its original angulation following treatment; but this change tended to diminish with age.

Downs (15) analyzed the lateral cephalometric roentgenograms taken of six patients before treatment, after treatment, and after retention. He found a variation in the changes of the mandibular plane. One patient had no change in angulation, while five patients had an opening of .5° to 4°. During retention the mandibular plane remained constant in two patients; in three patients it closed slightly; one had an opening of 3.5°. Similar variations were found in the palatal plane. The most variable palatal plane angle was that of a female patient who had an opening of 1.5° with treatment, and this angle closed 2.5° during retention.

Epstein (20) found, in 1948, that there were no significant changes in the mandibular, palatal, and occlusal planes in 12 patients treated with extraoral anchorage (headcap).

Silverstein (39) reported, in 1954, that the mandibular plane angle decreased in both treated and untreated males. The amount of angular decrease was less in the treated males than in the untreated males; therefore, the expected growth potential was not attained. In untreated females the mandibular plane angle decreased the same as in the untreated males. The treated females had an increase in the man-

dibular plane angle. The growth trend of the treated females was altered more by orthodontic treatment than in the treated males.

Tovestein (42) reported, in 1955, on 81 Class II non-extraction orthodontically treated cases. Each case had a lateral cephalogram before treatment, at the end of treatment, and two years after treatment. He found that the patient who exhibited the greatest growth during treatment had the least change in the inclination of the occlusal plane. The patients having the least growth had the greatest change in the occlusal plane inclination. The mean angular differences were 4.0^{o} for the growers and 7.48^{o} for non-growers. The after treatment records showed that the occlusal plane on the group exhibiting the most growth had the greatest tendency to return to their original readings. The opposite was found for the non-growing group whose occlusal planes showed much less tendency to return to the before-treatment readings. The total mean angular changes in the occlusal plane of the growers in the period before treatment and the period of two years after treatment was 1.88^{o}. The non-growers had a change in angulation of 5.88^{o}.

In 1957, Klein (27) studied 24 cases that were treated with the Kloehn type appliance. He found that there was an average increase in the angulation of the palatal plane of 1.75^{o}. The greatest increase was 4^{o}. Of his sample,

20 cases showed an increase in
angulation of the palatal plane

4 cases had no change

0 patients decreased in angulation

He measured the angle formed by the occlusal plane and the mandibular plane and found very little change in angulation. The mean change was an increase of .5° with a range of +3° and -2° change.

King (26) also studied the effects of cervical anchorage on 50 treated patients. He found slight changes in the occlusal and mandibular planes. He did not study the changes in the palatal plane.

Blueher (10) studied the cephalograms of 34 patients who were treated with a full edgewise appliance and cervical anchorage. He found that the mandibular plane had a mean increase in its angulation. The angulation in the majority of boys either decreased or remained the same, but the majority of girls had an increase in angulation. The palatal plane increased in the majority of boys and girls, but he speculated on the possibility of a tracing error. The greatest increase was +5° and the largest decrease in angulation was -1.5°.

Ricketts (33) studied the effects of orthodontic treatment on facial growth and development. In studying the mandibular plane he found that in the 50 combination treatment cases, i.e., anchorage control with headgear, there was a decrease in angulation of -1°.

He found that the palatal plane had an increase of +1.6° in the 50 patients treated with a headgear alone. The combination treatment with anchorage control cases had an angular increase in the palatal plane of +1.3°. In 50 patients treated with intermaxillary elastics

alone there was no change in the palatal plane angulation. The occlusal plane had an increase in angulation of +3.4° in patients who were treated with intermaxillary elastics. The combination treatment and anchorage control group had an increase of +2.4° in its angulation with anterior cranial base.

Clark (16) studied the changes in angulation of the palatal, occlusal, and mandibular planes as a result of orthodontic treatment. His sample consisted of 87 Class II, Division 1 malocclusions: 48 were female and 39 were male. Cephalograms were taken before and after treatment. The average age at the start of treatment was 11 years 9 months and the average treatment time was 33 months.

He found that the palatal plane was quite stable during treatment. The mean change in its angulation was +.5°. The greatest increase was +5° and the greatest decrease was -5°.

48 patients increased in angulation

27 patients decreased in angulation

12 patients had no change in angulation

The occlusal plane was also fairly stable. The mean change was an increase in angulation of +1°. Here the greatest increase was +9° and the greatest decrease was -7°.

48 patients had an increase in angulation

28 patients had a decrease in angulation

11 patients had no change

The mandibular plane had a mean angular change of less than 1^{o}. The mean before treatment reading was 32.6^{o} and the mean after treatment reading was 33.1^{o}. The largest increase in angulation was 8^{o} and the largest decrease was -7^{o}.

45 patients had an increase in angulation

26 patients had a decrease in angulation

16 patients had no change

Amason (1) found that the treatment of Class II malocclusions with extraoral anchorage only - no intermaxillary elastics - caused no change in the inclination of the occlusal plane. The cases treated with Class II elastics exhibited a significant change in the occlusal plane. Each of his samples consisted of 11 patients.

Turchetta (43) studied 50 patients - 34 females and 16 males - treated with the Begg orthodontic technique. Some of his findings were:

1. The occlusal plane tends to increase its angulation with the sella-nasion plane.
2. Class I and Class II cases behaved the same.
3. There was no significant difference in the extraction and non-extraction cases.

The occlusal plane to the sella-nasion plane had a mean change of $+2.5^{o}$ with a range of $+10^{o}$ to -4.5^{o}.

36 cases showed an increase in angulation

11 cases showed a decrease in angulation

3 cases showed no change

He also measured the occlusal plane-mandibular plane angle. Here he had a mean decrease of -1.39° with a range of -6° to +4°.

36 cases had an increase in angulation

10 cases had a decrease in angulation

4 cases had no change

Phillips (30) studied 14 patients - 13 females and 1 male - who were treated with the light wire differential force technique advocated by Begg. Before treatment, after treatment, and after retention roentgenographic cephalograms were obtained for each patient. From these he found that the occlusal plane-Frankfort plane angle increased +9.7° during treatment. There was no significant change in this angulation during retention.

The mandibular plane-Frankfort plane angle increased +6.7° with treatment, and it decreased -5.6° during retention. Therefore, he found only a total change of +1.1°.

The occlusal plane-mandibular plane angle decreased during treatment by -6.7°, but it increased +3.8° during retention. One patient had an increase of +22° in this angle during retention; the other patients had very slight increases in the occlusal plane-mandibular plane angle; and one patient even had a decrease of -1.5°.

R. J. Williams (45) found in his patients treated by the Begg technique that the mandibular plane angle increased during the first two stages of treatment. Then, during the third stage, he found that

it decreased in angulation. After treatment the mandibular plane angle occasionally would close significantly to an angulation less than the before-treatment reading. This decrease in angulation of the mandibular plane in both the third stage and post-treatment to the original reading, or even less, he feels depends upon the fundamental inherent growth characteristics of the patient.

Mathew Guido (21) studied the effect of Class II traction on the maxillary complex of patients treated by the Begg technique. He had a sample of 50 patients who had an average at the start of treatment of 12.60 years and at the end of treatment 14.96 years. He used sella-nasion as his reference plane and measured the angulation of the palatal and mandibular planes.

Guido found the following changes in the S.N.-palatal plane angle:

Mean pre-treatment angle	7.41° S.D. 3.65
Mean post-treatment angle	8.32° S.D. 3.37
Net change	0.91°

The T score was 3.34, which has a level of significance of 1%. In this sample the following changes occurred:

37 patients increased in angulation

10 patients decreased in angulation

3 patients had no change

The palatal plane, in reference to the anterior cranial base, had a mean change in angulation of 0.91°. The anterior nasal spine

tended to drop slightly more than the posterior nasal spine.

He found no statistically significant change in the mandibular plane in its relation to the anterior cranial base. He had the following results:

Mean pre-treatment angle	35.00° S.D. 5.18
Mean post-treatment angle	35.40° S.D. 5.18
Net change	0.40°

The T score was .41, which was not a significant change. In this sample the following changes occurred:

28 patients had an increase in angulation

19 patients had a decrease in angulation

7 patients had no change

In summary, the growth changes during conventional edgewise treatment will be separate from the Begg treatment. With conventional edgewise orthodontic treatment there are only small angular changes in the palatal plane. It appears that when headgear is used a greater increase in angulation will occur. This increase is only slightly greater - less than 1°. The occlusal plane increases its angulation to anterior cranial base during treatment. The average angular increases range from +1.0° to +3.4°. In all samples there were isolated decreases. The greatest increases in the angulation of the occlusal plane occur when intermaxillary elastics are used. When headgear was used alone there were no angular changes in the occlusal plane. The mandibular plane had an average change in its

angulation ranging from -1^{o} to $+1^{o}$. Isolated cases had changes in angulation of the mandibular plane ranging from $+8^{o}$ to -7^{o}. Therefore, one can see the importance of large samples.

The study done on the Begg technique by Phillips does not agree with the studies by Guido and Turchetta. The mean angular change of the occlusal plane, according to Turchetta, was $+2.5^{o}$, while Phillips reported it to be $+9.7^{o}$. The occluso-mandibular plane angle had a similar disagreement in the mean angular change. Phillips found a change of $+6.7^{o}$ while Turchetta reported the mean angular change to be $+1.35^{o}$. The mandibular plane had a change in its angulation of $+6.7^{o}$, according to Phillips, but Guido states that there was no significant change in the angulation of the mandibular plane during Begg orthodontic treatment. From these studies one can see a wide variation in the results. These variations are due to sample size and experimental design. Phillips must be criticized for his sample size (14 patients) and the plane of reference that he used (Frankfort horizontal).

Factors to be Considered in Changing the Occlusal and Mandibular Planes

Reidel (31) stated that mandibular plane inclination probably cannot be altered permanently by treatment unless it is in a negative direction. Thus, if one increased the inclination of the mandibular plane with treatment and no growth potential remained, the return of

the mandibular plane to its original inclination would probably increase the overbite. If one has grown, and the maxillary and mandibular teeth are retained with a minimum of overbite, one can expect an increase in posterior facial height with a leveling of the mandibular plane without increasing the overbite. He also believed that the occlusal plane could not be altered permanently except in a negative direction. The tipping of the occlusal plane during treatment with Class II elastics was undesirable when no further growth could be expected. This was due to the uprighting of the occlusal plane during and after retention, which would cause an increase in the overbite and an end-to-end molar relationship.

Holdaway (22) also felt that altering the occlusal plane was undesirable because it would tend to return to its original angulation. He stated that Class II elastics without anchorage control would elevate the lower molars, elongate the maxillary incisors, and depress the lower incisors, thus tipping the occlusal plane. When the appliances are removed the occlusal plane would tend to upright itself because of the downward growth of the upper depressed molars and the elongation of the depressed lower incisors to their correct heights. He felt that these undesirable effects could be overcome by anchorage preparation with a high-pull headgear thus counteracting the undesirable effects of Class II elastics.

F. F. Schudy (36), however, took the opposite point of view. He stated that it was possible to change the occlusal plane, and that

such change occurred. It would increase its angulation with Class II elastics and this would tend to remain increased if good function resulted. The changes in the occlusal plane after treatment occurred because of growth. He stated, "We must not think of post-treatment occlusal plane changes as a rebounding reaction, as though something returns to where it once was. This seldom, if ever, happens, but depressed incisors, in some cases, do subsequently extrude. The same kind of growth that causes this plane to flatten before treatment also causes it to flatten after treatment. In a high percentage of cases the occlusal plane does not change subsequent to treatment unless there is post-treatment growth." (38)

The mandibular plane could be altered, according to Schudy. If one increased the mandibular plane downward, it would not return to its original relationship except with the occurrence of late condylar growth that would tend to carry the chin forward.

The occluso-mandibular angle - "OM angle" - positions the teeth in a vertical plane. "It is thought to be an indicator of the vertical growth of the alveolar process as related to the vertical growth of the ramus and condyle, and significantly related to vertical overbite" (36).

The average OM angle is 16^{o} with a range of $+5^{o}$ to 6^{o}. To the extreme are two dramatically opposed individual types. The patients with a low OM angle (below 11^{o}) are hypo-divergent cases. These have excessive anteroposterior growth and lack vertical

growth. These patients have excessive overbites and it is difficult to correct and maintain within acceptable limits. On this type of patient Class II elastics are very desirable. The molars should be moved occlusally as much as possible; thus tipping the occlusal plane. Lower incisors should not be depressed if this is possible.

Patients with a high OM angle (over 21°) are hyper-divergent cases. These have an excess of vertical growth in the anterior facial height as compared to the posterior facial height. These patients tend to have open bites. Class II elastics on these patients are very undesirable because they will tend to aggravate the situation by elevating the molars, and tipping the occlusal plane. Thus one can see that different treatment procedures should be used in the extremes of the OM angle.

In summary, one can see that there are variations in opinions that might be alleviated by more thorough analysis of treatment results.

METHOD AND MATERIALS

This study was designed to investigate the following:

1. To determine the changes which occur in the angulations of the palatal, occlusal, and mandibular planes in patients treated by the Begg technique.
2. To determine the angular changes which occur in these anatomic planes after the completion of the Begg orthodontic treatment.
3. To analyze statistically these angular changes and determine their significance.
4. To determine if there is a significant difference in the treatment response of males and females.
5. To determine if there is a significant difference in the treatment response of Angle's Class I and Class II malocclusions.

In order to determine the angular changes which occurred during orthodontic treatment, two lateral roentgenographic cephalograms were obtained for each patient - one before treatment and the second at the completion of treatment. The average time between cephalograms one and two was 29 months. A third cephalogram was also obtained for each patient. This was used to determine the changes in angulation that occurred in the palatal, occlusal, and mandibular planes after the completion of treatment. The average time between

cephalograms two and three was 21 months.

The lateral roentgenographic cephalograms for this study were obtained from three orthodontists in private practice. Three cephalograms for each of 45 patients were used for this study - there were 22 females and 23 males. Other patient statistics are:

1. The age range at the start of treatment was 10 years to 16 years 7 months.
2. All had four first bicuspids extracted.
3. Twenty-two were Class I. Of these, 11 were male and 11 were female.
4. Twenty-three were Class II. Of these, 12 were male and 11 were female.

Since there were three cephalograms for each patient, a total of 135 lateral roentgenographic cephalograms was used.

The lateral roentgenographic cephalograms were traced on .003 matt acetate using 2H Eagle turquoise drawing lead. Both the right and left hand structures were traced and an average was determined. Thus all bilateral structures were treated as midline structures. Each cephalogram was traced twice but at a different time.

The following anatomical structures were used (Fig. 1):

S. The midpoint of sella turcica as determined by inspection.

N. Nasion, the external surface of the naso-frontal suture.

A.N.S. Anterior nasal spine, the median process formed by the forward prolongation of the two maxillae at the lower margin of the anterior nasal aperture.

P.N.S. Posterior nasal spine - formed by the posterior midline projection of the palatal portion of the palatine bones.

Go Gonion, the external angle of the mandible. It is located by bisecting the angle formed by tangents to the posterior border of the ramus and the inferior border of the body of the mandible.

Me Menton, where the inferior border of the mandible meets the cross-section of the symphysis.

The following planes were used (Fig. 1):

Anterior cranial base plane (S.N.) - a line connecting S. and N.

Palatal plane - a plane connecting A.N.S. and P.N.S. as determined by inspection.

Natural occlusal plane - a plane which approximates the best line of occlusion of the buccal segments as determined by inspection (24).

LANDMARKS, PLANES, ANGLES

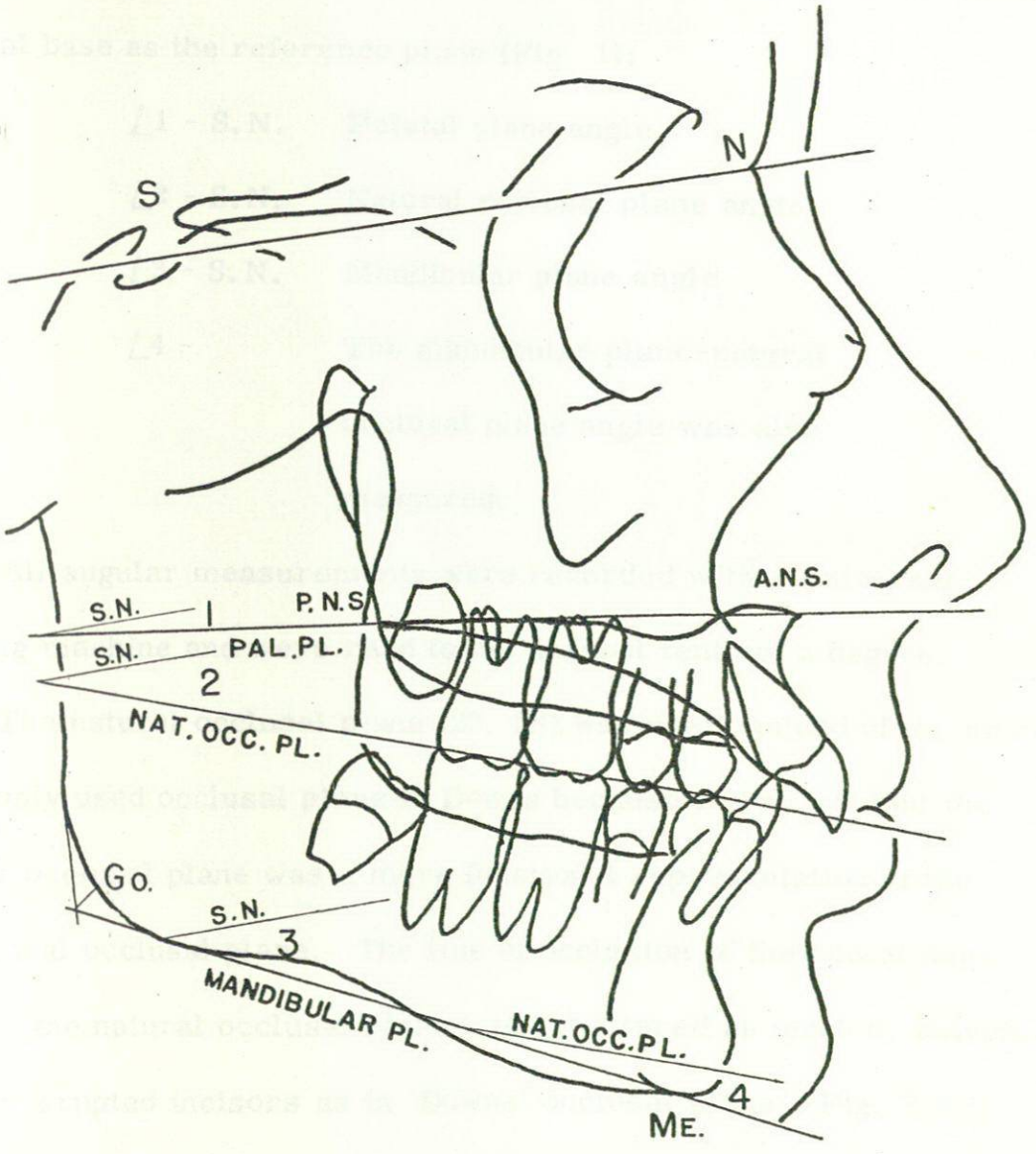


FIGURE 1

Mandibular plane - a line at the lower border of the mandible tangent to the gonion angle and the profile image of the symphysis (18).

The following plane angles were constructed using the anterior cranial base as the reference plane (Fig. 1):

∠1 - S.N. Palatal plane angle

∠2 - S.N. Natural occlusal plane angle

∠3 - S.N. Mandibular plane angle

∠4 - The mandibular plane-natural occlusal plane angle was also measured.

All angular measurements were recorded with a Universal drafting machine and were read to the nearest tenth of a degree.

The natural occlusal plane (23, 29) was used instead of the more commonly used occlusal plane of Downs because it was felt that the natural occlusal plane was a more functional representation of the anatomical occlusal plane. The line of occlusion of the buccal segments - the natural occlusal plane - is not altered as much by extremely over-erupted incisors as is Downs' occlusal plane. Fig. 2 will illustrate this difference. In such cases it would tend to diminish the tipping effect of Class II elastics.

The 1080 angular measurements were analyzed by The Department of Statistics of Western Reserve University.

TWO OCCLUSAL PLANES

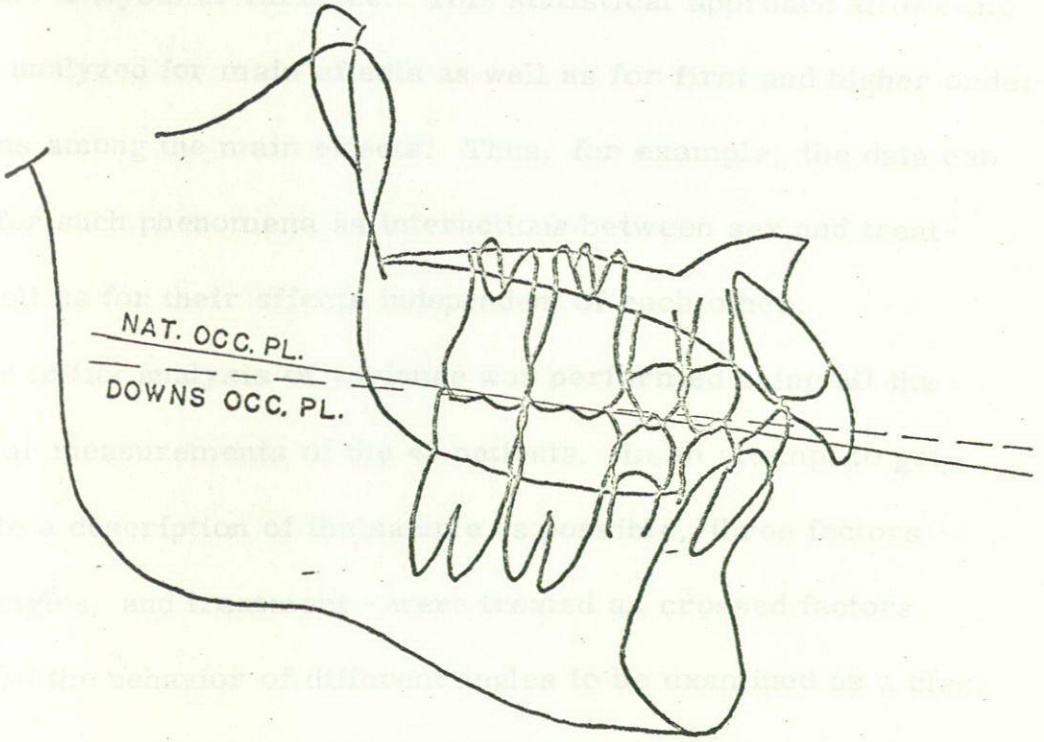


FIGURE 2

FINDINGS

The general technique used in analyzing this experimental data was the analysis of variance. This statistical approach allows the data to be analyzed for main effects as well as for first and higher order interactions among the main effects. Thus, for example, the data can be tested for such phenomena as interactions between sex and treatment as well as for their effects independent of each other.

The initial analysis of variance was performed using all the 1080 angular measurements of the 45 patients. In an attempt to get as complete a description of the sample as possible, three factors - patients, angles, and treatment - were treated as crossed factors. This allowed the behavior of different angles to be examined as a class as well as within individual patients. For the purpose of analysis the main effects were designated as follows:

1. N - individual patients
2. A - angles
3. T - treatment

The above designations can be expanded in the following manner: "N_1" refers to a specific individual, "N_2" refers to another specific individual, etc. To say that there is an "N" effect is to say that there

are discernible differences between individuals. For example, one individual may have a larger cranium with a different angular configuration of the anterior cranial base than another individual. This could cause all the angles to have a larger or smaller value than for a second individual. Such a phenomenon would be called an "N" effect, the result of anatomical differences between people.

"A" refers to the four angles measured in this study. The angle is the actual measurement that was taken. Thus, "A_1" signifies the palatal plane angle, "A_2" the occlusal plane angle, "A_3" the mandibular plane angle, and "A_4" the occluso-mandibular angle. To say that there is an "A" effect means that across patients and treatment the various angles will have different mean values.

The third factor considered is the treatment effect "T". This is represented at the three different levels of time - before treatment, after treatment, and after retention. A significant "T" effect would indicate some gross effect of treatment across all angle locations and all patients.

Table 1 gives the results of the analysis of variance performed on all 45 patients using the above three factors in the design. The very highly significant "N", "A","T", "NA", and "NAT" effects are the product of the high variability within and between patients. The "NT" effect indicates an interaction between patients and treatment. This means that some patients respond more to treatment than others. The final, highly significant effect, "AT", indicates that across all patients

Table 1

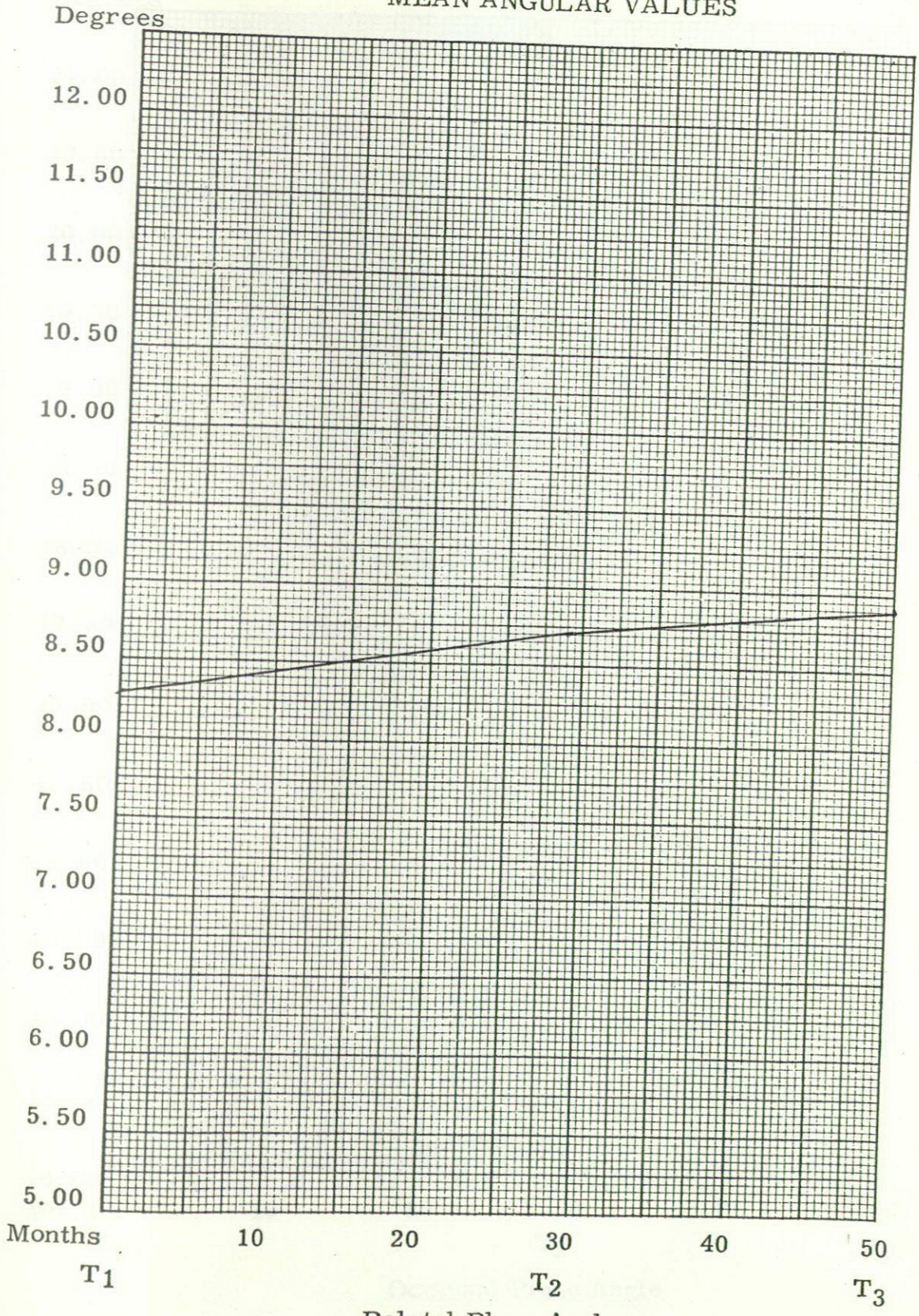
CROSSED ANALYSIS OF VARIANCE

S.V.	S.S.	df	M.S.	F	Fc	Conc.
N	9738.33	43	226.47	167.	1.59	.001 sig.
T	70.08	2	35.04	6.90	4.98	.001 sig.
A	91119.39	3	30373.13	447.	3.95	.001 sig.
NT	437.10	86	5.08	3.76	1.36	.001 sig.
NA	8820.47	129	68.38	50.65	1.44	.001 sig.
AT	263.22	6	43.87	8.14	2.89	.001 sig.
NAT	1391.55	258	5.39	3.99	1.39	.001 sig.
R(NAT)	710.96	528	1.35	---	---	---

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

Fig. 3

CROSSED ANALYSIS OF VARIANCE
MEAN ANGULAR VALUES



Palatal Plane Angle

Fig. 4

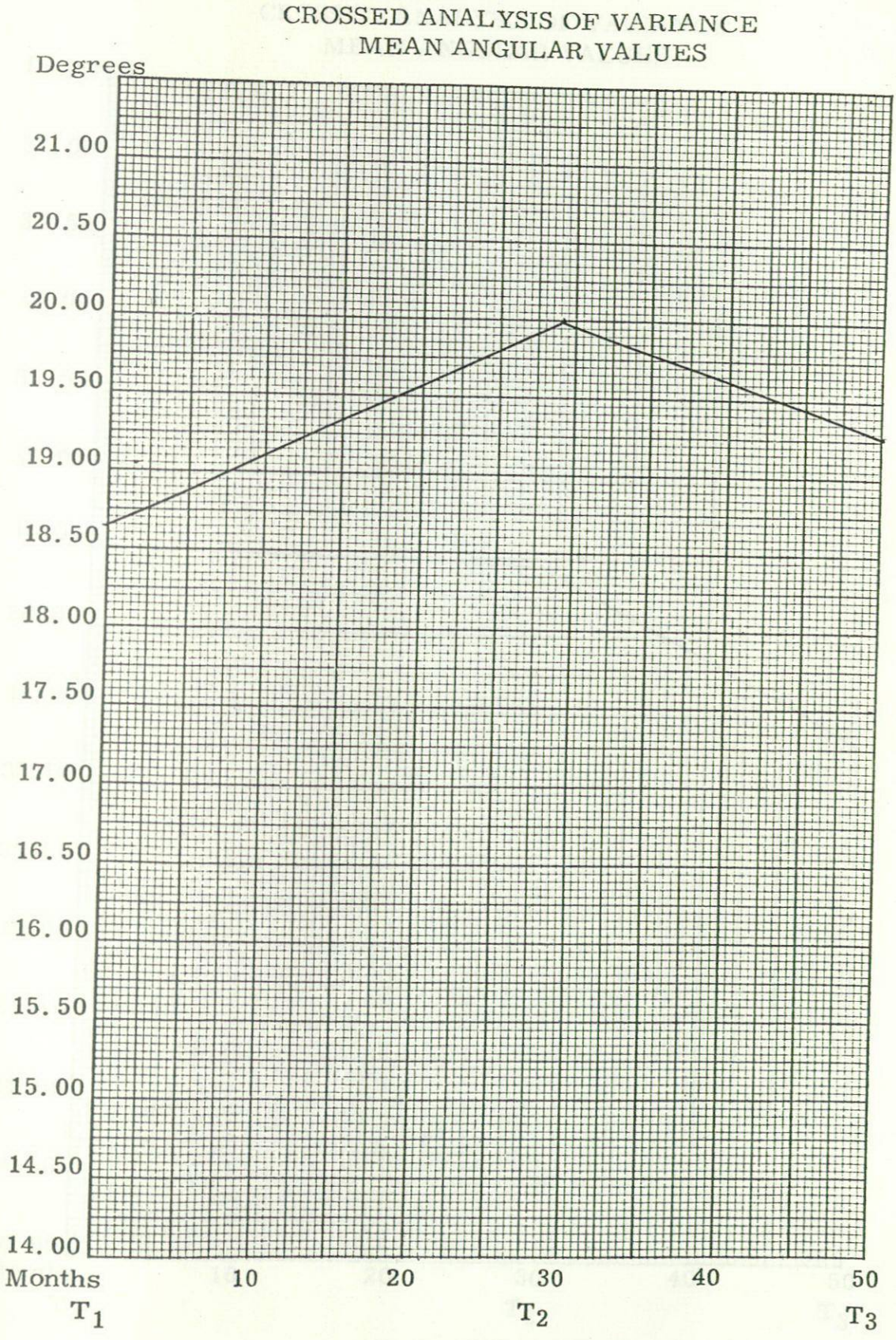
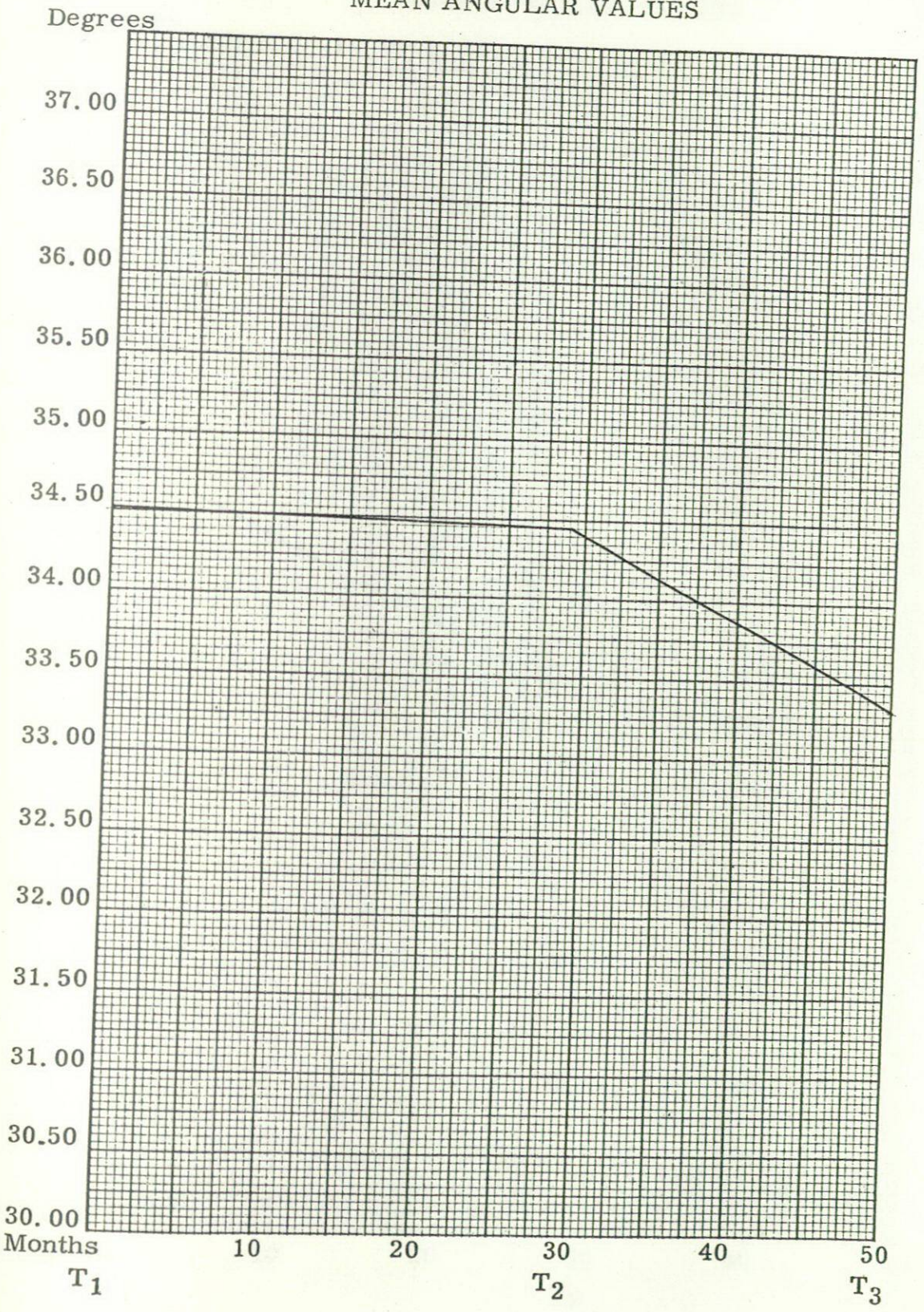

CROSSED ANALYSIS OF VARIANCE
MEAN ANGULAR VALUES
Degrees
21.00
20.50
20.00
19.50
19.00
18.50
18.00
17.50
17.00
16.50
16.00
15.50
15.00
14.50
14.00
Months
10
20
30
40
50
T1
T2
T3
Occlusal Plane Angle

Fig. 5

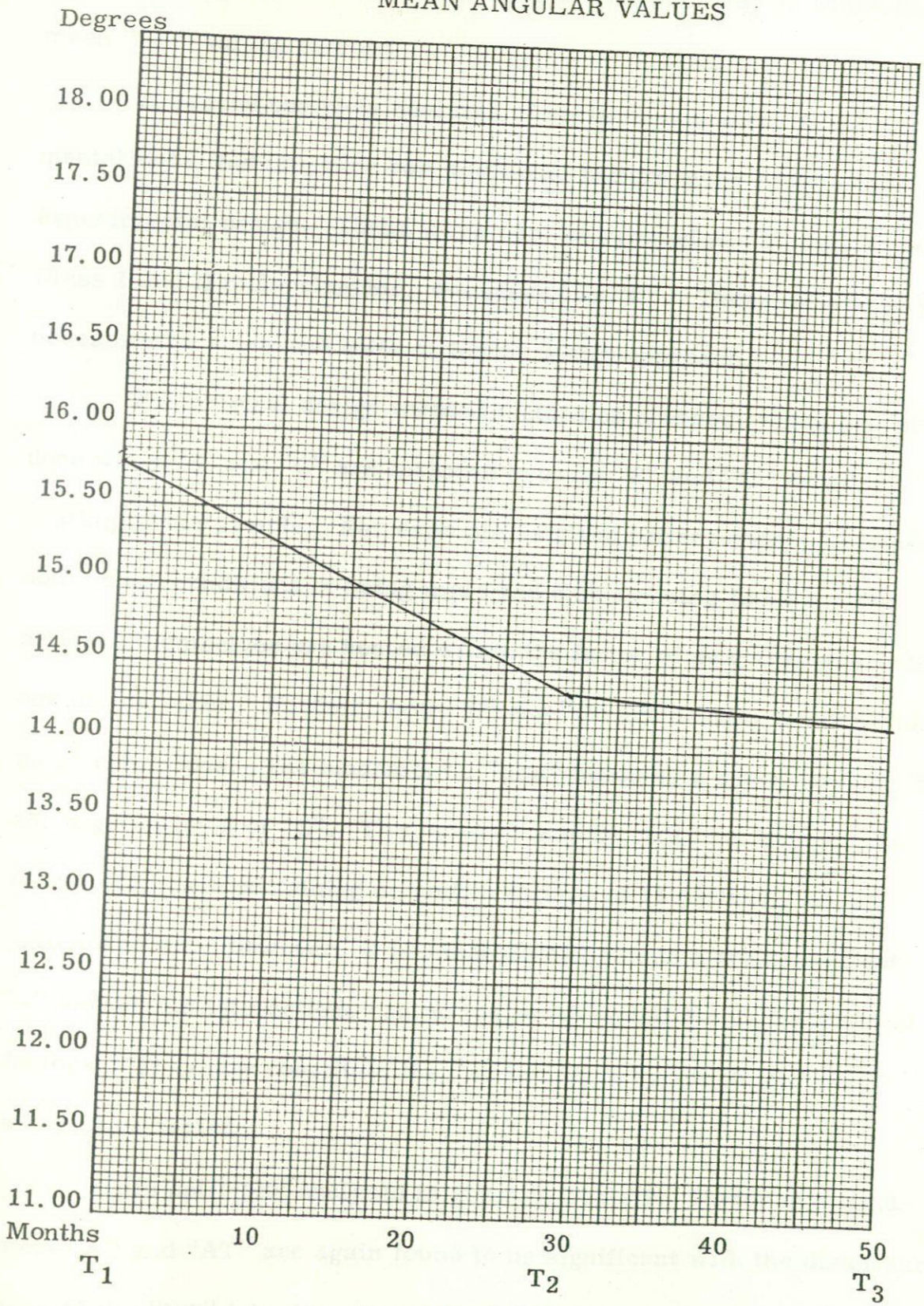
CROSSED ANALYSIS OF VARIANCE
MEAN ANGULAR VALUES



Mandibular Plane Angle

Fig. 6

CROSSED ANALYSIS OF VARIANCE
MEAN ANGULAR VALUES



Occluso-Mandibular Angle

some angles respond differently to treatment than others. Figs. 3, 4, 5, and 6 give a graphic representation of the exact way in which these mean "AT" values respond.

A second complete analysis of variance was done on the experimental data, but this time two additional factors were added to the experimental design. These were sex, designated as "S" and Angle's Class I and II malocclusions, designated as "C". These new factors necessitated a new and quite different design approach.

The original design treated factors as crossed. This cannot be done when "S" and "C" are included because "S" and "C" require nesting of the sample. For example, a given patient cannot be tested both under conditions of being male and also as being female. The patients themselves are nested within the factor of sex; they are either one or the other. Further, both "S" and "C" are nesting factors under these conditions. The fundamental "plot" becomes a given level of "S" and a given level of "C". The original sample could be divided into four plots, each containing a random sample of 11 patients, or 44 patients in all. However, it is fundamental to such a treatment that "N" and all its interactions can no longer be tested for as independent factors. They now constitute the "error" term by which the "real" effects are tested.

This split-plot analysis is given in Table 2. Under this treatment "A" and "AT" are again found to be significant with the disappearance of the "NT" into the error term. "T" is found to be significant.

Table 2

SPLIT-PLOT ANALYSIS OF VARIANCE

S.V.	S.S.	df	M.S.	F	Fc	Conc.
S	544.5337	1	544.5	2.57	4.08	no sig.
C	499.2725	1	499.3	2.36	4.08	no sig.
SC	232.8667	1	232.87	1.10	4.08	no sig.
N(SC)	8461.7133	40	211.54	---	---	---
T	70.0781	2	35.04	6.70	4.88	.01 sig.
TS	17.2017	2	8.60	1.64	3.11	no sig.
TC	.6704	2	.335	<1	---	no sig.
TSC	.6313	2	.316	<1	---	no sig.
TN(SC)	418.6011	80	5.23	---	---	----
A	91119.391	3	30373.13	448.7	3.94	.001 sig.
AS	370.5737	3	123.52	1.82	2.68	no sig.
AC	31.5874	3	10.53	<1	---	no sig.
ASC	295.6133	3	98.54	1.46	2.68	no sig.
NA(SC)	8122.6972	120	67.69	---	---	---
AT	263.2183	6	43.87	8.45	2.90	.001 sig.
ATS	32.1528	6	5.359	1.03	2.14	no sig.
ATC	97.7095	6	16.28	3.14	2.90	.01 sig.
ATSC	15.4336	6	2.57	<1	---	---
ATN(SC)	1246.2509	240	5.19	---	---	---
R(ATHSC)	710.9570	528	1.3465	---	---	---

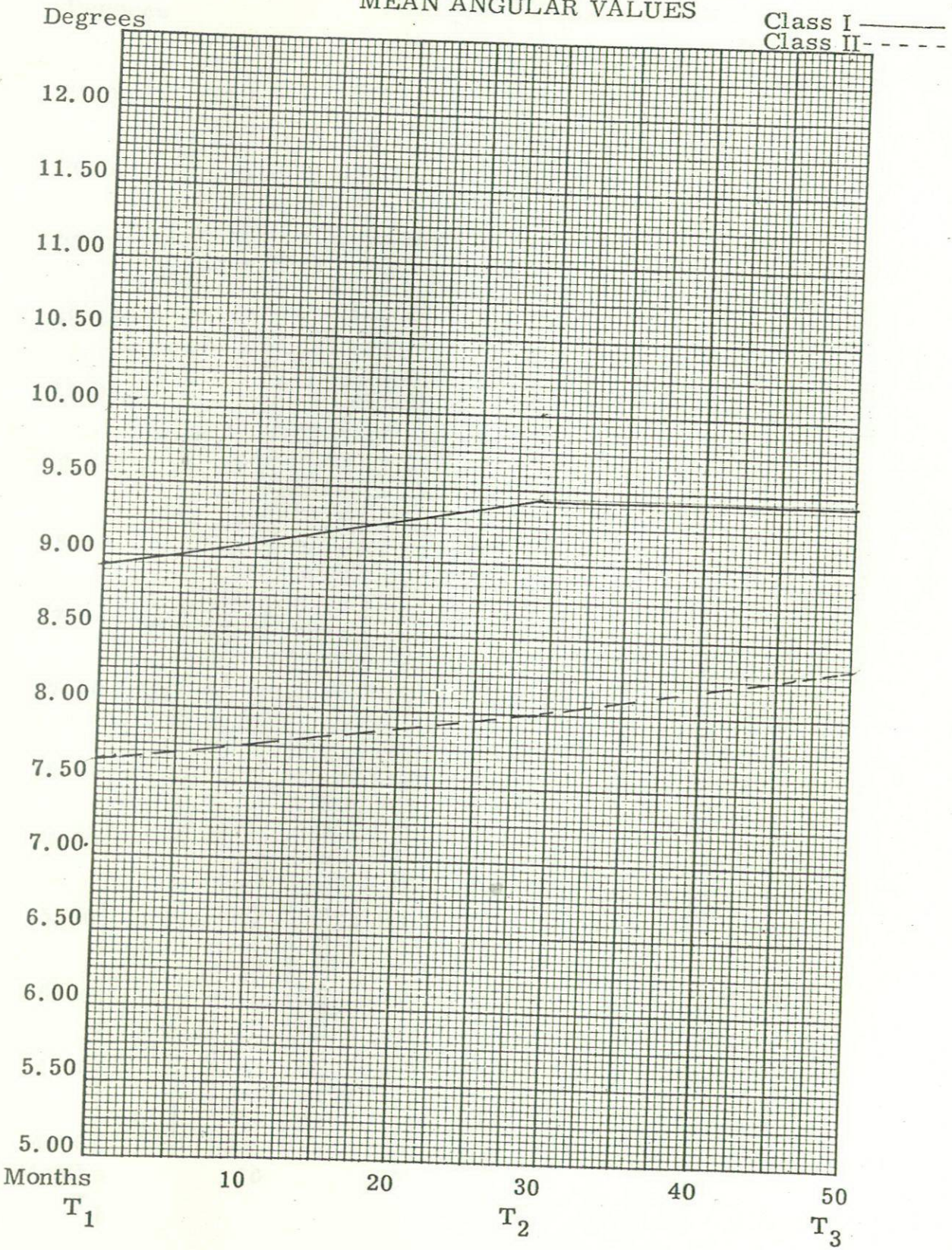
S.V. - source of variance
S.S. - sum of squares
df - degree of freedom
M.S. - mean of squares
F - F test
Fc - F critical
Conc. - conclusion

It is this "ATC" term that is of interest to us. This means that across both classes - Angle's Class I and Class II - some angles respond differently to treatment than others. Figs. 7, 8, 9, and 10 graphically represent the mean "ATC" responses.

There were no significant interactions for sex. Thus both males and females responded alike. Table 2 illustrates this.

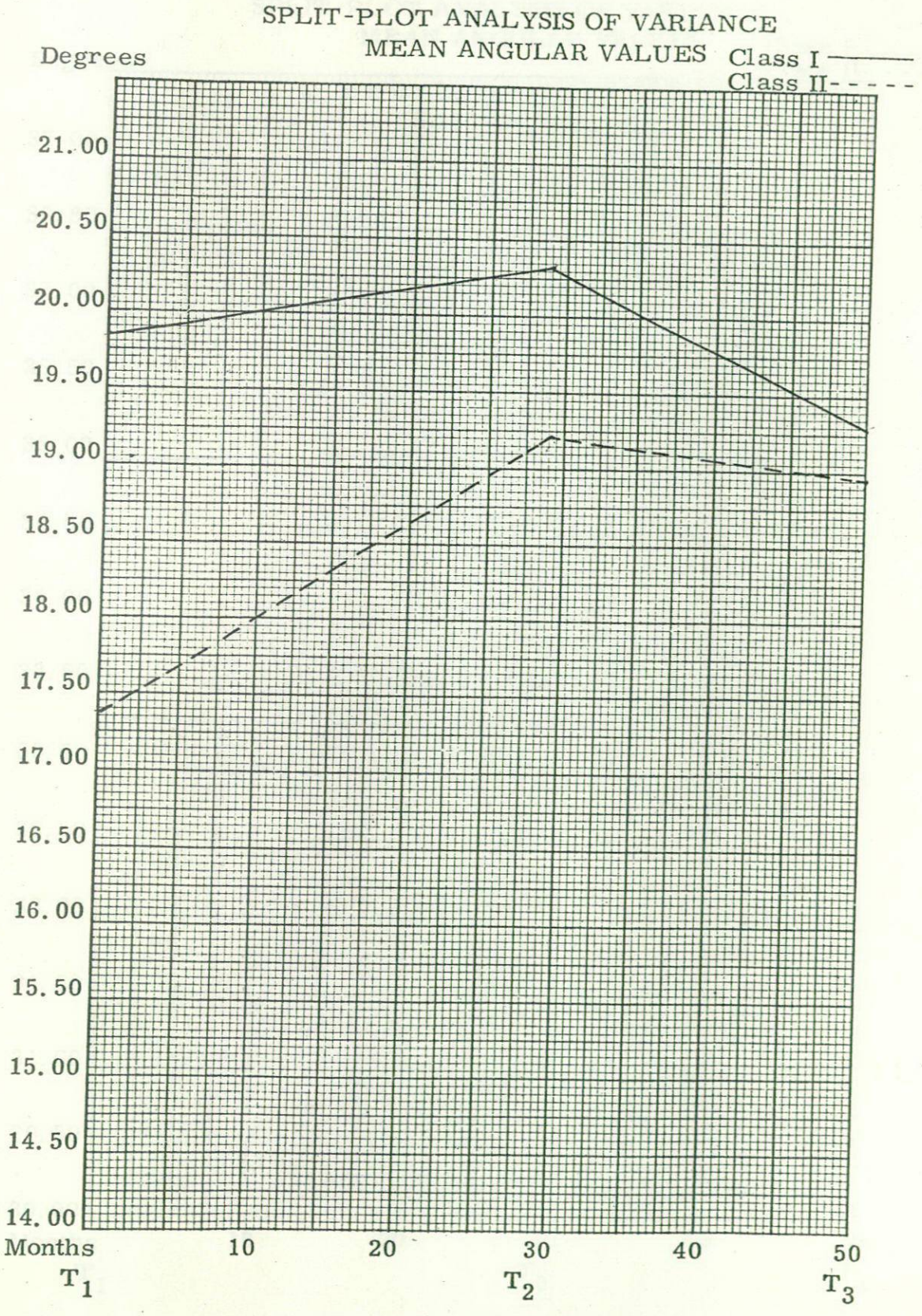
Fig. 7

SPLIT-PLOT ANALYSIS OF VARIANCE
MEAN ANGULAR VALUES



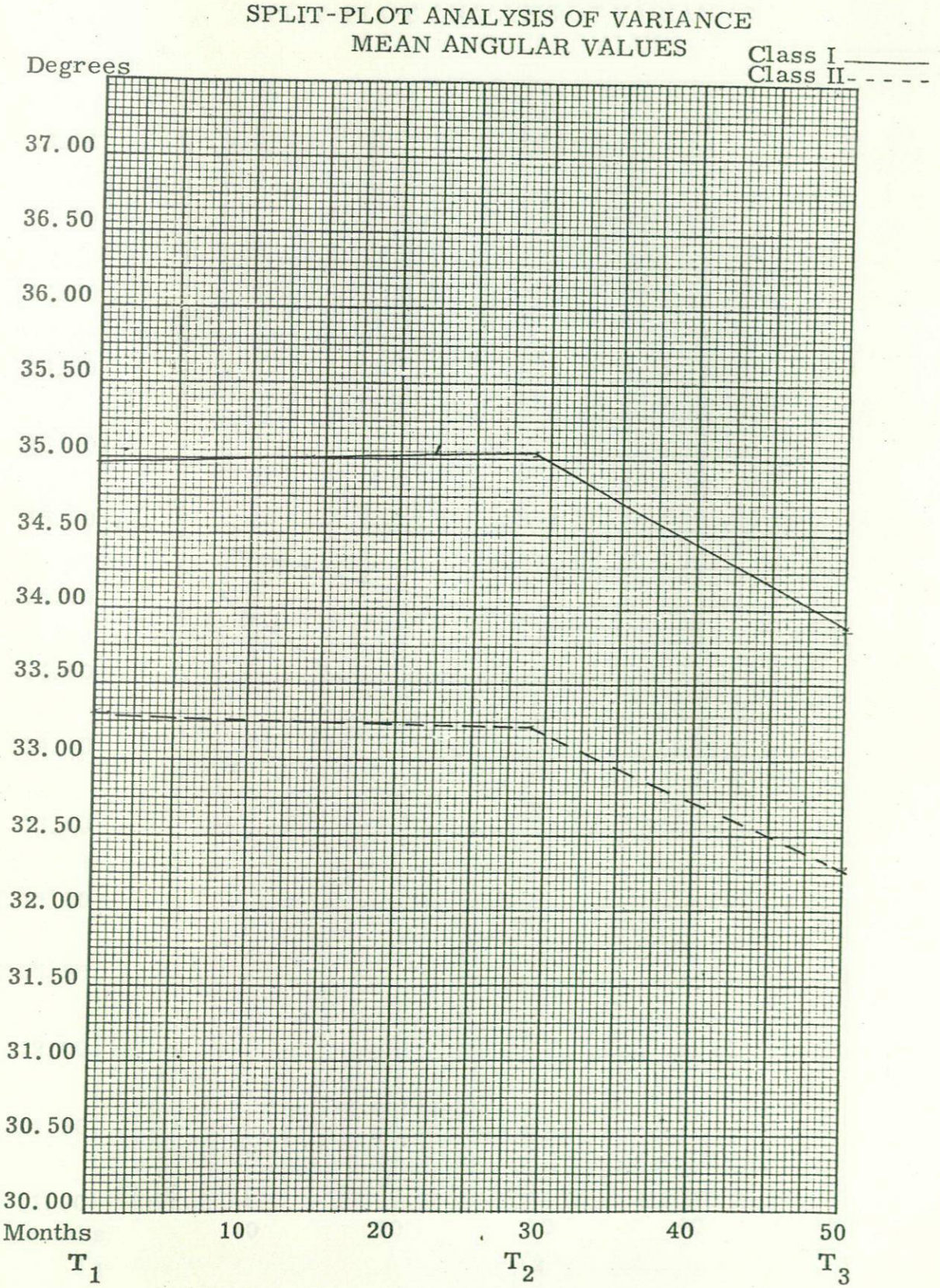
Palatal Plane Angle

Fig. 8



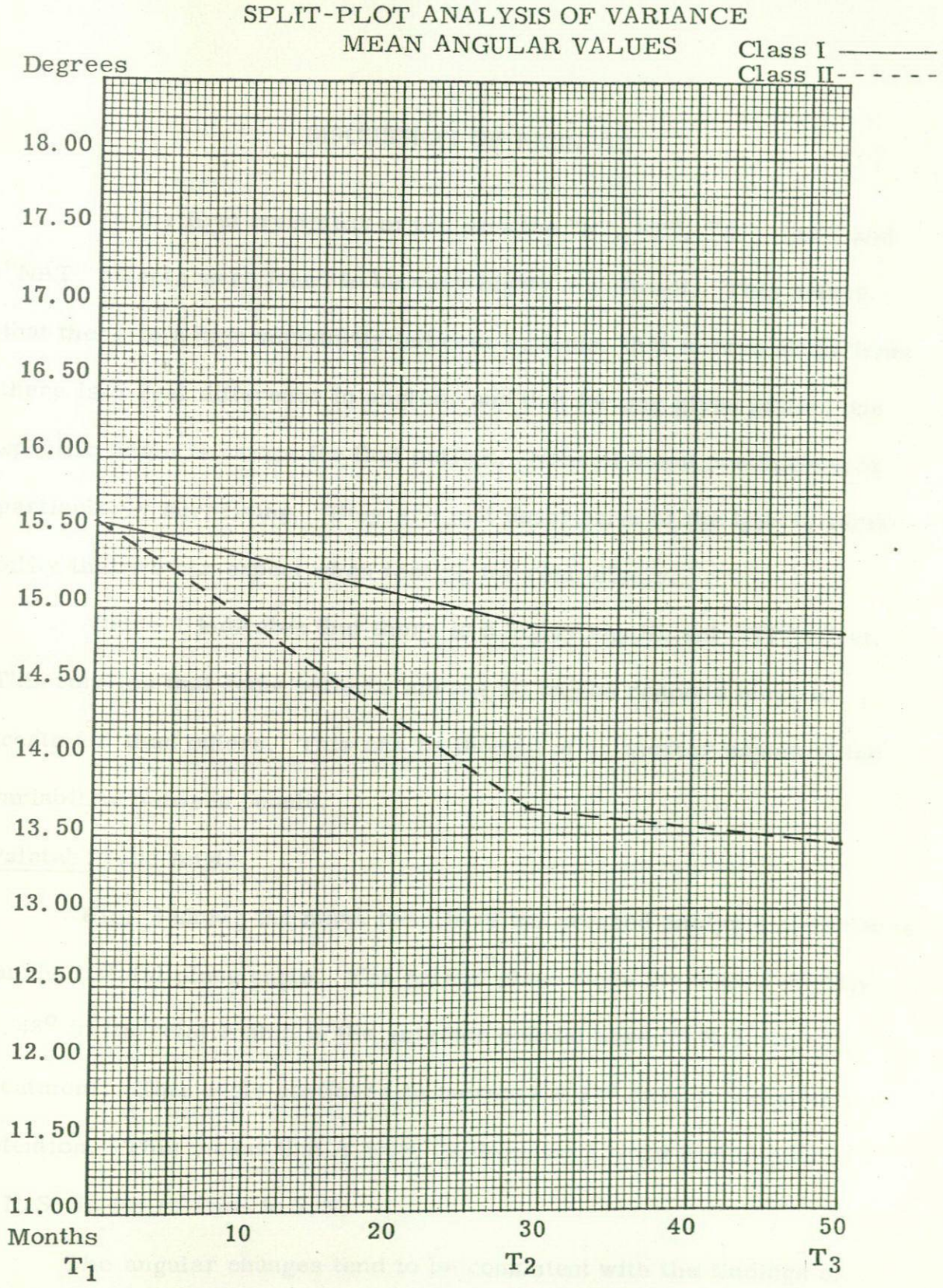
Occlusal Plane Angle

Fig. 9



Mandibular Plane Angle

Fig. 10



Occluso-Mandibular Angle

DISCUSSION OF RESULTS

In the first treatment of the data the "N", "T", "A", "NA" and "NAT" effects were found to be very highly significant. This means that there is a high variability between patients, that across all patients there is a real difference in angles, and that for any given patient one specific angle is unique for that patient. None of these conclusions is particularly surprising. They are just descriptive of the type of variability that we can expect when testing for real effects.

Table 1 indicates that there is a highly significant "NT" effect. This implies that some patients across all angles respond more to treatment than others. This can be thought of as another aspect of the variability between people.

Palatal Plane Angle

Fig. 3 shows the mean results of the crossed analysis of variance for the palatal plane angle. The palatal plane angle increased slightly $+.43^{o}$ in its relationship to the anterior cranial base (S.N.) during treatment. This angle continued to increase $+.19^{o}$ during and after retention. This means that A.N.S. is dropping a little faster than P.N.S. in its relation to S.N.

The angular changes tend to be consistent with the findings of Ricketts (33). The palatal plane is not significantly altered by Class II

elastics. The changes which occurred in the palatal plane seem consistent with growth (9, 33).

Guido (21) found that the palatal plane angle had an increase of $+0.91^{o}$. These results are two times greater than those found in this study. These differences could be due to experimental design.

Occlusal Plane Angle

The occlusal plane angle had a mean increase of $+1.35^{o}$ in its relation to S.N. during treatment. There was a decrease of $-.71^{o}$ after the completion of treatment. (Fig. 4). The treatment changes are consistent with those of Turchetta (43) who found a mean increase of $+2.5^{o}$. The difference in the mean readings is due to the experimental design because Turchetta used Downs' occlusal plane. Fig. 2 illustrates this difference.

After completion of treatment the occlusal plane had a decrease of $-.71^{o}$. This decrease should not be thought of as a rebounding action but as a post-treatment growth change. This change supports completely the finding of Schudy (36-38).

Mandibular Plane Angle

The mandibular plane angle, in its relation to the anterior cranial base, did not change during treatment (Fig. 5). These findings agree with those of Guido (21), who also found no treatment changes. The post-treatment change was a mean decrease of -1.13^{o} in the mandibular plane in its relationship to the S.N. These changes seem consistent with the findings of Bjork (9), Lande (28), Downs (19), Ricketts (33),

and Silverstein (39); i.e., the mandibular plane angle decreases during growth.

Since the mandibular plane angle does not change during treatment, this supports Silverstein's (39) finding that treatment will suppress the expected growth potential. Silverstein found a sex difference in the mandibular plane angle (39). When a split-plot analysis of variance was done for this study no sex differences were discernible.

Occluso-Mandibular Angle

The occluso-mandibular angle had a decrease of -1.42^{o} during treatment (Fig. 6). These results are very consistent with those of Turchetta (43) who found a decrease of -1.39^{o}. Phillips had a greater decrease when he measured the occluso-mandibular plane angle. He had a decrease of -6.7^{o}. This difference is due to differences in experimental design and sample size.

The post-treatment changes in the occluso-mandibular angle continued to decrease. The mean change was $-.17^{o}$. This strongly supports the findings of Schudy (36-38), who says that one can alter the occlusal plane angle and it will remain changed if good function results.

Phillips (30) found a post-treatment increase of $+3.8^{o}$ in the occluso-mandibular angle. It is difficult to account for his findings, but one possibility for these results is that one of his patients had a $+22^{o}$ increase in this angle after treatment and, because of his small sample size, this abnormal change could significantly influence his results.

Split-Plot Analysis of Variance

The split-plot analysis of variance showed an "ATC" effect. This means that some angles responded differently to treatment in Angle's Class I than in Class II malocclusions. These results do not agree with those of Turchetta who said that Class I and II cases behave the same (43). The occlusal plane angle increased nearly four times more in the Class II cases with treatment than in the Class I cases. The opposite occurred after treatment. Here the Class I cases had an angular decrease that was four times greater than in the Class II cases.

The occluso-mandibular angle also responded differently in Class I cases when compared to the Class II cases. The Class II patients had a mean decrease of -1.90° with treatment and the Class I patients had a mean decrease of $-.72^{\circ}$. During and after retention the Class II patients continued to have a greater angular change than the Class I patients. These angular "ATC" responses are graphically represented in Figs. 7, 8, 9, and 10.

The differences which occur in the treatment responses of Class I and Class II patients seem to be mainly limited to the occlusal plane. Because Class II malocclusions generally have greater discrepancies to correct; i.e., bite opening, than Class I malocclusions, it is felt that they should have a greater treatment response.

The split-plot analysis of variance, Table 2, was unable to show any difference in the treatment response of males and females. Silver-

stein (39) said that the mandibular plane was altered more by orthodontic treatment in females than males. Our data does not support Silverstein's findings. No sex differences could be discerned.

SUMMARY AND CONCLUSIONS

This investigation was designed to analyze the changes occurring in the palatal, occlusal, and mandibular planes of patients accompanying and following Begg orthodontic treatment. A total of 45 patients was used. The sample consisted of 22 patients with Angle's Class I malocclusion - 11 male and 11 female - and 23 patients with Angle's Class II, Division 1 malocclusion - 12 male and 11 female. All patients had four first bicuspids extracted. Three lateral cephalograms were used on each patient - before treatment, at the completion of treatment, and on the average of 21 months after the completion of treatment. A total of 1080 angular measurements was recorded and these measurements were analyzed for significance, using the analysis of variance technique.

Summary

The palatal plane had a very slight acceleration in its anterior tipping. It had more tipping than one might expect with normal growth, but so slight that it was not clinically significant. The mandibular plane angle also was not significantly altered during treatment. There was a post-treatment angular decrease in both the mandibular and occlusal planes in their relation to S.N. This decrease is interpreted as normal post-treatment growth. The changes in the occluso-mandibular angle

were both interesting and surprising. This angle exhibited only a slight decrease during treatment, and it did not rebound or relapse after treatment. Since Begg orthodontic treatment involves the use of Class II elastics almost continually, such a small decrease in the angulation of the occlusal plane was most surprising. This small angular change in the occlusal plane suggested that the undesirable tipping of the occlusal plane did not occur during treatment because the elastic force was so light. Even more surprising was the observation that after treatment the occlusal plane did not rebound to its pre-treatment status as is commonly believed. Actually there was a very small, continued decrease in the occluso-mandibular angle during and after retention. It is felt that the continuous use of Class II elastics in the Begg technique is not undesirable because the force is very light and the occlusal plane is not undesirably tipped.

Conclusions

The following conclusions can be made from the results of this investigation:

1. The palatal and mandibular plane angles had no significant mean angular changes during Begg orthodontic treatment.
2. The occlusal plane angle had a significant mean angular increase, and the occluso-mandibular angle had a significant mean angular decrease during treatment.

3. The palatal plane angle and the occluso-mandibular angle had no significant mean angular changes during and after retention.
4. The mandibular plane angle and the occlusal plane angle had significant mean angular decreases during and after retention.
5. Angle's Class I malocclusions had significantly different mean angular changes than did the same plane angles in Class II malocclusions during treatment, and during and after retention.
6. There were no significant differences between males and females in their responses to treatment, or during and after retention.

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APPENDIX

Table 3

ABSOLUTE ANGULAR MEASUREMENTS

	T1				T2				T3			
	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4
N_1	2.7	18.8	37.8	19.3	1.5	16.0	41.3	25.5	3.6	19.3	41.3	22.3
	3.2	18.9	38.0	19.2	3.0	16.5	41.5	25.3	4.2	19.3	41.4	22.4
N_2	8.6	15.4	27.4	12.3	8.0	22.5	26.6	5.5	7.9	19.7	26.2	6.8
	8.0	15.0	27.3	12.6	8.0	22.5	27.0	5.2	8.1	19.8	27.0	7.7
N_3	9.8	18.0	34.7	17.4	11.9	27.0	35.8	8.4	11.3	24.0	34.9	11.0
	9.8	18.5	35.6	17.2	12.1	26.6	34.8	7.8	11.0	24.0	35.0	11.3
N_4	9.1	23.3	44.1	20.6	9.0	25.8	45.9	19.8	9.2	24.5	43.5	19.2
	8.9	23.8	43.6	20.3	10.0	25.4	44.6	19.5	9.8	24.2	43.7	19.7
N_5	5.3	24.4	36.7	12.5	7.0	29.0	38.2	9.5	6.6	26.8	38.8	12.6
	5.2	22.8	36.8	14.0	6.9	28.6	38.0	9.0	6.8	26.8	39.0	12.0
N_6	6.2	18.2	30.0	12.0	7.5	17.3	27.6	10.5	7.0	17.0	27.0	9.5
	7.8	18.6	30.4	12.0	7.4	17.4	27.8	10.8	7.4	17.0	26.9	10.0
N_7	12.5	21.7	43.0	21.5	11.2	19.4	42.1	22.8	11.2	19.9	41.8	22.5
	13.0	22.0	43.0	21.4	11.2	19.3	42.5	23.0	12.0	19.4	41.5	22.4
N_8	5.3	23.4	40.0	16.5	3.4	24.0	39.8	16.0	4.7	21.0	37.5	16.8
	6.4	23.9	41.5	17.8	4.0	24.0	39.4	15.5	4.5	21.5	37.7	16.8
N_9	10.4	20.6	28.0	7.7	9.5	20.5	27.2	6.6	8.5	19.6	26.5	7.0
	10.3	20.8	27.9	7.2	10.0	19.8	27.0	7.1	8.5	19.7	25.8	6.2
N_{10}	9.5	15.6	25.0	9.5	8.5	15.7	24.2	8.5	8.7	16.5	24.5	8.2
	9.0	15.3	26.0	10.6	8.5	15.6	24.0	8.5	8.3	16.5	24.6	8.2
N_{11}	3.0	17.5	35.0	17.3	2.7	14.5	34.0	9.6	4.0	19.5	33.6	14.0
	2.2	18.5	35.2	16.8	2.7	14.0	34.0	10.2	4.5	20.9	33.7	12.8
N_{12}	9.0	22.0	31.9	10.0	8.0	19.5	29.4	10.0	8.0	18.6	28.8	11.0
	9.8	21.7	32.1	10.2	8.3	18.7	30.0	11.1	7.6	16.8	28.6	12.1
N_{13}	9.0	12.8	36.8	14.2	10.0	22.3	36.8	14.4	10.0	22.3	36.0	13.5
	8.4	12.9	36.5	13.7	9.5	22.5	36.6	14.2	9.8	22.0	36.3	14.0
N_{14}	7.1	17.5	35.5	17.5	7.8	15.5	34.9	19.4	8.0	16.0	34.8	18.6
	7.5	17.8	35.3	17.1	7.3	15.6	34.4	18.8	8.0	16.3	34.6	18.4
N_{15}	6.8	14.0	27.0	13.1	7.0	16.1	24.3	8.1	7.8	16.6	23.6	7.2
	6.3	14.0	27.2	13.0	6.6	16.5	24.5	8.0	8.0	16.9	23.7	6.7
N_{16}	9.7	17.8	33.2	15.6	8.1	20.0	33.0	13.0	8.6	19.5	31.9	12.5
	9.6	17.2	32.1	15.5	9.2	20.5	33.4	13.3	8.3	19.5	31.8	12.9
N_{17}	12.4	22.5	42.4	19.6	17.4	20.8	41.0	20.4	16.2	20.4	39.5	19.6
	13.8	23.3	41.8	18.9	17.8	21.8	41.7	20.5	17.6	20.8	39.9	19.0
N_{18}	7.7	17.2	33.8	16.6	7.4	17.3	35.4	18.3	7.5	15.5	33.5	18.2
	6.5	18.0	34.2	16.4	7.2	16.7	36.1	19.6	7.1	15.3	34.0	18.5
N_{19}	4.2	14.0	31.5	17.6	3.9	12.3	29.8	17.8	4.8	12.7	28.9	16.3
	4.3	13.0	31.6	18.6	3.8	12.0	29.8	18.0	4.3	11.5	28.4	16.8
N_{20}	10.3	17.9	38.2	20.6	8.6	17.8	34.8	17.3	9.5	18.9	35.2	16.7
	9.0	16.8	37.9	21.1	7.4	17.5	35.0	17.7	8.4	17.8	34.0	16.6

	T1				T2				T3			
	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4
N_{21}	7.4	16.3	25.8	9.4	9.0	19.1	24.6	5.4	9.4	18.5	24.2	5.6
	7.0	17.0	25.4	8.6	8.2	19.0	24.6	5.6	8.8	18.8	24.6	6.0
N_{22}	6.6	21.3	41.5	20.6	7.5	21.0	43.8	23.0	7.8	20.0	44.2	24.2
	6.7	22.0	42.6	21.0	7.5	20.4	44.0	23.9	7.8	20.0	44.0	23.8
N_{23}	12.2	15.6	31.6	16.3	11.8	19.9	33.3	13.3	12.5	18.0	32.6	15.0
	11.7	15.6	32.3	16.8	11.3	20.0	33.0	13.0	12.0	18.0	32.6	14.6
N_{24}	6.9	18.5	31.8	13.4	9.0	22.4	34.3	12.2	10.0	22.3	32.5	10.6
	6.8	18.3	30.1	12.5	8.5	21.2	34.2	13.1	10.3	22.4	33.8	11.6
N_{25}	10.7	22.6	47.0	24.6	11.0	22.9	49.4	26.5	11.0	22.7	49.0	26.6
	10.6	22.5	47.0	24.7	12.0	23.6	50.0	26.9	10.4	23.0	49.2	26.5
N_{26}	12.0	24.8	35.6	11.0	12.6	17.3	31.5	14.7	13.3	18.9	31.1	12.5
	12.2	25.2	35.5	11.1	13.0	17.4	31.9	14.5	13.5	19.0	31.1	12.7
N_{27}	7.8	20.0	35.5	16.0	9.4	18.3	35.8	17.5	10.4	19.7	34.7	14.8
	7.8	19.8	36.0	15.6	9.6	18.4	35.5	17.6	10.3	19.9	35.0	15.0
N_{28}	9.7	17.0	29.0	12.0	11.3	21.8	27.0	5.0	11.6	21.0	23.7	3.5
	9.5	16.8	28.5	12.1	10.6	21.3	26.4	5.0	11.0	20.5	23.3	3.2
N_{29}	5.6	18.4	33.3	15.3	8.0	20.3	33.2	12.9	9.4	20.5	32.3	12.5
	6.3	20.8	33.0	12.5	9.5	21.0	33.5	12.8	9.0	19.3	31.5	12.5
N_{30}	7.0	16.3	38.0	21.8	7.5	15.1	34.5	19.6	7.2	15.8	33.9	18.4
	6.8	16.5	37.8	21.8	7.6	15.2	35.0	19.5	7.4	15.6	34.0	18.5
N_{31}	10.3	23.4	39.3	15.7	10.8	27.1	39.0	12.0	9.8	27.6	38.2	10.6
	10.5	23.5	39.4	16.0	10.6	27.5	39.1	11.8	9.7	27.5	38.1	10.6
N_{32}	1.0	15.0	28.5	13.2	3.5	17.5	27.9	10.6	5.0	17.8	28.7	11.0
	1.0	15.3	28.3	13.4	3.3	17.7	28.3	10.7	5.1	17.7	28.9	11.2
N_{33}	10.0	23.4	41.3	18.2	12.3	27.2	45.0	18.4	11.8	25.7	42.5	16.9
	11.0	23.0	41.4	18.7	13.0	29.3	44.8	15.5	11.4	25.7	42.5	16.9
N_{34}	10.3	19.5	33.9	14.9	12.0	19.9	31.8	12.2	11.8	16.8	28.5	12.0
	10.2	19.2	33.9	14.6	12.6	20.0	32.3	12.3	11.6	16.8	28.8	12.1
N_{35}	9.5	16.4	33.6	17.5	11.1	22.6	35.7	12.5	9.3	21.0	34.5	13.0
	9.0	16.4	33.4	17.2	11.3	22.8	35.7	13.0	8.7	21.2	34.0	12.5
N_{36}	11.2	20.4	33.0	12.8	7.4	20.0	36.0	15.8	9.6	19.3	34.0	14.8
	11.0	19.0	34.0	15.0	7.8	19.8	35.0	15.4	10.0	19.2	33.8	14.4
N_{37}	8.9	16.0	30.0	14.3	8.9	16.8	29.9	13.2	9.3	14.6	29.0	14.5
	8.0	14.2	29.8	15.4	8.3	16.7	29.5	13.0	8.2	16.0	28.8	13.2
N_{38}	4.8	10.4	33.9	23.4	7.5	12.6	33.0	20.4	7.0	9.5	30.5	21.3
	4.2	9.7	33.0	23.2	7.0	12.9	33.0	20.3	6.6	10.6	29.7	19.1
N_{39}	9.6	13.5	28.4	15.2	9.9	13.2	28.5	15.2	9.8	13.0	27.2	14.6
	9.1	14.2	28.0	14.3	9.8	15.2	28.5	13.0	9.2	12.6	26.6	14.0
N_{40}	9.5	23.5	40.7	17.2	8.0	26.0	40.0	13.9	9.0	24.3	38.0	14.2
	8.5	23.0	39.9	17.0	8.7	27.6	39.2	12.0	10.0	25.4	38.8	13.5
N_{41}	8.0	24.0	35.8	12.0	8.0	23.0	37.7	15.0	8.0	19.6	34.0	14.3
	7.8	25.5	35.5	10.4	8.2	24.5	37.6	13.2	7.6	20.8	33.4	13.2
N_{42}	9.6	15.2	26.0	10.2	10.0	14.2	24.3	10.2	9.8	13.0	21.0	8.0
	10.0	15.4	26.0	10.4	9.8	14.0	24.2	10.0	9.6	13.0	20.8	8.3

	T1				T2				T3			
	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4
N_{43}	7.4	16.0	31.2	15.0	7.3	14.5	33.2	19.0	6.2	12.6	31.5	19.0
	7.5	16.0	31.4	15.3	7.2	14.5	33.3	19.0	6.4	13.0	31.5	18.8
N_{44}	11.0	18.0	32.3	14.4	9.3	21.2	31.4	10.5	10.4	20.3	32.2	11.8
	11.1	18.0	32.3	14.6	9.0	21.3	31.5	10.5	10.4	20.4	32.0	11.6
N_{45}	7.3	20.2	44.5	24.2	8.7	29.6	47.6	18.0	9.2	25.5	44.2	18.5
	8.1	20.0	44.5	24.4	7.5	29.5	47.4	18.0	8.8	26.7	44.0	17.2

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