Arch development in untreated class II division 2 malocclusions : a longitudinal study

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Acknowledgments

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The current extraction vs. non-extraction debate in orthodontics is not a new issue. Practitioners since the time of Angle[1] and Tweed[2] have argued over the pros and cons of each treatment modality. Throughout the course of orthodontic history individuals have based a large percentage of these arguments on the long term post-retention stability of orthodontically treated cases. Many authors[3,4,5] have written on the benefits of maintaining the pre-treatment intercuspid and intermolar widths. Likewise, various researchers[6,7] have expounded on the value of maintaining pre-treatment arch form throughout the duration of orthodontic therapy. However, in order to fully understand the relapse phenomenon in orthodontically treated cases one must first comprehend the normal development of the dental arches.

Early researchers, such as Moorrees[8] and Brown and Daugaard-Jensen[9], measured such parameters as arch length, arch width, overbite and overjet. These measurements clearly indicated the developmental changes occuring in the dental arches over time. However, these early studies made no attempt to separate developing malocclusions into distinct groups.

Recently, Sinclair[10] has reported on the maturational changes in untreated normal occlusions. However, little research exists concerning the development of untreated malocclusions, such as a Class II division 2.

This research will measure the developmental changes (overbite, overjet, intercuspal width, intermolar width, arch length, incisor irregularity) in Class II division 2 malocclusions over time. The measurements will take place at three distinct time periods. The mixed dentition (9-ll years), early permanent dentition (12-13 years) and early adulthood (19-20 years). The data will be analyzed statistically and the significance of changes over time will be determined by the T-test for paired data.

Most post retention research[3,4,5] has shown a continuing decrease in arch width and arch length with concomitant increases in overbite, overjet and incisor irregularity. However, the biggest problem has been to determine whether these changes have occurred as a result of orthodontic treatment or whether they are part of the normal maturational process. As Horowitz and Hixon stated;[11] "Orthodontic therapy may temporarily alter the course of these continuous physiologic changes and possibly, for a time, even reverse them; however, following mechanotherapy and the period of retention-restraint, the developmental maturational process resumes."

It is hoped that by following a developing malocclusion over time one will be better able to understand, and possibly predict, the expected post retention changes in orthodontically treated cases and perhaps shed new light on the extraction vs. non-extraction debate so prevalent in orthodontics today.

Review of the Literature

Since the time of Angle's classification of malocclusion, many researchers have done work on the morphology of a Class II malocclusion. At times, these researchers have made a distinction between the different divisions of a Class II malocclusion and many have tried to show that the two divisions are separate entities. Angle[1] himself, states that a "division 2 is characterized by distal occlusion of the teeth in both lateral halves of the lower dental arch, indicated by the mesiodistal relations of the first permanent molars, but with retrusion instead of protrusion of the upper incisors. The result of distal occlusion and recession of the jaw and chin, greatly mars the facial line."

In his 1921 study on human skulls, Milo Hellman[12] found that in Class II division 2 subdivision cases the mandible and mandibular arches were symmetrical while the maxilla and maxillary arches were not symmetric. He discovered that the maxillary molars on the Class II side were located further forward than those on the subdivision side. Therefore, he feels it is not a distal locking of the mandibular molars but rather a mesial locking of the maxillary molars which contributes to this malocclusion. Hellman[12] concludes that in skulls presenting Class II division 2 occlusal relationships it appears that the maxillary alveolar processes have drifted anteriorly with the result being the mesial relation of the maxillary teeth to those found in the mandible.

To Hellman[12], the primary etiologic factor in this and other types of malocclusions are the retardations and accelerators associated with growth which influence the formation and completion of the masticatory apparatus.

Robert Dunn[13] in his article on "the problem of malocclusion of the types of Class II", points to the lack of vertical development in the mandibular molar and premolar region as the prime etiologic factor in Class II division 2 malocclusions. Due to the lack of vertical growth, the mandibular incisors, through action on the lingual inclined planes of the maxillary incisors, force the mandible into an abnormal anterior-posterior relationship with the maxilla. To Dunn, there exists in each individual a definite vertical arrangement in the mandibular molar and premolar region which correlates with the temporo-mandibular joint and the mandibular incisors. It is this vertical arrangement which determines the ultimate position of the mandible.

In his article on the diagnosis and treatment of Class II malocclusions, Hellman[14] states that the mandible is narrower and longer in Class II division 2 as compared to Class II division I malocclusions. Likewise, the mandible is normal in its artero-postero position. The upper face is either normal or supernormal in height and width and more anterior than normal in position. However, the dentition and alveolar arches as a whole, remain subnormal in position.

In 1935 the Eastern Component Group[15] of the Angle Society presented a paper on the clinical study of Class II division 2 malocclusions. This society found that the mandible is of adequate width in the molar and premolar regions but tends towards narrowness across the canine area with a resultant malalignment of the incisor teeth. Likewise, in the anterior-posterior direction the mandibular dentition appears "stubby" due to the characteristic lingual position of the lower incisors. There is seldom any Curve of Spee but rather the molars and premolars are arranged on a level in the horizontal plane. The incisors are located on a different plane to the occlusal of the molar plane. There is a lack of vertical growth in the mandibular molar and premolar regions resulting in an excessive closure of the mandible. This closure of the mandible allows the mental protuberance to be forward of its natural position thereby disguising the profile disharmony. Hypertrophy of the mentalis muscle is evident and the lower lip is rolled over in a characteristic fashion.

In terms of etiology, the Eastern Component[15] feels that three forces exist which serve to form the Class II division 2 malocclusion. These forces include muscle forces, mechanical forces from occlusion and general metabolic forces, i.e. growth. The lack of vertical growth in the mandibular posterior region with a concomitant hypertrophy of the mentalis muscle act to produce distal pressure on the anterior portion of the mandibular body. This pressure is sufficient to cause a retardation of the forward growth of the mandible leading to a distal locking of the mandibular molar teeth. From this position the forces of occlusion aid in limiting the forward growth of the mandible.

In treatment, the Eastern Component[15] feels that one must first correct the vertical growth in the molar and premolar regions. Ideally, this correction should take place during a period of accelerated growth to aid in retention.

Earl Elman[16], in his study on the relationship of the lower six year molar to the mandible, determined that in the vertical and horizontal plane of space the lower six year molar bears a definite relationship to the mandible. Likewise, this relationship appears identical in both "control" and Class II malocclusions thereby leading to the belief that Class II malocclusions result from a recessive mandible.

In his first of two studies, J. P. Baldridge[17] showed that gnathion has the same relative antero-postero position to the face and cranium in Class I and Class II division 2 malocclusions. Therefore, he assumes that the basal bone of the mandible is in the correct anterior-posterior position, however, it might be longer in its overall length.

In 1948 Earl Renfroe[18] studied the facial patterns associated with the different classes of malocclusions and found the maxilla to be further forward in Class I and Class II division 2 malocclusions as compared to a Class II division I. Likewise, the position of the maxillary first permanent molar is almost identical in both divisions of Class II, located slightly posterior to the position found in a Class I malocclusion. In terms of the occlusal plane, those in Class I and Class II divison 2 malocclusions tend to be parallel. Gonion, in Class II division 2 malocclusions, is located posterior to the position of gonion in a Class I malocclusion. Furthermore, the mandibular angle is more acute resulting in a square type of facial pattern with an increased posterior facial height and a decreased anterior facial height. Renfroe[18] feels that Class II division 2 malocclusions are not characterized by any lack of development of the mandible but rather a mandible and mandibular arch which is posteriorly positioned. In spite of this relationship the chin point is almost as far forward as in Class I malocclusions arising from the fact that the mandibular border is nearly horizontal.

Adams[19] used cephalometrics in his study of the form of the human mandible and found that the absolute dimensions of the mandible in Class II malocclusions did not differ essentially from those observed in Class I malocclusions. To Adams[19], these findings rule out mandibular underdevelopment as a factor in Class II malocclusions, however the possibility remains that the teeth might be in posterior relation to the basal bone thereby giving the characteristic Class II occlusal pattern.

Elsasser and Wylie[20] showed statistically that in Class II division 2 males the maxillary first permanent molar is further forward on the body of the maxilla than in males with Class I malocclusions.

In contradiction, Baldridge[21] related the upper first permanent molar to the Frankfort Horizontal and showed that this tooth assumes the same relationship to the face and cranium in both Class I and Class II malocclusions.

In a study to determine whether statistically significant differences in facial skeletal patterns existed among the different classes of malocclusions, Eugene Blair[22] found a greater effective length of the mandible, a greater gonial angle and a more acute SNA angle in Class I malocclusions as compared to Class II division 2 malocclusions. To Blair[22], a Class II division 2 malocclusion with a smaller gonial angle and a mandibular body of equal length will have a more horizontal lower mandibular border and a more forward position of the body of the mandible. However, a high degree of variability was seen in each class of malocclusion.

In his 1954 article, Gordon Swann[23] postulated a theory which would explain the origin of Class II division 2 malocclusions. He felt that shortly after the eruption of the maxillary permanent laterals the maxillary first permanent molars move mesially due to the advanced eruption pattern of the maxillary second permanent molar. This eruption occurs prior to tuberosity development. Due to this movement, the canines bring pressure on the roots of the upper lateral incisors tipping these teeth into labio-version. Likewise, the tipping of the upper posterior teeth results in loss of vertical dimension with concomitant bite closure and increase in freeway space. As the upper deciduous molars are lost, the freeway space is closed from the distal thereby stabilizing the Class II position. To Swann[23], the Class II division 2 malocclusion is primarily a problem in the development of the maxilla and the eruption of the teeth.

To verify his hypothesis, Swann[23] showed that the upper second permanent molar was advanced in its eruption and that the forward movement of the upper first permanent molars significantly exceeded the forward movement of the maxilla, leading to the development of a Class II division 2 malocclusion. However, in spite of these findings, Swann[23] believes that there are many other factors superimposed on the development of this type of malocclusion. One should consider factors such as tooth size and bone size as well as functional aspects, in the form of mechanical interferences of the deciduous canines and permanent central incisors. He feels this malocclusion deals with a definite etiologic pattern involving the timing of tuberosity growth and the sequence of eruption of certain permanent teeth. Superimposed on this pattern are factors such as tooth and bone size and interferences of anterior teeth.

Morton Heide[24] described the Class II division 2 malocclusion as being characterized by a marked overbite, with the incisal edges of the lower anteriors contacting the soft tissue of the palate. There exists an inverted maxillary occlusal plane and two distinct occlusal levels in the mandibular arch - one for the anterior teeth and one for the posterior. Likewise, a large freeway space and well developed muscle fibers of the orbicularis oris and sometimes the mentalis are present. The lower incisors are usually forced into a crowded position due to their relation to the lingual of the upper incisors and the closed bite.

In treating these cases Heide[24] feels that one must make an effort to avoid extracting lower bicuspids due to the danger of eventual relapse of the corrected overbite.

In his cephalometric evaluation of Class II division 2 malocclusions Robert Hedges[25] found a flatter mandibular plane and a more acute gonial angle. However, the most noticeable difference was the upright position of the incisor teeth. This position resulted from coronal tipping rather than a variation due to skeletal dysplasia. Likewise, the larger angle of convexity (N-A-Po) supports the belief that the maxillary basal bone is either larger or in a more anterior position. In spite of these findings, Hedges[25] feels that the Class II division 2 malocclusion is not a specific clinical entity and most likely arises as a result of compensatory variation, eruptive disharmony and muscular pressure.

Robert Strang[26] in his 1958 essay on Class II divison 2 malocclusions feels that faulty growth patterns have a role in the development of this type of malocclusion. These growth patterns are typified by the lack of vertical growth below the nasal area and by the distal position of the mandible. Likewise, muscular activity in the form of pressure against the maxillary central incisors, combined with excessive closure of the bite are mechanical factors which one should consider in the final position of the mandible. The overall sucess in stabilizing the corrected overbite is related to the amount of vertical growth that remains in each individual patient. If there exists evidence of lack of vertical growth in the facial area below the nose, it is possible to correct the overbite but following the removal of retentive devices a collapse will invariably occur.

Perry Hitchcock[27], in his study on the cephalometric distinction of a Class II division 2 malocclusion found 13 measurements which showed statistically significant differences when compared to the "normal" occlusion sample of the Alabama Analysis[28]. The angle SNB indicated that point B is located further distal in Class II division 2 cases which led to a highly significant difference in the measurement ANB. Likewise, the upper incisor, as related to the occlusal plane, NA and SN is significantly different in Class II division 2 malocclusions. On the average, the upper incisor is about 12 degrees more vertical than those found in the "normal" occlusal sample. The lower incisors are also more upright but to a lesser extent than their counterparts. Moreover, linear measurements to NA and NB are significantly different which indicate that not only are the incisors more recumbent but they are also more retrusive. The Class II division 2 sample also shows a significant increase in overbite and overjet from the "normal" sample. From these results and in contrast to Hedges[25], Hitchcock[27] feels that although the Class II division 2 malocclusion is not stereotypical, it <u>does</u> represent a specific clinical syndrome.

Frans van der Linden[37], in his book, Development of the Dentition, states that the most important characteristic of the Class II division 2 malocclusion is the high position of the lip line in relation to the maxillary incisors. To Van der Linden[37] the abnormal position and excess forces from the lips cause two or more maxillary permanent incisors to tip palatally during eruption. Due to the palatal tipping of the maxillary incisors, the mandibular incisors will move lingually. This movement changes the arch form from ovoid to rectangular. In combination with the high lip line and the lingual tipping of the incisors, there exists excess anterior soft tissue. The lower lip is rather voluminous and results in a "dished in" profile.

Obviously from a review of the literature one can see that there are many different viewpoints concerning the constitution and etiology of a Class II division 2 malocclusion. Gordon Swann[23] in his essay on the diagnosis and interception of a Class II division 2 malocclusion states that this malocclusion is not seen in the deciduous dentition and that it appears at a specific stage of dental development.

In terms of dental and arch development Brown and Daugaard-Jensen[9] studied changes in the dentition from the early teens to the early twenties. In a comparison of orthodontically treated vs. untreated individuals Brown and Daugaard-Jensen[9] found that 70% of their untreated subjects (N=24) had a mean decrease in maxillary intercanine width of .89 mm from the early teens to the early twenties.

In contrast, 29.2% exhibited a mean increase of 1.18 mm In the mandible 75% showed a mean decrease of .88 mm in intercanine width whereas 16.7% had an average increase of 1.3 mm. 8.3% of their subjects were unchanged.

In terms of maxillary intermolar width, 58.3% showed a mean decrease of .9 mm whereas 37.5% increased on average, .69 mm. In the mandible, 50% exhibited a mean decrease of .83 mm while 29.2% increased 1 mm. The remainder of the subjects showed no change.

In measuring arch length, Brown and Daugaard-Jensen[9] found that 100% of the untreated sample decreased on average 1.6 mm in the maxilla. In the mandible 95.8% of the subjects decreased 1.7 mm while 4.2% increased .4mm.

In terms of overbite, 70% of the subjects showed a decrease of .78 mm while 29.7% increased on average .58 mm. In summary, these authors feel that there appears to be an overall tendency towards space closure and an increase in crowding with age.

In their study of 51 children using 528 sets of serial casts, Gerald Barrow and J. Romald White[29] investigated the developmental changes of the maxillary and mandibular dental arches. These authors[29] found that there was little intercanine width change from 3 to 5 years of age. Between 5 and 9 the intercanine width increased rapidly, on average 4 mm in the maxillary arch and 3 mm in the mandibular arch. After age

14, the intercanine width normally decreased from .5 to 1.5 mm.

In studying intermolar width, these authors[29] found that from age 7 to 11 the average increase in intermolar width was 1.8 mm in the maxilla and 1.2 mm in the mandible. From 11 to 15 years this measurement decreased on average .4 mm in the maxilla and .7 mm in the mandible. This decrease was due primarily to the difference in tooth size of the succedaneous permanent premolars and molars. Between the ages of 15 and 17 more than 50% of the cases showed a continual decrease in intermolar width and the mesial migration of the posterior teeth.

In terms of arch length, the average decrease in length of the maxillary and mandibular dental arches was .33 mm between the ages of 4.5 to 6. From 6 to 12 the maxillary arch increased 1 mm whereas the mandibular arch decreased on average 1.2 mm. From age 4.5 to 13 the total change was an increase of approximately .2 mm in the maxillary arch and a decrease of 2.2 mm in the mandibular arch.

In measuring overbite, Barrow and White[29] determined a mean of 2.0 mm at age 4. Overbite showed an increase of 1.75 mm by the age of 11. From age 11 to 17 these authors found only minor changes in overbite.

In terms of crowding, no cases in the maxillary arch at age 6 exhibited crowding. However, by the age of 14, 24% of these cases had measurable crowding. In the mandible, the crowding incidence rose from 14 to 51% of the cases between the ages of 6 and 14.

B. S. Cryer[30], in an annual survey of 1,000 London schoolchildren studied lower arch changes between the ages of 11 and 14. He found that by the age of 14, 62% of his sample had a degree of lower anterior crowding of which 60% showed an increase in crowding during the period of survey. To Cryer[30], an adverse tooth/tissue ratio (i.e. tooth size - arch length discrepancy) was a prime component of lower anterior crowding.

In summary, Cryer[30] states that by extracting lower permanent teeth one is able to reduce the incidence and degree of lower anterior crowding.

T. D. Foster, M. C. Hamilton and C. L. B. Lavelle[31] in a study of dental arch crowding in four different age groups found overall spacing of the arches in the 2 1/2 to 3 year age group. In the 6 to 7 year age group, greater than 85% of the subjects had maxillary crowding, while 70% had mandibular crowding. The 13 to 14 year old age group exhibited a greater degree of crowding than the previous group. Between 18 and 25 the crowding appeared to decrease with smaller proportions of the subjects showing crowding in both the maxilla and the mandible. Overall, females had a greater number of subjects with crowding.

In summary, these authors[31] state that although spacing of the teeth is a feature of the primary dentition, crowding of the teeth is the predominant feature of the mixed/permanent dentitions. Likewise, females appear to have smaller teeth and smaller dental arches with a greater tendency towards crowding.

In an investigation of the changes in crowding and spacing of the teeth with age, Anders Lundstrom[32] studied 100 twin pairs. The average time between casts was 14 years. His study revealed a relatively stable arch width but a reduction in arch length of 1-2 mm.

To Lundstrom[32], a reduction in spacing of the teeth with age and an increase in crowding is a fairly common development in both the deciduous and early permanent dentitions. This trend is due more to a reduction in the anterior-posterior dimension rather than the transverse dimension.

J. H. Stillman[33], in his longitudinal study on the dimensional changes of the dental arches from birth to 25 years, found that in males arch length decreases 1 to 5 mm in the maxilla and 2.0 mm in the mandible.

In terms of intercuspid width there is an overall increase of 5 mm in the maxilla and 3.5 mm in the mandible from birth to age 2. This dimension continues to increase until about age 13. Thereafter it remains relatively stable.

From age 3 until age 13 the intermolar width increases approximatley .5 mm/year in the maxilla and .2 mm/year in the mandible. After age 13 the intermolar dimension shows no significant change in both arches. Overall, Stillman[33] feels that these changes in development of the dental arches occur just prior to the eruption of teeth.

C. Moorrees and J. Chada[34], in their study on the available space for the incisors during dental development, found a sudden decrease in available space during the emergence of the central and lateral incisors. This change resulted in 1.6 mm of crowding in the mandibular dentition for males and 1.8 mm of crowding for females. In the maxilla of both sexes either a small excess or small (.2 mm) lack of space was present. To Moorrees and Chada[34] it appears that one cannot expect a relief of crowing in the incisor segment after the complete eruption of the lateral incisors. However, to alieviate this crowding one can prevent mesial migration of the permanent first molars and thereby make provisions for the utilization of the leeway space by the anterior teeth.

In his longitudinal study of dental arch depth and width from age 12 to adulthood, William DeKock[35] found a decrease in maxillary arch depth in males of 3.2 mm. In contrast, females showed a decrease of 2.6 mm. In the mandible, males exhibited a decrease of 2.87 mm whereas females showed a decrease of 3.01 mm. Overall, all subjects showed a decrease in arch depth after the age of 15.

In terms of arch width, females show no significant change in either arch whereas males show a significant increase in both arches from age 12-15.

To DeKock[35], the tendancy toward the return of crowding in the mandibular incisor area following orthodontic treatment is possibly related to the decrease in arch depth over time.

Virginia Knott[36], in her longitudinal study of dental arch width at four stages of the developing dentition showed that males yielded larger measurements in bicanine diameter than females. Likewise, the width at the deciduous canine increases approximately 2.8 mm in both dental arches during the period of eruption of the permanent central, lateral and first molar. In the mandibular arch this width increase occured largely before the eruption of the permanent canine teeth. Followed into the permanent dentition and young adult stage, the bicanine diameter shows little or no change. Overall, in males the intercanine distance increased 2.9 mm in the mandible and 3.1 mm in the maxilla from the deciduous to the young adult dentitions. In females, Virginia Knott found mean intercuspid increases of 3.4 mm in the maxillary arch and 4.2 mm in the mandibular arch.

In one of the more extensive investigations on arch and dental development, Coenraad Moorrees[8] reported on the dentition of the growing child. In a longitudinal study between 3 and 18 years of age Moorrees[8] found that the average arch length is smaller at 18 than at age 3 in both males and females. This decrease in arch length is greater in the mandibular arch and occurs primarily between the ages of 4 to 6 and 10 to 14. Before this overall reduction, the arch length increases markedly in the maxilla and slightly in the mandible during the emergence of the permanent incisors. The first decrease in arch length occurs due to the disappearance of interdental spaces between the deciduous molars and canines. The second decrease is due to the difference in size between the deciduous molars and permanent premolars. Overall, for males, this decrease is approximatley 1.6 mm in the maxillary arch and 2.5 mm in the mandibular arch. Females show arch length decreases of 2.2 mm in the maxilla and 3.3 mm in the mandible.

In terms of arch breadth, the distance between the deciduous maxillary canine increases slightly between the ages of 3 to 4 in both males and females. A second growth phase begins between 5 and 6 and ends approximatley 1 3/4 years before the emergence of the permanent maxillary canines. Just before the eruption of the permanent canine a third growth phase begins which may add as much as 2 mm to the previous intercuspid dimension. Overall, males show average intercuspid increases of 5.2 mm in the maxillary arch whereas females show increases of 4.3 mm.

In the mandible the intercuspid dimension increases continuously from ages 5-10 in males, whereas females show no increase after age 9. Following the emergence of the permanent canines there is a slight decrease in intercuspid distance. This dimension changes very little after age 12. Overall, males show an intercuspid increase of 3.4 mm from age 3 to 18 whereas females show average increases of 2.7 mm.

In terms of intermolar distance Moorrees[8] found that the increase in distance between the permanent maxillary molars is more marked in males than in females. In males this dimension continues to increase until age 18, with an average overall increase of 5.0 mm. In females, the average overall intermolar increase is 1.9 mm between ages 6 to 18. However, the intermolar distance tends to decrease after age 12.

In the mandible males exhibit an average intermolar increase of 2.4 mm whereas females show average increases of 1.5 mm.

In measuring overbite, Moorrees[8] found that overbite increases in males, on average, 1.2 mm and in females, .9 mm between the ages of 3 and 18. However, betweeen ages 4-6 and 12-18 there is a slight decrease in measurable overbite. Overall, it appears that the average amount of overbite in both the deciduous and permanent dentitions is 35-40% of the clinical crown height of the mandibular incisor.

In an overview of his study one should remember that Moorrees' sample consisted of individuals with a "normal" anatomic occlusion at age 18. Likewise, in each aspect of the study Moorrees[8] comments on the high degree of individual variability, which should make application of his findings to individual orthodontic patients tenuous at best.

Materials and Methods:

The material used in this study was selected from the files of children included in the Child Growth Clinic of the Oregon Health Sciences University School of Dentistry in Portland, Oregon. The sample was limited to individuals with Angle Class II division 2 malocclusions in the adult dentition, as evidenced from an examination of study casts. No individuals had undergone orthodontic treatment. Fifteen cases with records in the mixed, early permanent and early adult dentitions were collected. Sample selection was based on the presence of an Angle Class II molar relationship in the adult dentition, either full cusp or end to end, as well as retrusion of the upper incisors. Of the original sample a total of six cases presented with Angle Class II subdivision molar relationships in the adult dentition. This group will be included in the pooled statistical analysis but will also be analyzed separately to see if any differences in arch changes over time exist between Angle Class II and Angle Class II subdivision cases. Likewise, male-female differences will be statistically analyzed.

The time periods were determined as follows:

Time 1 (T_1), Mixed Dentition Stage- the mandibular permanent incisors and first molars were present. Likewise, either the deciduous or permanent canines plus deciduous first and second molars were in the arch.

Time 2 (T_2), Early Permanent Dentition Stage- the casts showed complete eruption of the permanent mandibular dentition, apart from the third molars.

Time 3 (T_3), Adult Dentition Stage- to qualify for inclusion in this stage individuals must be at least 17.5 years of age with complete eruption of the mandibular dentition , apart from the third molars.

The casts were photographed and the photographs digitized as suggested by Baumrind[38,39], (see Appendix 1-B,C) making sure that the glass plate and camera lens were parallel to the occlusal plane and to one another. A total of 25 points were digitized (see appendix 1-A) and the following information obtained:

Irregularity Index- the summed displacement of the anatomic contact points of the lower anterior teeth[40]. In addition an irregularity index for the upper anterior teeth was computed.

Maxillary/Mandibular Intercanine Width- the distance between cusp tips, or estimated cusp tips in cases of wear facets, of the maxillary and mandibular deciduous or permanent cuspids.

Maxillary/Mandibular Intermolar Width- the distance between mesiobuccal cusp tips, or estimated cusp tips in cases of wear facets, of the maxillary and mandibular first permanent molars.

Maxillary/Mandibular Arch Length- measured as the sum of the right and left distances from the mesial anatomic contact points of the first permanent molars to the contact point of the central incisors or to the midpoint between the central incisors if these teeth are spaced or rotated[41].

Likewise, a dial caliper, calibrated to the nearest 1/1000 of an inch, was used to measure the following parameters directly from the study casts.

Overbite- overlap of a maxillary to mandibular central incisor.

Overjet- the distance, parallel to the occlusal plane, from the labial surface of a mandibular central incisor to the labial surface of the most retruded maxillary central incisor.

This data was converted to milimeters and, along with the data from the digitized photographs, analyzed by the UCSF Orthodontic Research System Analysis Package as suggested by Baumrind[39,42,43].

Measurement error was established by double determination of the digitized points and caliper measurements and amounted to the following:

Overbite-.13mm

Overjet-.19mm

Measurement error for molar width, cuspid width, incisor irregularity and arch length was included in the analysis package. Any second digitized point which differed by greater than 1mm from the origional digitized point was omitted by the computer and the point remeasured. In this regard, measurement error is taken to be less than 1mm for each digitized point. It should be noted that in the process of digitizing the photographs no two points showed a discrepency of greater than 1mm.

Likewise, due to the difference in size between the photographic images and the actual casts, a conversion factor of .721 was included to offset the enlargement of the photographic images. This factor was determined by measuring the actual distances between the fiducial points[43] on the glass plate and comparing that distance to the distance between the fiducial points on the photographic image. The error involved in this type of convesion was determined by comparing the distances between the fiducial points to the new converted distances as taken off the digitized photographs. This error amounted to less than 1%.

Due to the small sample size, statistical significance was established at $p \leq .01$.

Results:

Maxillary Arch Length

From table II and figure 1, one can see that the combined sample shows statistically significant decreases in arch length between time periods 1 and 2 (2.33±2.07mm) and between 2 and 3 (2.21±2.86mm). In all, a reduction of 4.55±2.33mm occurs between time periods 1 and 3. This value is significant to the $p \leq .0001$ level. Likewise, males show significant reductions in arch length between the three time periods. The overall reduction for males is 3.64±1.07mm between time periods 1 and 3. This value is significant to $p < .0001$. In contrast, females do not show significant changes between successive time periods. However, the reduction in arch length between time periods 1 and 3 (6.3±2.79mm) is statistically significant to the $p < .01$ level. Overall, females show greater reductions in arch length than males.

In terms of malocclusion severity, the class II sample did not show significant reduction in arch length between the successive time periods. However, between the mixed dentition stage and early adulthood a significant reduction of 4.72±2.91mm occured. This reduction was significant to the $p < .01$ level. On the other hand, the class II subdivision sample showed significant reductions between all three time periods. The overall reduction in maxillary arch length of this sample was 4.29±1.02mm.

Mandibular Arch Length

The mandible closely parallels the maxilla in terms of reduction in arch length. In the combined sample, significant decreases in arch length occured between both the mixed dentition and the early permanent dentition (2.68±1.45mm) and between the early permanent dentition and the adult dentition (1.29±.83mm). Overall, a reduction of 3.68±1.53mm occured in the mandibular arch between the three time periods. Both males and females showed significant reduction in arch length between the mixed dentition and early permanent dentition (2.02±1.24mm and 3.72±1.18mm). However, only males showed a significant decrease in arch length (1.38±.83mm) between the early permanent dentition and the early adult dentition. Overall, both males and females showed significant decreases in arch length between the first and third time periods. Male arch length decreased on average 3.28±1.73mm whereas females showed decreases of 4.47±.54mm. As in the maxilla, females showed greater reductions in arch length.

In contrast to the maxilla, the class II sample showed significant arch length reduction between the three time periods. Overall, a reduction of 2.79±1.08mm occured. This value was significant to the $p<.001$ level. The class II subdivision sample showed a significant reduction between the first and 2nd time period as well as between the first and third time period. This group showed a greater reduction (4.67±1.6mm) than the class II sample.

Maxillary Cuspid Width

As seen in figure 4 and table II the combined sample showed an overall increase in maxillary cuspid width of .72±1.09mm between the mixed dentition and the early adult dentition. However, this value was not significant. It should be noted that the cuspid width increased between the mixed and early permanent dentitions. Maxillary cuspid width then decreased between the early permanent and early adult dentition.

The male/female sample and the class II/subdivision sample showed no significant change in maxillary cuspid width over the three time periods. As in the combined sample, cuspid width first increased then decreased over time.

Mandibular Cuspid Width

In contrast to the maxilla, the mandibular cuspid width for the combined sample showed an overall decrease of .71±1.27mm. However, this value was not significant. The male/female sample showed no statistically significant values. However, in contrast to the maxillary arch, mandibular cuspid width tended to decrease over time.

In the class II/subdivision sample the class II group showed a significant reduction of .6±.47mm between the early permanent and early adult dentitions.

Maxillary Molar Width

The combined sample showed an overall increase of intermolar width of .96±1.44mm. This value was not significant. A significant change did occur between the mixed dentition and the early permanent dentition (1.13±1.04mm). After the early permanent dentition the intermolar width decreased slightly.

Males showed a significant increase in maxillary molar width of 1.44±.98mm between the first and 2nd time period. After the early permanent dentition there was no significant change in intermolar width. However, the overall change was significant to the $p<.005$ level. Females did not show a significant change in intermolar width, either between or over time.

The class II/subdivision sample showed no significant changes in intermolar width.

Mandibular Molar Width

Mandibular intermolar width showed a slight increase of .46±1.15mm over time, however, this change was not statistically significant.

The male/female and class II/subdivision samples showed no significant changes over time.

Maxillary Incisor Irregularity

Although maxillary incisor irregularity showed an overall decrease of 1.34±3.7mm between the mixed and early adult dentitions, this change was not statistically significant. In the male/female sample the only change that was statistically significant occured in females between the mixed dentition and early adulthood. This value decreased 1.72±.48mm and was significant to the $p \leq .01$ level.

The class II/subdivision sample showed no significant changes over time.

Mandibular Incisor Irregularity

Lower incisor irregularity showed virtually no changes between the mixed dentition and the early adult dentition. Likewise, changes in the male/female and class II/subdivision samples were not statistically significant.

Overbite

Although overbite tended to increase (.25±1.03mm) between the mixed dentition and early permanent dentition and then decrease

(.71±.98mm) between the early permanent dentition and early adulthood, these changes were not significant.

No significant changes in overbite were noted among the male/female or class II/subdivision samples

Overjet

Although there was a progressive decrease (1.12±1.69mm) in overjet over time, in the combined sample, this value was not statistically significant. In the male/female sample only males showed statistically significant decreases (1.8±1.44mm) in overjet over time. Likewise, the male sample showed a significant decrease between the early permanent and early adult dentitions of .82±.79mm. This value was significant to the $p<.01$ level.

The class II/subdivision sample showed no significant changes.

Discussion

In terms of arch length, the class II division 2 sample appears to show greater reductions in both maxillary and mandibular arch length when compared to earlier research. Brown and Daugaard-Jensen[9] found reductions of only 1.6mm in the mandible and 1.7mm in the maxilla from the early teens to the early twenties. Anders Lundstrom[32], in his twin studies, reported arch length reductions of 1-2mm. In this sample, a total reduction of 4.55mm occurs in the maxillary arch. Mandibular arch length reduces 3.68mm over time. However, in more recent research, Sinclair[10] reports that a substantial loss (4.83mm) of mandibular arch length in Class I malocclusions was noted by early adulthood.

In a comparison of males vs females, William DeKock[35] notes a decrease in maxillary arch debth in males of 3.2mm. Females show a decrease of 2.6mm. Moorrees[8] reports reductions of 1.6mm in maxillary arch length and 2.5mm in mandibular arch length for males. Females show reductions of 2.2mm in the maxilla and 3.3mm in the mandible. In this sample, males show an overall maxillary arch length reduction of 3.64mm whereas arch length in females reduces 6.3mm.

In the class II division 2 sample male arch length decreased 3.28mm and female arch length decreased 4.47mm. In all, female arch length reduces a greater extent than male arch length. This reduction is statistically significant at the $p \leq .01$ level in both the mandible and maxilla during the T_1-T_2 time interval. In contrast, males show a statistically significant greater reduction in mandibular arch length at the T_2-T_3 time interval.

Intercuspid dimension and its changeability has long been the subject of debate in the orthodontic literature[44,45]. Barrow and White[29] reported reductions of .5 to 1.5mm in mandibular intercanine width after the age of 14. In contrast, Stillman[33] shows that the intercuspid dimension is relatively stable after the age of 13. Knott[36] and Moorrees[8] show little change in mandibular bicanine dimension when followed into the early permanent and early adult dentitions. Sinclair[10] found a decrease of .74mm in mandibular intercanine width from the mixed dentition into early adulthood. This result is very similiar to the result from the class II division 2 sample. This sample showed a decrease in mandibular cuspid width of .71mm over time. This result tends to support the suggestion that intercanine width remains virtually unchanged after the eruption of the permanent dentition. If one could assume the necessity of a stable intercuspid width, then the clinical implication would be to take the stance of Strang[45]. He feels that the intercanine width is a very stable dimension and should not be violated during the course of orthodontic treatment.

In terms of male vs female differences, males showed a statistically significant increase in maxillary cuspid width at the T_1-T_2 time interval when compared to females.

As a measure of posterior arch width, Barrow and White[29] reported a continual decrease in intermolar dimension after the age of 11. However, Stillman[33]shows this dimension to be stable after the age of 13. In this sample, maxillary intermolar width increased .96mm over time. This value was not significant. Likewise, slight (.46mm) non-significant increases were evident in mandibular intermolar width. Sinclair[10] reports intermolar width to be a relatively stable dimension. The results of this study tend to suggest that although there are small increases in intermolar width over time, this dimension, like cuspid width, appears relatively stable.

In terms of male/female differences this research is similiar to that reported by Sinclair[10] in that males show small non-significant increases in intermolar width over time whereas females show small decreases in width over time.

The combined class II division 2 sample was quite similiar to the sample reported by Sinclair[10] when measuring changes in overbite. Although overbite tended to slightly increase in the transition from the mixed to early permanent dentition and then decrease from the early permanent to early adult dentitions, these changes were not significant. These findings also corresposd closely to those reported by Barrow and White[29] who found only minor changes in overbite after the age of 11. Likewise, Moorrees[8] states that between the ages of 12 and 18 there is a slight decrease in measurable overbite. This phenomenon also takes place in the class II division 2 sample. However, overbite reported in this sample was about 1mm greater than that reported by Sinclair[10] at all three time intervals. This finding agrees with Hitchcock[27] who feels that class II division 2 malocclusions have a significantly greater amount of overbite when compared to class I malocclusions.

There were no significant differences in the change in overbite between males and females.

Although Hitchcock[27] reports that the class II division 2 malocclusion has a significant increase in overjet when compared to a class I malocclusion this sample did not differ dramatically from the class I sample of Sinclair[10], except in the mixed dentition. At the early permanent and early adult dentition the values for overjet were very similiar between the two samples. However, Sinclair[10] reports a slight increase then a slight decrease, with little resultant change in overjet over time. In contrast, this sample shows a continual decrease in overjet over time, with males having a statistically significant decrease in overjet between the mixed and early adult dentition.

Although there was little change in mandibular incisor irregularity over time the overall amount differed dramatically to that reported by Sinclair[10]. The class II division 2 sample had values for incisor irregularity, as determined by Little[40], at close to 6mm for all three time periods. In contrast, the class I malocclusion sample of Sinclair[10] had incisor irregularity values of between 2-3mm. Various authors[29,30,31,32] report an increase in crowding with time. However, this sample showed a stable mandibular irregularity index and a maxillary irregularity index which actually decreased over time. It should be noted that a major problem with the Little Irregularity

Index[40] is the question of spacing. Since Little's Index[40] is concerned with the distance between adjacent contact points, any spacing in the arch form will give an abnormally high irregularity index. In this situation, if the arch matures over time and becomes more crowded, the irregularity index will actually decrease because the contact points are getting closer together. This scenario would give a false value for the irregularity index. Therefore, these values should be looked at with some caution. There was no significant difference in change in incisor irregularity over time between males and females.

There were no significant differences between changes in the class II sample as compared to changes in the class II subdivision sample in all parameters of this study. This result suggests that these types of malocclusions tend to mature from the mixed to early adult dentitions in a similiar manner.

Summary

1. There was a consistent and statistically significant trend towards reduction in arch length from the mixed to early adult dentitions.

2. Overall, females tend to show greater reductions in arch length over time.

3. There is a small increase in maxillary cuspid width over time,

but this value is not statistically significant.

4. There is a small decrease in mandibular cuspid width over time, but this value is not statistically significant

5. Maxillary and mandibular molar widths showed slight increases over time, but these values were not significant

6. Overbite tended to increase and then decrease over time, with little resultant change overall.

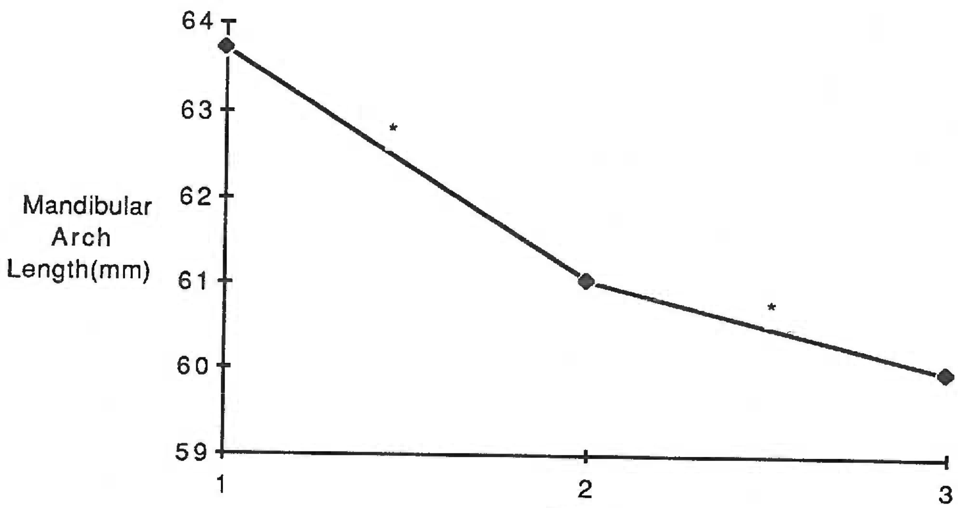
7. Overjet showed a continual decrease with time, but this value was not significant.

8. Mandibular irregularity tended to remain relatively stable over time while maxillary irregularity tended to decrease.

9. In a comparison of class II vs class II subdivision samples there appears to be no statistical difference in the way these malocclusions develop over time.

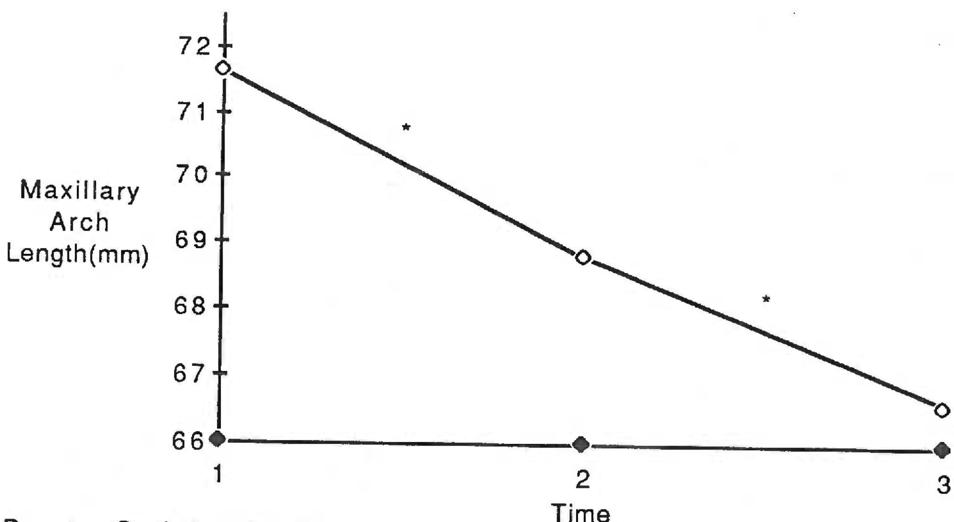
10. In a comparison with a previously reported untreated class I malocclusion sample[10] all parameters were very similar in terms of initial dimension and subsequent changes over time except for incisor irregularity and overbite. The class II division 2 sample showed a greater degree of incisor irregularity and overbite when compared to the class I sample.

Mandibular Arch Length Combined



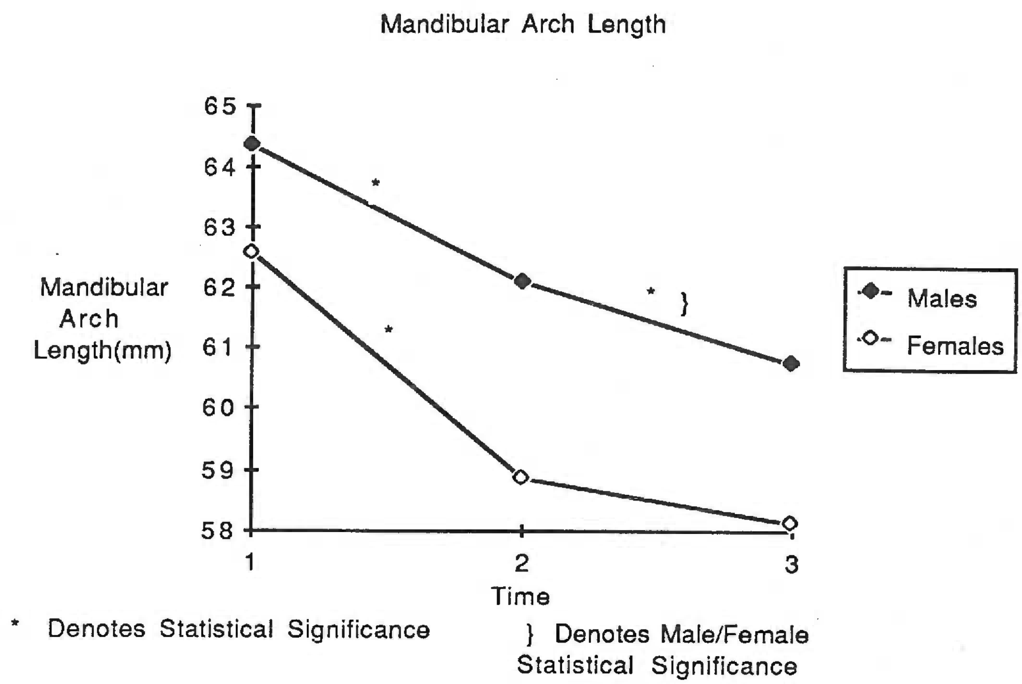
* Denotes Statistical Significance

Maxillary Arch Length Combined



* Denotes Statistical Significance

Fig. 1 Combined mandibular/maxillary arch length



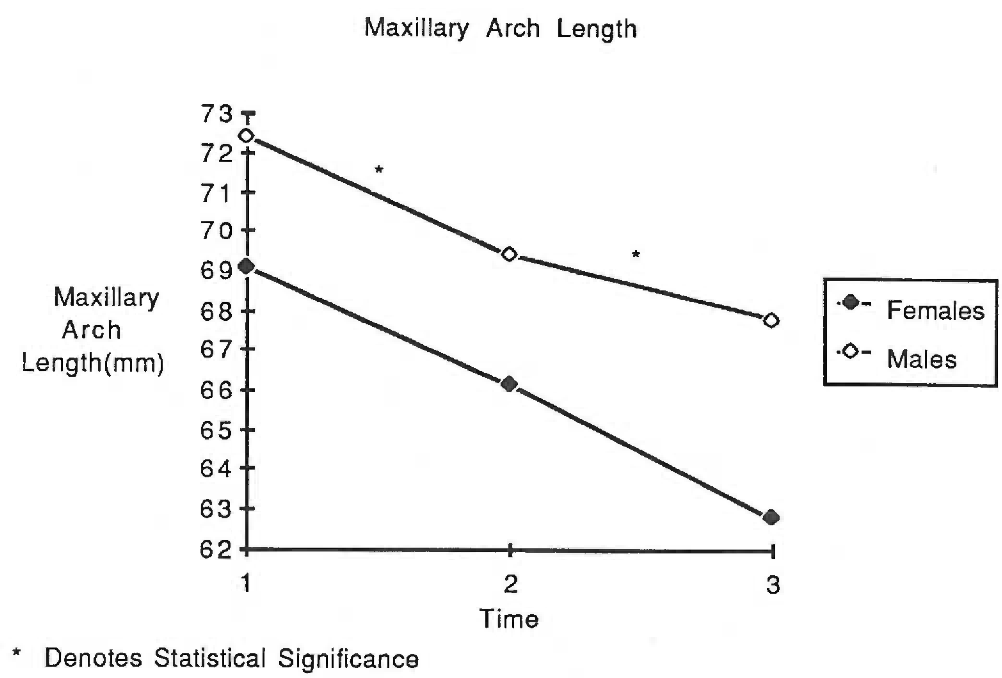
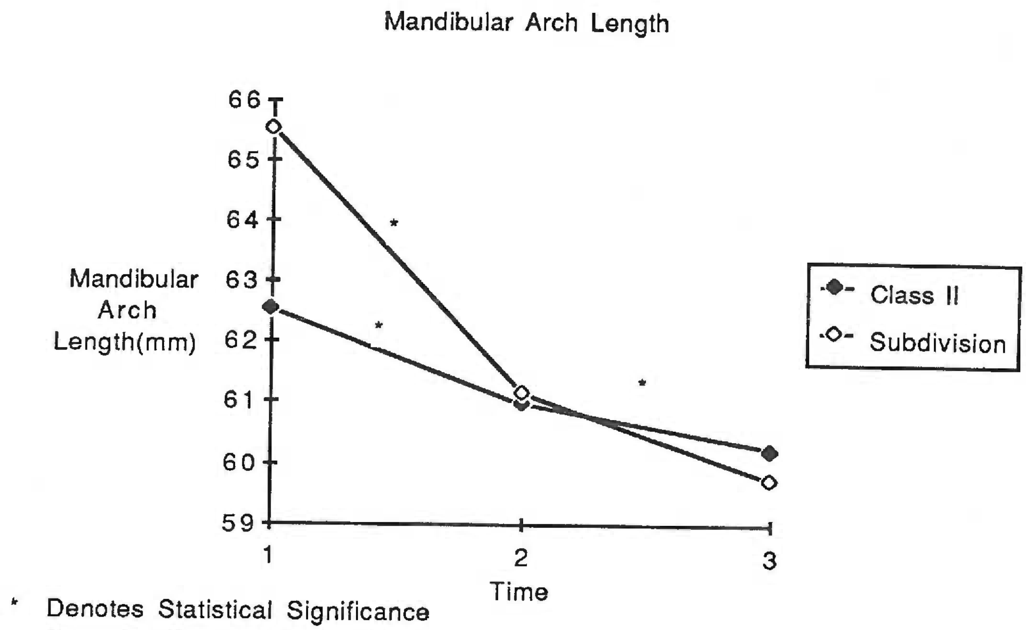


Fig. 2 Mandibular/maxillary arch length male vs female



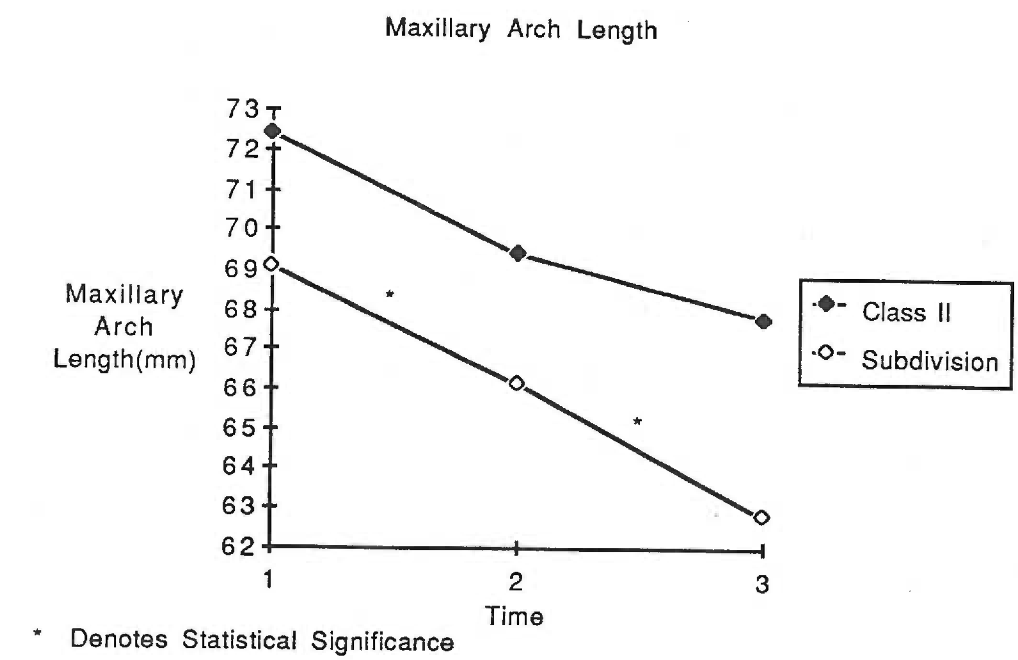
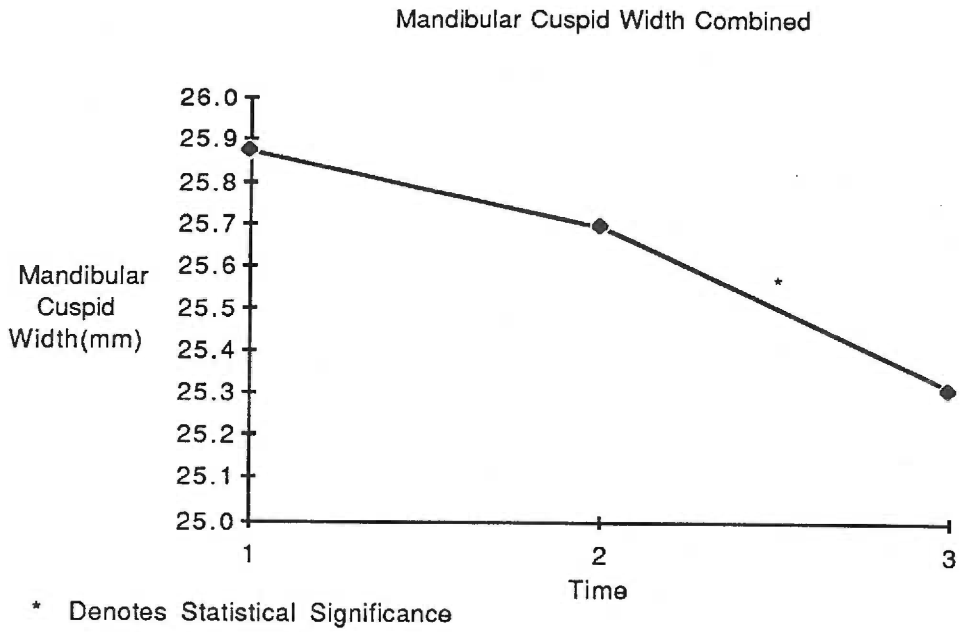


Fig. 3 Mandibular/Maxillary arch length class II vs subdivision



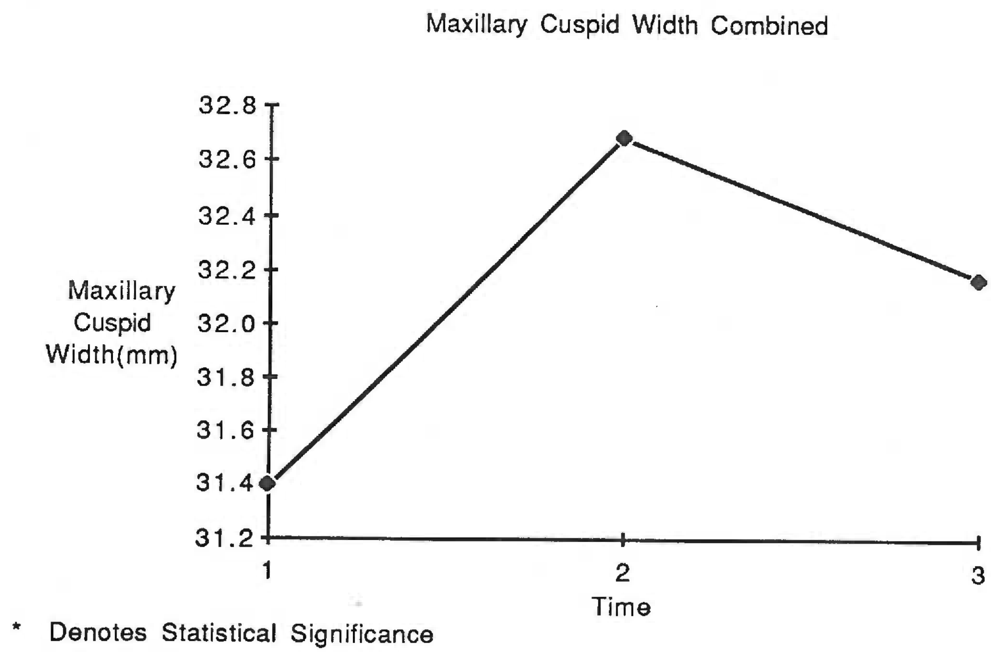
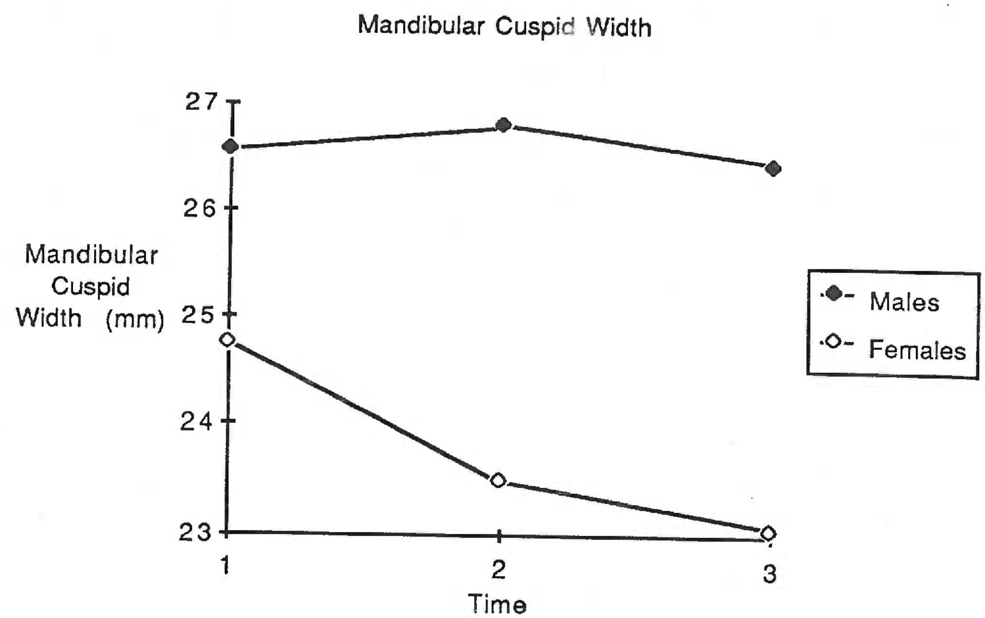
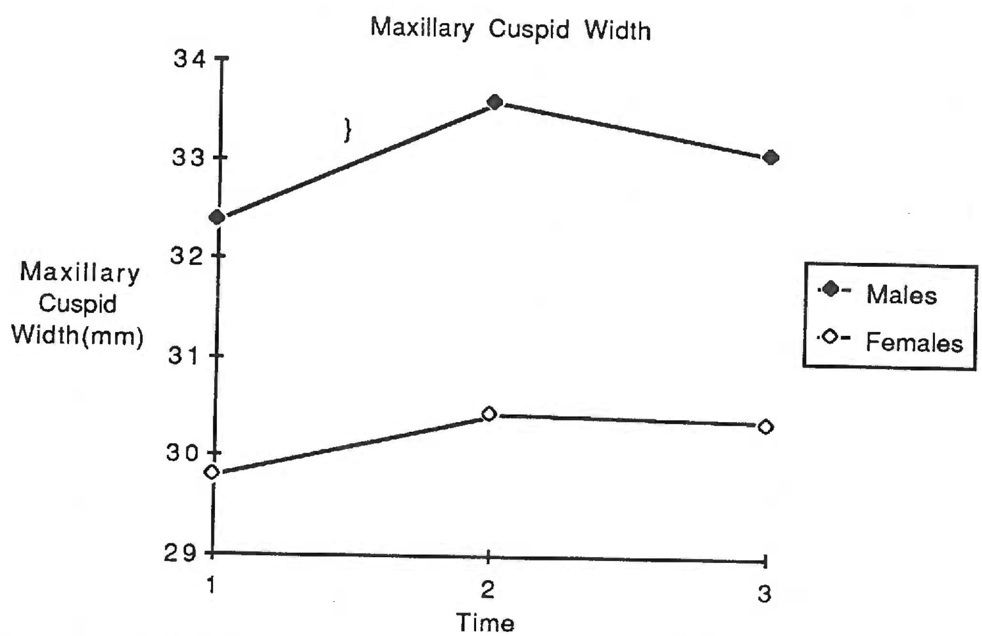


Fig. 4 Combined mandibular/maxillary cuspid width



* Denotes Statistical Significance

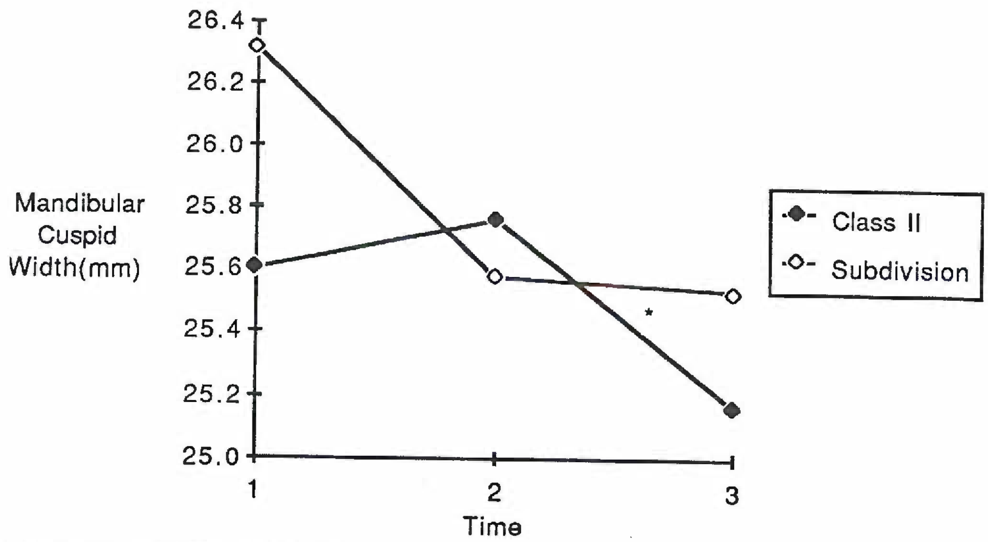


* Denotes Statistical Significance

} Denotes Male/Female Statistical Significance

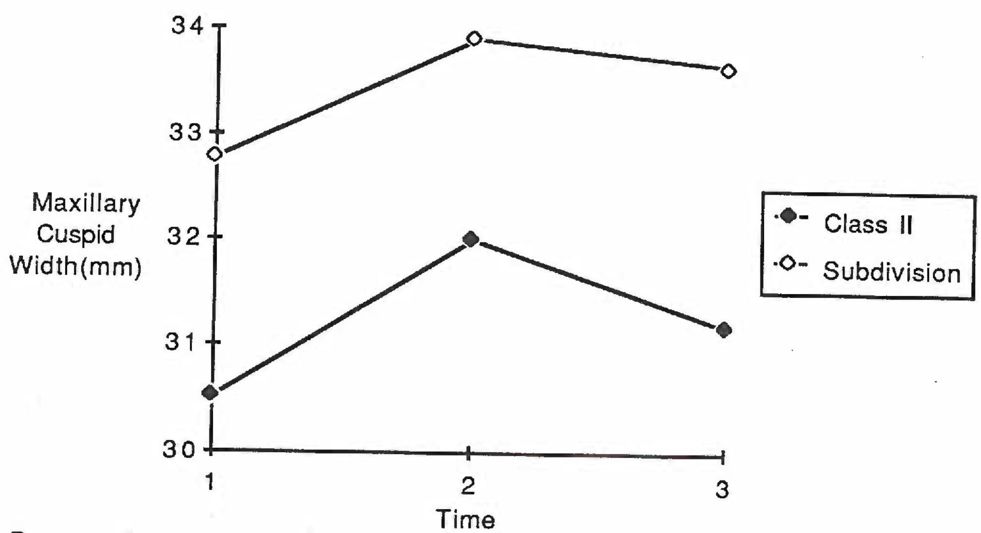
Fig. 5 Mandibular/maxillary cuspid width male vs female

Mandibular Cuspid Width



* Denotes Statistical Significance

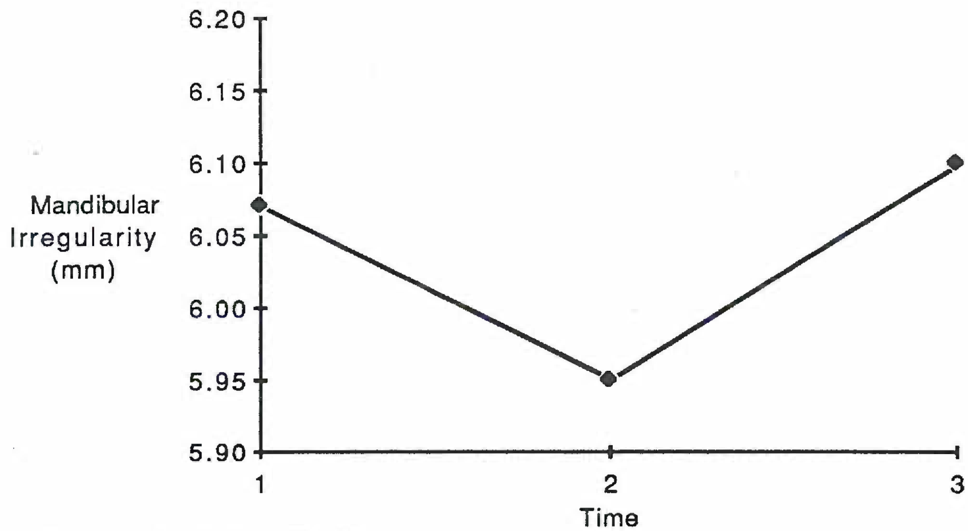
Maxillary Cuspid Width



* Denotes Statistical Significance

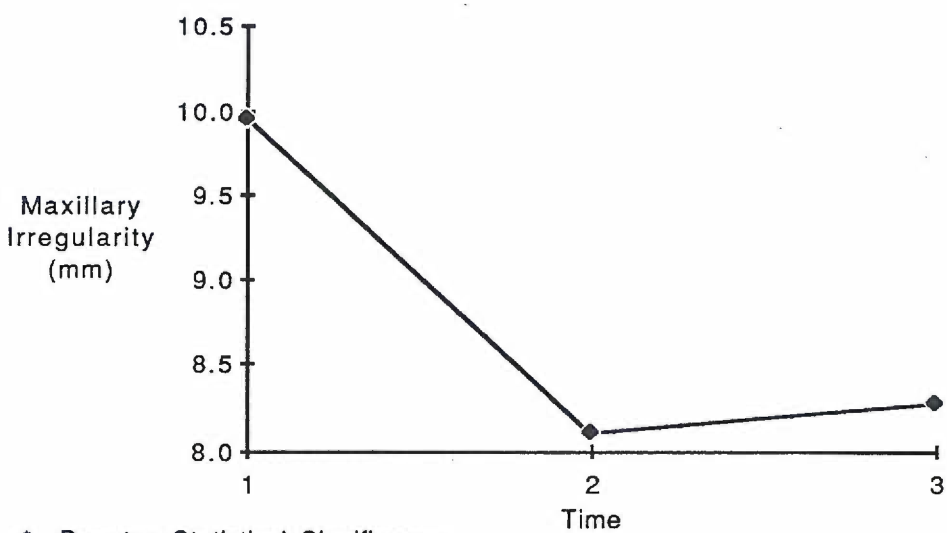
Fig. 6 Mandibular/maxillary cuspid width class II vs subdivision

Mandibular Irregularity Combined



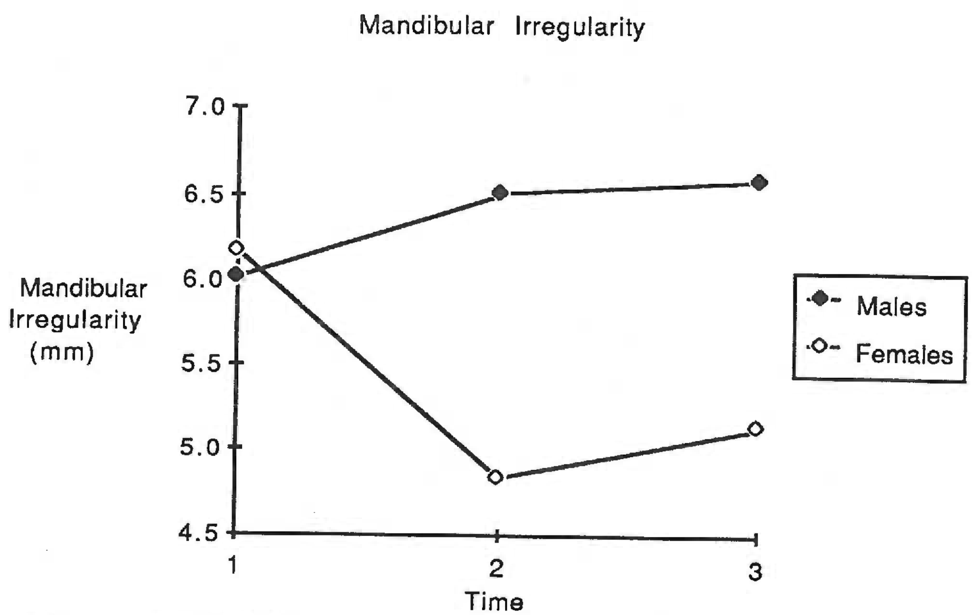
* Denotes Statistical Significance

Maxillary Irregularity Combined

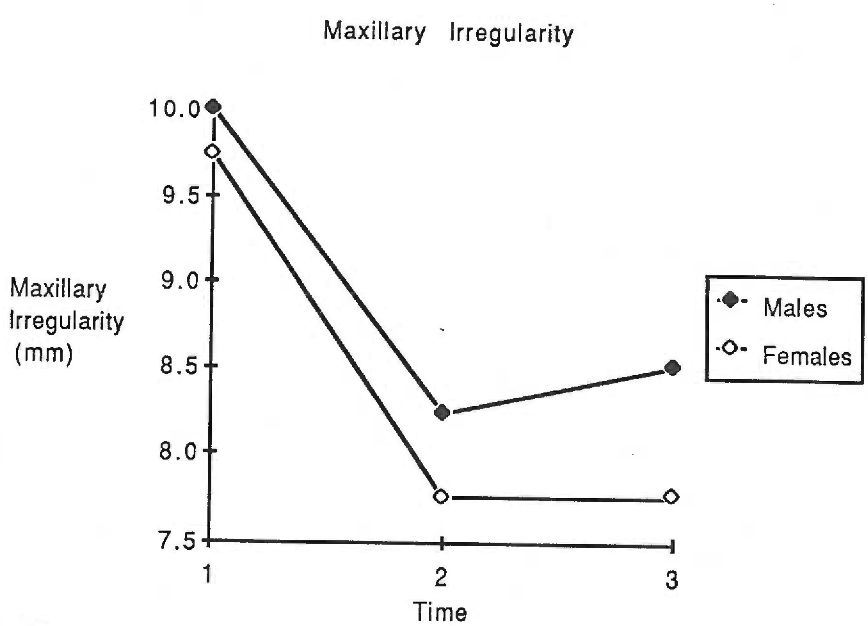


* Denotes Statistical Significance

Fig. 7 Combined mandibular/maxillary irregularity

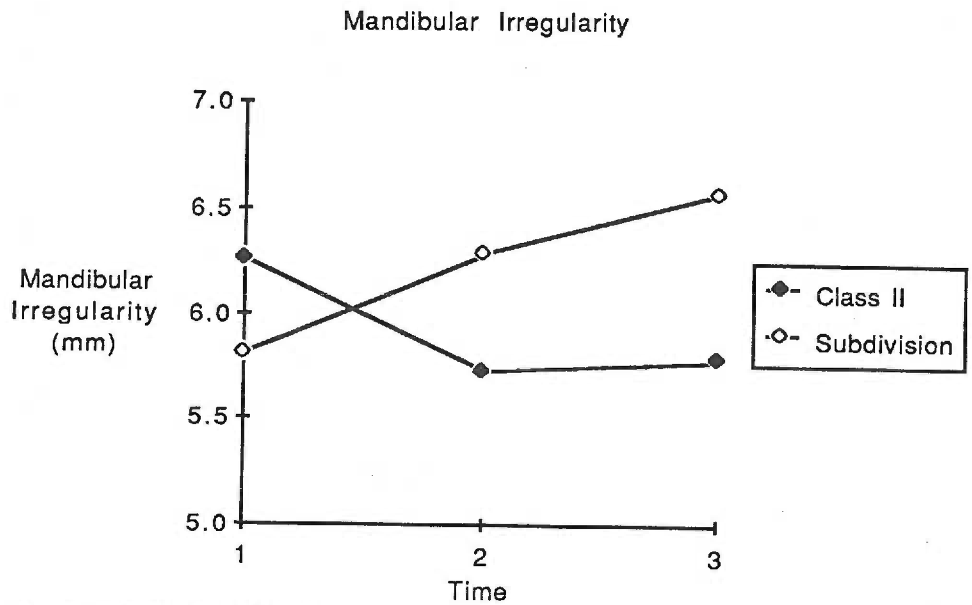


* Denotes Statistical Significance



* Denotes Statistical Significance

Fig. 8 Mandibular/maxillary irregularity male vs female



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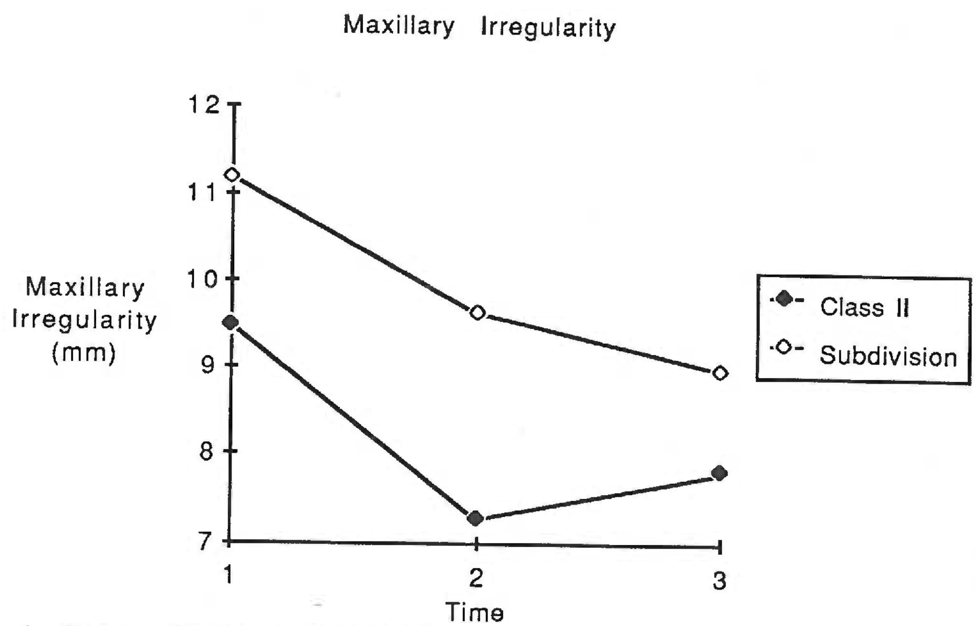
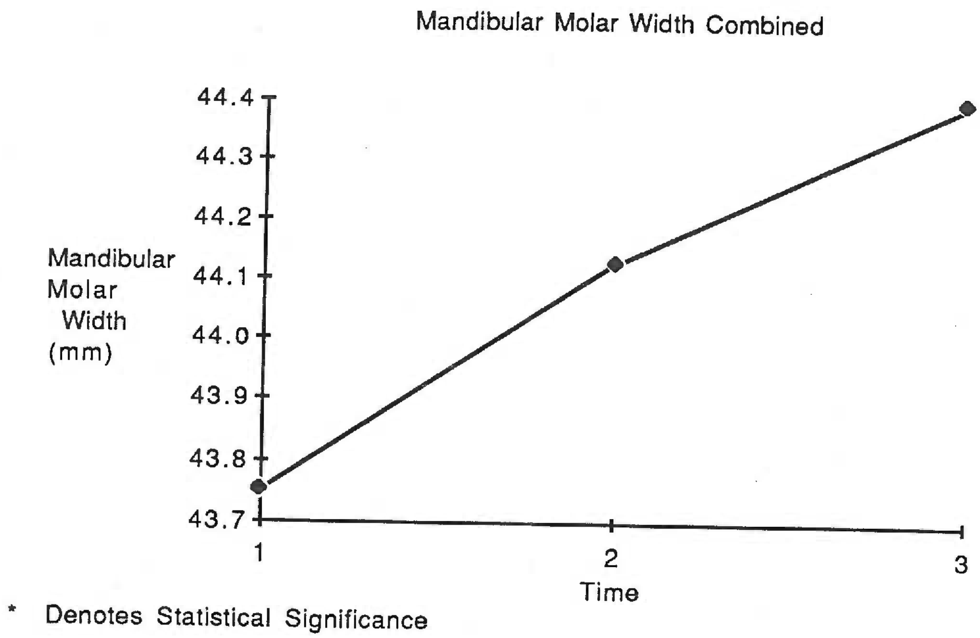


* Denotes Statistical Significance

Fig. 9 Mandibular/maxillary irregularity class II vs subdivision



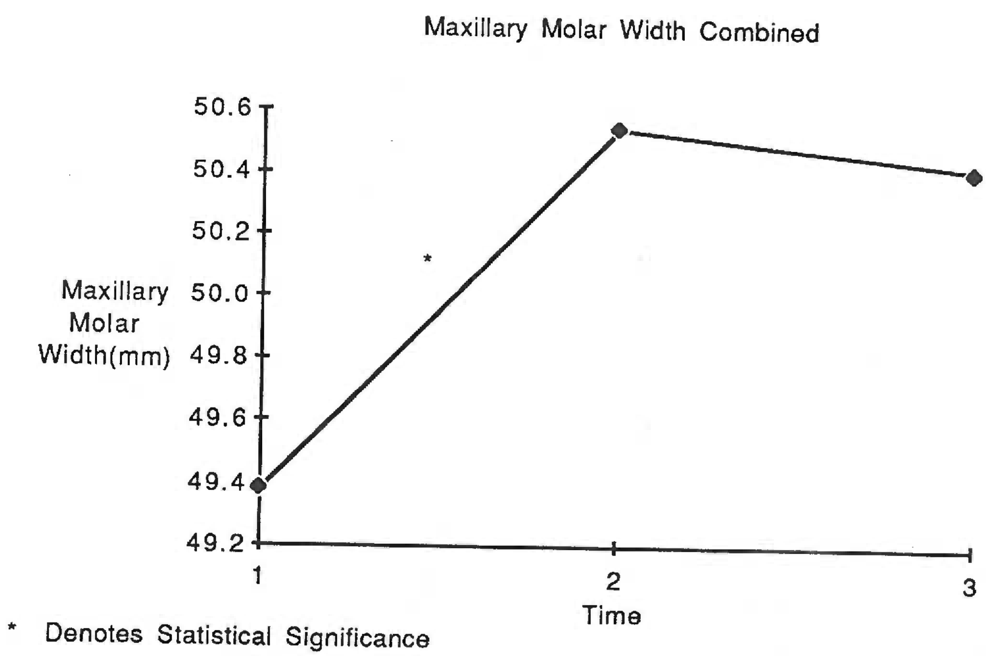
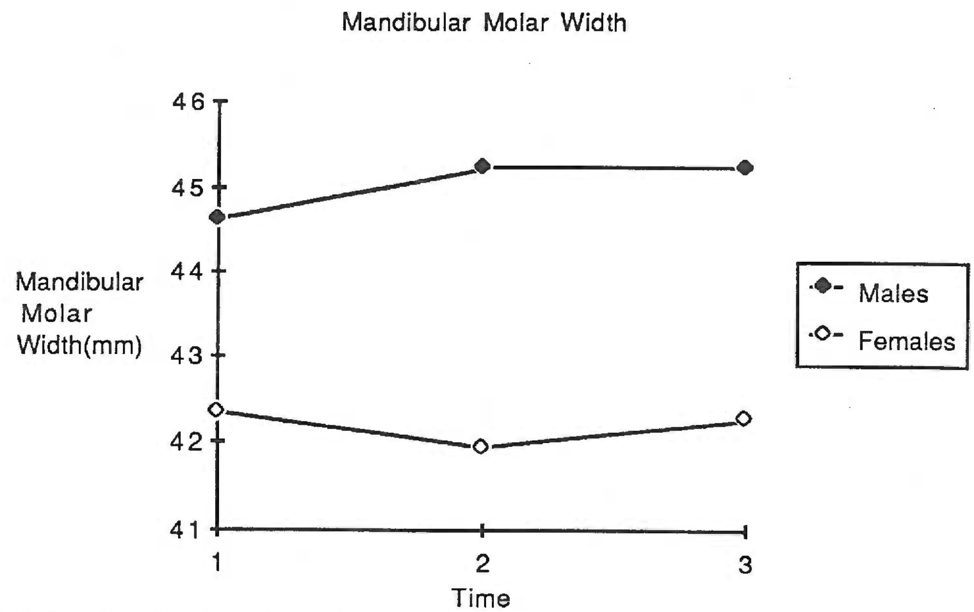


Fig. 10 Combined mandibular/maxillary molar width



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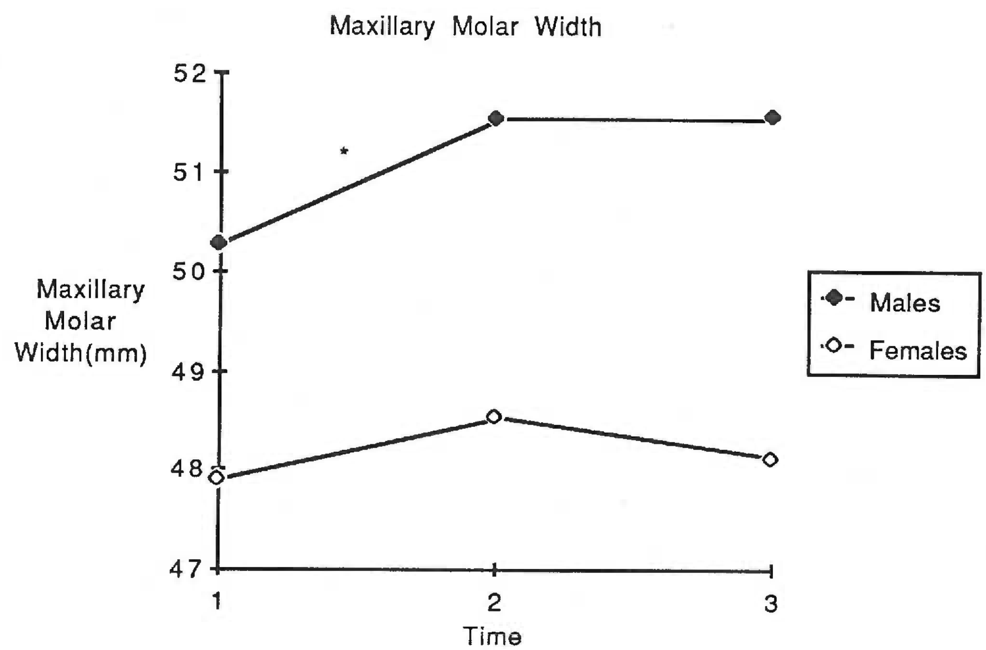
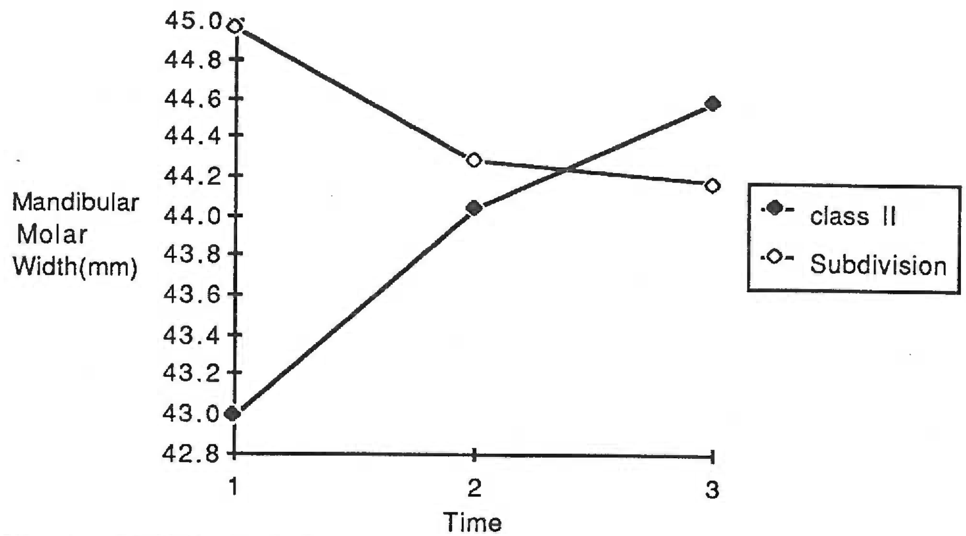


* Denotes Statistical Significance

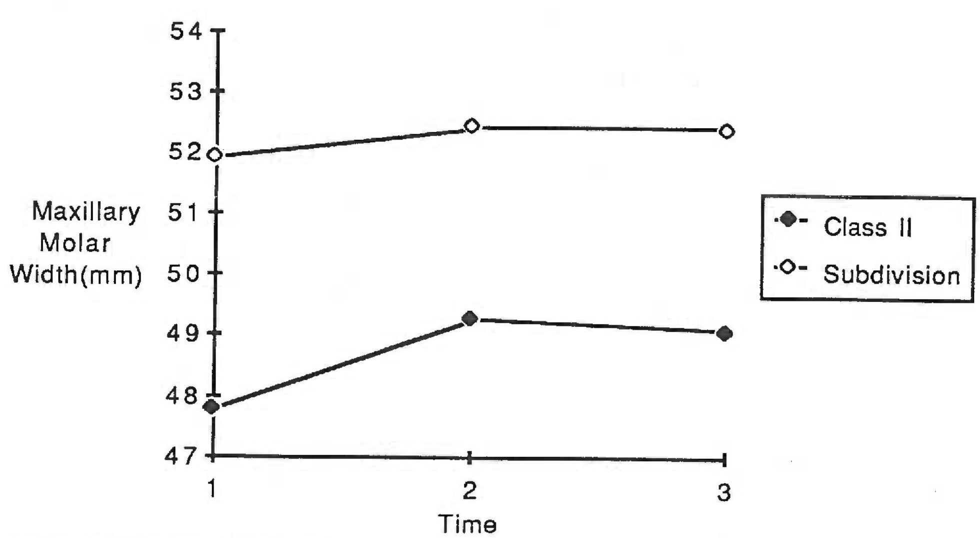
Fig. 11 Mandibular/maxillary molar width male vs female

Mandibular Molar Width



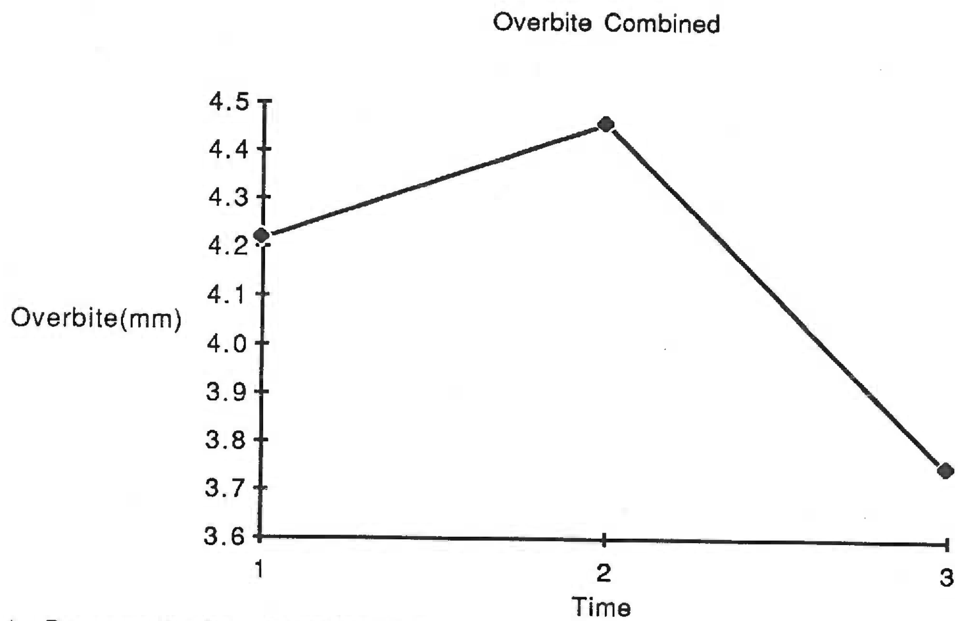
* Denotes Statistical Significance

Maxillary Molar Width



* Denotes Statistical Significance

Fig. 12 Mandibular/maxillary molar width class II vs subdivision



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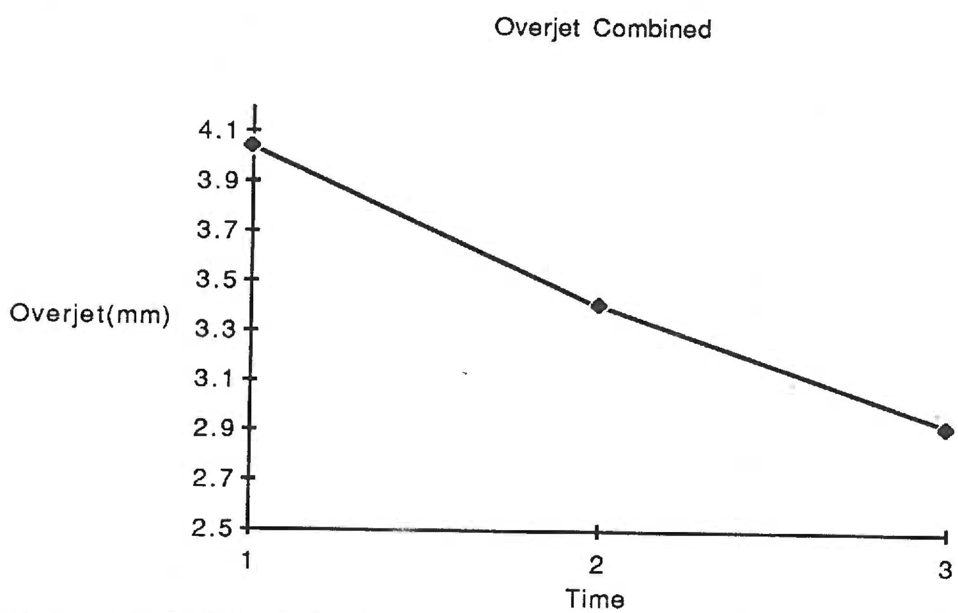
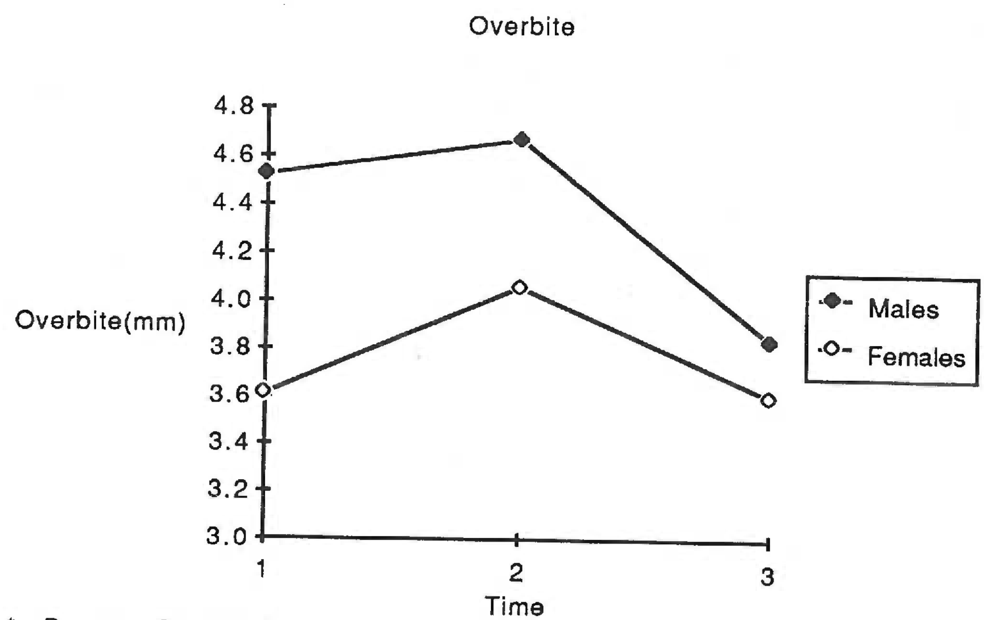


* Denotes Statistical Significance

Fig. 13 Combined overbite/overjet



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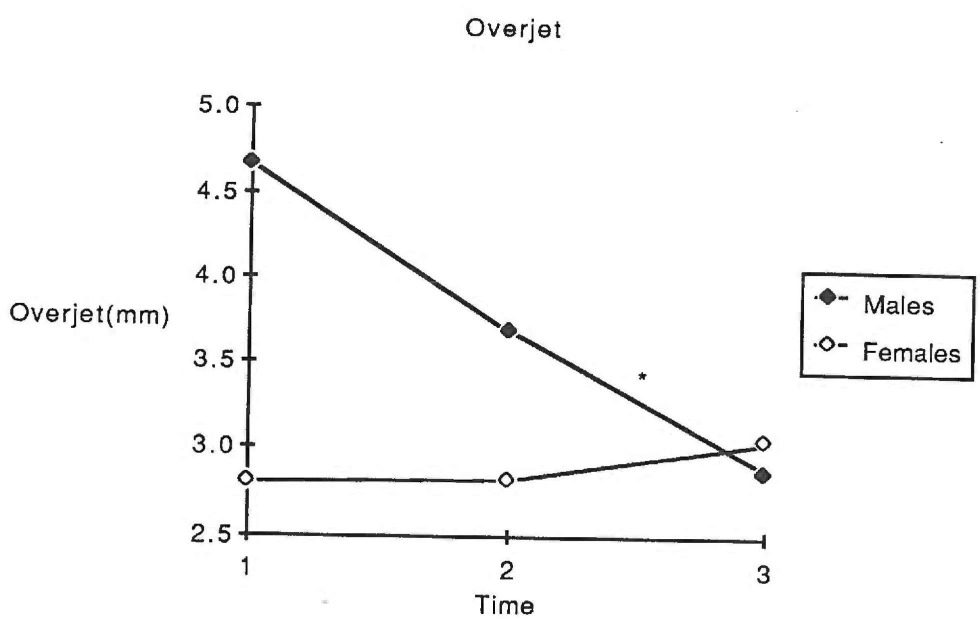
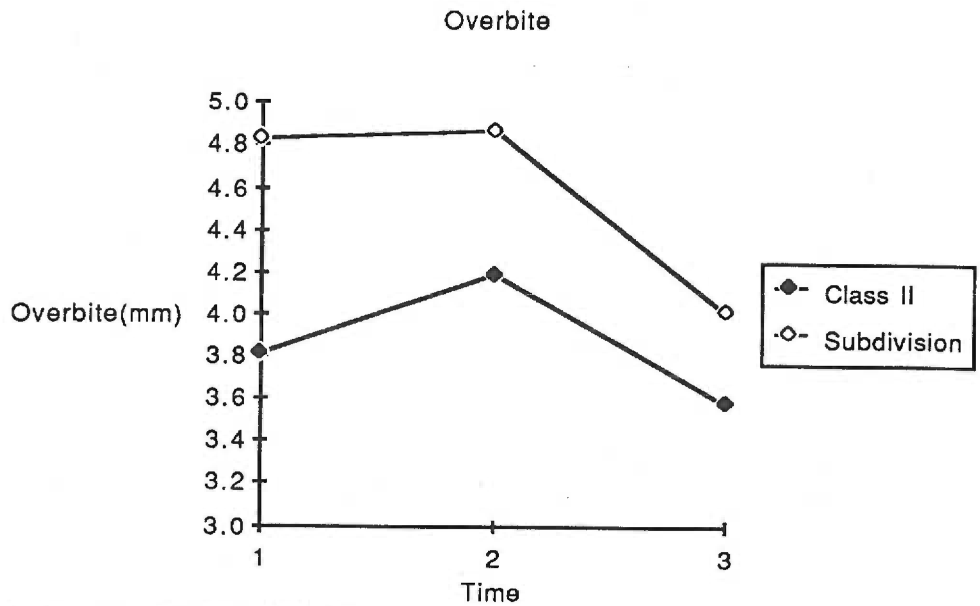
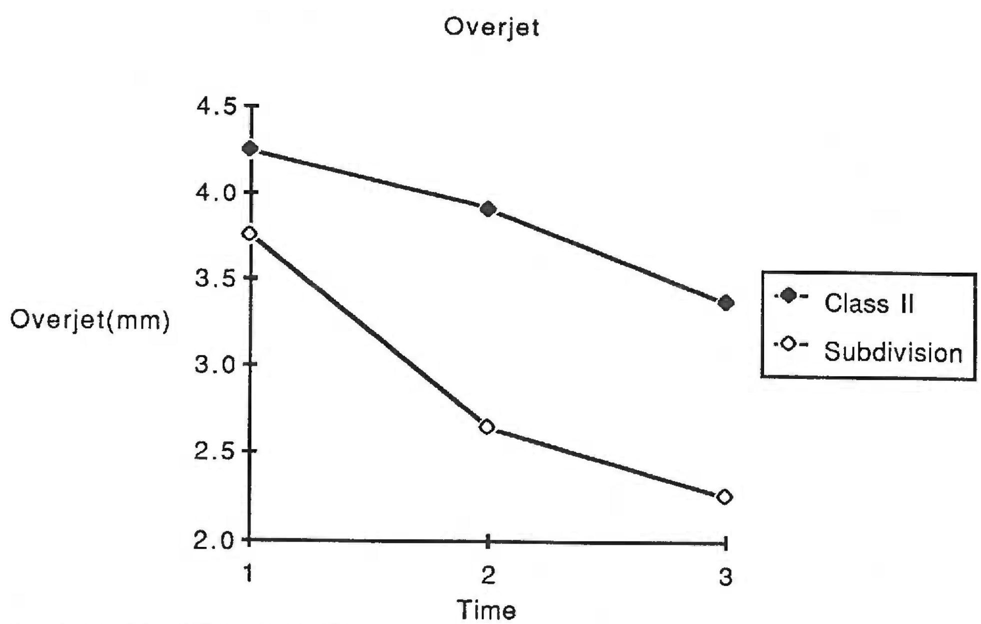


* Denotes Statistical Significance

Fig. 14 Overbite/overjet male vs female



* Denotes Statistical Significance



* Denotes Statistical Significance

Fig. 15 Overbite/overjet class II vs subdivision

Table 1 Sample Demographics

	N	Mean(yr)	Range(yr)
Mixed Dentition -T_1			
Male	8	9.17	7.0-10.92
Female	5	8.58	8.0-9.0
Pooled	13	8.94	7.0-10.92
Early Permanent Dentition-T_2			
Male	10	14.33	12.92-16
Female	5	13.9	13.0-15.0
Pooled	15	14.12	12.92-16
Early Adulthood-T_3			
Male	10	20.08	17.5-23
Female	5	20.1	18.5-22.3
Pooled	15	20.09	17.5-23

Table II Composite Cast Measurements

	T_1		T_2		T_3	
	Mean	SD	Mean	SD	Mean	SD
Maxillary Arch Length	71.14	3.94	68.31*	3.86	66.1*	5.20
Mandibular Arch Length	63.69	3.41	61.04*	3.38	59.98*	3.27
Maxillary Cuspid Width	31.39	2.53	32.68	2.11	32.17	2.51
Mandibular Cuspid Width	25.87	1.68	25.69	2.01	25.31*	2.19
Maxillary Molar Width	49.38	3.16	50.54*	3.20	50.41	3.48
Mandibular Molar Width	43.75	2.35	44.13	2.82	44.4	2.61
Maxillary Irregularity	9.95	2.72	8.10	2.22	8.27	2.73
Mandibular Irregularity	6.07	1.51	5.95	1.97	6.10	2.34
Overbite	4.22	1.59	4.46	1.49	3.75	1.93
Overjet	4.04	2.0	3.40	1.51	2.92	1.17

All measurements in mm

* Indicates a statistically significant ($p \leq .01$) difference from the previous measurement

Table III Composite Cast Measurements
Class II division 2 vs Class I*

	T_1		T_2		T_3	
	Mean	SD	Mean	SD	Mean	SD
Mandibular Arch Length						
Class II div 2	63.69	3.41	61.04	3.38	59.98	3.27
Class I	63.12	2.98	60.24	3.41	58.29	3.15
Mandibular Cuspid Width						
Class II div 2	25.87	1.68	25.69	2.01	25.31	2.19
Class I	25.45	1.47	25.14	1.43	24.70	1.53
Mandibular Molar Width						
Class II div 2	43.75	2.35	44.13	2.82	44.40	2.61
Class I	43.74	2.40	43.69	2.77	43.59	3.16
Mandibular Irregularity						
Class II div 2	6.07	1.51	5.95	1.97	6.10	2.34
Class I	2.22	1.23	2.00	1.17	2.70	1.64

Table III (continued)

	T_1		T_2		T_3	
	Mean	SD	Mean	SD	Mean	SD
Overbite						
Class II div 2	4.22	1.59	4.46	1.49	3.75	1.93
Class I	2.95	1.20	3.35	1.00	2.76	1.20
Overjet						
Class II div 2	4.04	2.0	3.40	1.51	2.92	1.17
Class I	2.87	1.00	3.31	1.21	2.82	1.10

All Measurements in mm

*From Sinclair[10]

Table IV Composite Cast Measurements
Male vs Female Arch Changes Over Time

	T_1-T_2		T_2-T_3		T_1-T_3	
	Mean	SD	Mean	SD	Mean	SD
Maxillary Arch Length						
Male	-1.77	1.3	-1.63	.88	-3.46*	1.07
Female	-2.95	2.96	-3.36	4.94	-6.30*	2.79
Mandibular Arch Length						
Male	-2.02	1.24	-1.38*	.83	-3.28*	1.73
Female	-3.72	1.18	-1.05*	.91	-4.47*	.54
Maxillary Cuspid Width						
Male	1.34*	1.32	-.51	.81	.81	1.29
Female	.84*	1.80	-.51	1.48	.57	.77
Mandibular Cuspid Width						
Male	.31	1.20	-.35	.47	-.08	1.04
Female	-1.28	.73	-.44	.58	-1.72	.95
Maxillary Molar Width						
Male	1.44	.85	-.01	.64	1.43	.98
Female	.62	1.22	-.42	.64	.20	1.84
Mandibular Molar Width						
Male	.78	.89	.02	.42	.81	1.09
Female	-.42	.87	.01	.42	-.41	1.04

Table IV (continued)

	T_1-T_2 Mean	T_1-T_2 SD	T_2-T_3 Mean	T_2-T_3 SD	T_1-T_3 Mean	T_1-T_3 SD
Maxillary Irregularity						
Male	-1.72	3.6	.29	1.67	-1.12	4.74
Female	-1.98	1.45	.26	1.04	-1.72	.48
Mandibular Irregularity						
Male	.42	1.86	.08	1.46	.50	2.45
Female	-1.31	1.14	.30	.64	-1.29	1.44
Overbite						
Male	.14	1.18	-.84	1.07	-.69	1.61
Female	.45	.70	-.46	.83	-.01	.72
Overjet						
Male	-.98	1.01	-.82	.79	-.18	1.44
Female	.03	.92	.23	.45	.26	1.32

All Measurements in mm

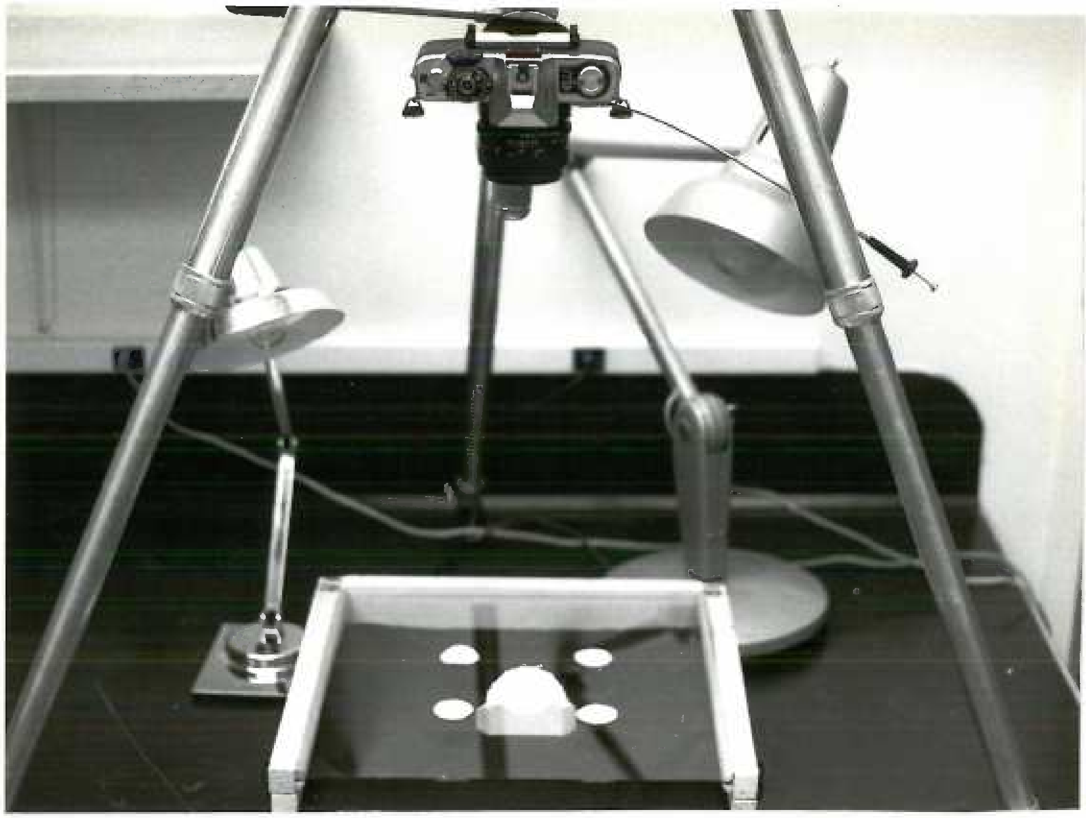
* Indicates a statistically significance ($p \leq .01$) difference between change in arch demension of males vs change in arch dimension of females.

Appendix 1-A

Digitized Points

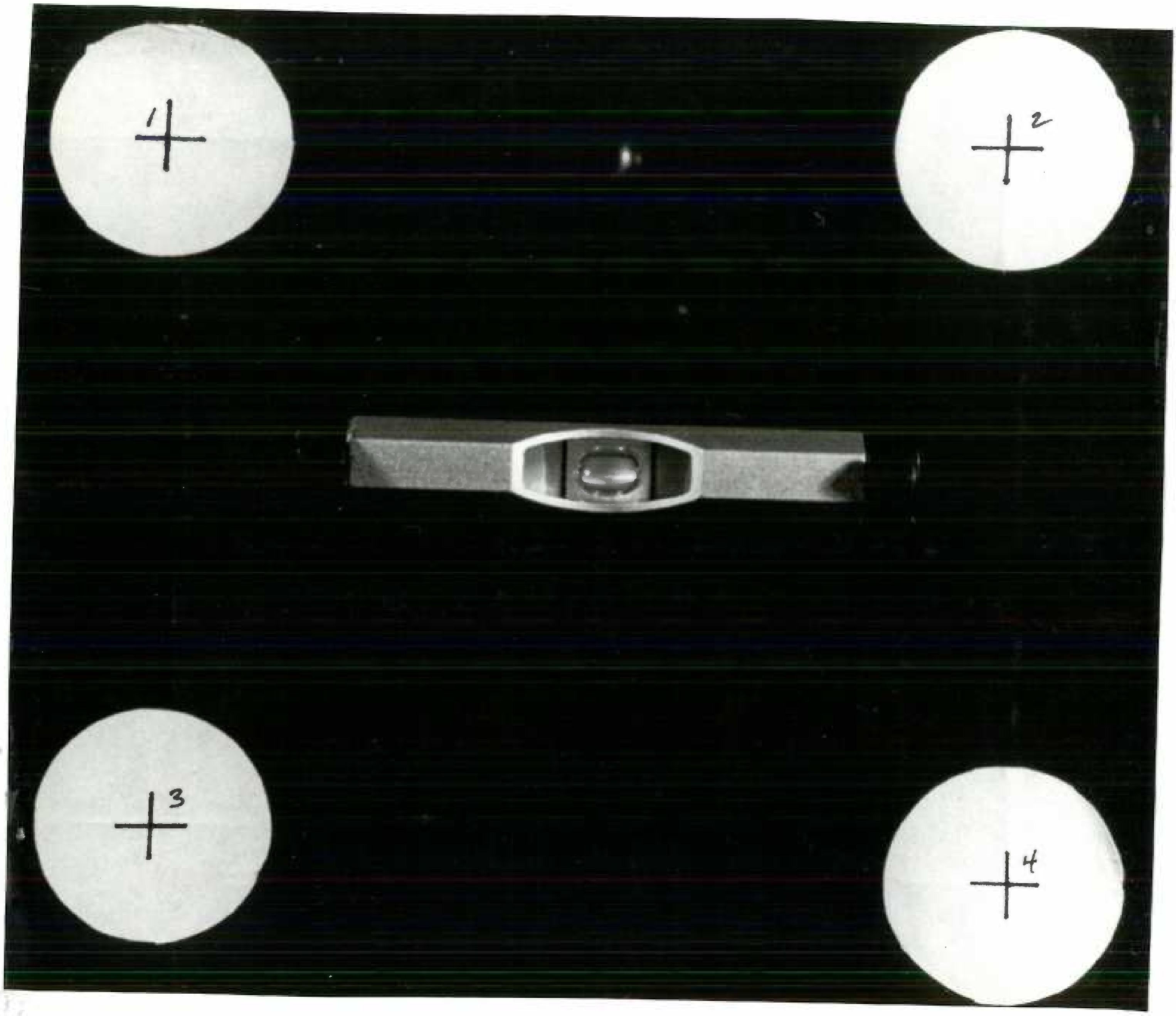
1. A Fiducial
2. B Fiducial
3. C Fiducial
4. D Fiducial
5. One Fiducial
6. Two Fiducial
7. Three Fiducial
8. Four Fiducial
9. Left 6 Cusp
10. Left 6Ridge
11. Left 3 Cusp
12. Midpoint
13. Right 3 Cusp
14. Right 6 Ridge
15. Right 6 Cusp
16. Left 3 Mesial
17. Left 2 Distal
18. Left 2 Mesial
19. Left 1 Distal
20. Left 1 Mesial
21. Right 1 Mesial
22. Right 1 Distal
23. Right 2 Mesial
24. Right 2 Distal
25. Right 3 Mesial

Appendix 1-B



Set up for production of photographic images from study casts while maintaining parallelism between the occlusal plane, glass plate and camera lens.

Appendix 1-C



Parallelism of glass plate

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