Quantitative Computerized Analysis of Lower Incisor Changes: A Longitudinal Implant Study In Man

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This paper is the outgrowth of the continuing analysis of data from a longitudinal growth study undertaken by one of us (Mathews) in 1966. The study encompasses approximately 1400 serial headfilms taken over the past decade of thirty-six children beginning at about six years of age. The children were selected randomly from patients being screened for treatment in the restorative dental clinic at the University of California. All subjects have had tantalum implants in the mandible and maxilla. Headfilms have been taken on an annual basis and include lateral centric relation, rest, frontal and 45° oblique views.

Figure 1 taken from the work of Björk[1,2] shows the locations of the implants which served as guides for implant placement in this study. Pins were placed in the anterior portion of the palate on either side of the midline if the permanent central incisors were unerupted and above the root apices on the labial surface if they had erupted. One pin was placed on the inferior surface of each maxillary zygomatic process. Three implants were placed in the mandible: one at pogonion, one well below the first permanent molar, and one in the approximate center of the ascending ramus. All implants were placed intraorally with the exception of the ramal implants which were done extraorally through the masseter muscle. Pinset-

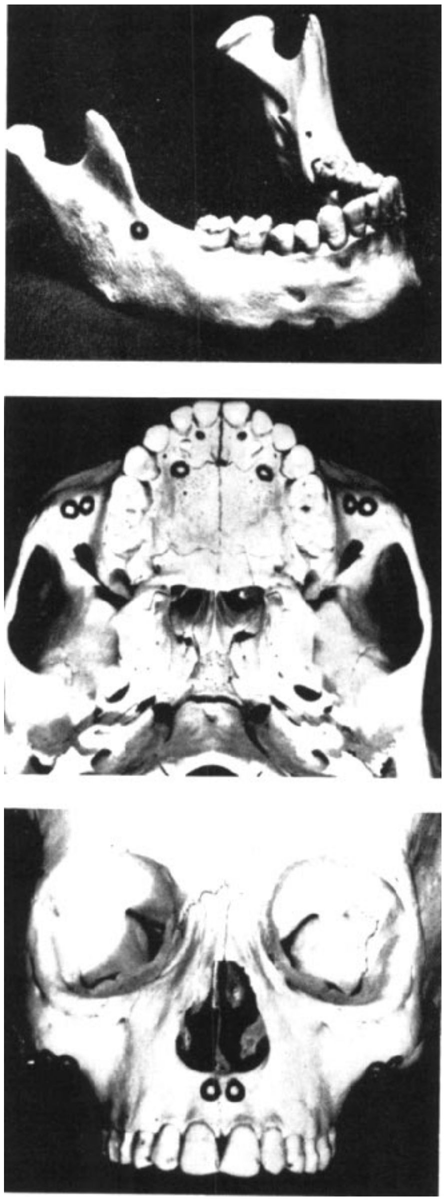

Fig. 1

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ters, fabricated after those described by Björk,[3] were modified to decrease their over-all diameters. An extension of thin stainless steel tubing two and one-half centimeters long to accommodate the 0.025″ diameter tantalum implant wire was added to afford tissue penetration with minimal tissue trauma. The ramal implant resulted in an increased distance between pins and thereby improved the accuracy of mandibular superpositioning.

Many in the health sciences have been reluctant to embrace computer technology. This has been particularly true in orthodontics at both the clinical and research levels where conclusions have been drawn from a relatively small data base. Computer technology is becoming increasingly sophisticated and perhaps awe-inspiring. Yet, we must not be intimidated realizing that accuracy and subsequent utility is totally dependent on the input received by the computer. The experienced orthodontist knows well the problems surrounding the location of the various cephalometric points employed in tracing headfilms. It is disturbing, to say the least, when the clinician leans heavily on the average value in the computer printout and attempts to fit the given patient to it.

The need to mechanically process the data amassed from this study has become increasingly apparent. Hand tracing of hundreds of headfilms becomes a monumental task replete with uncontrolled error. Among the sources of error are projectional enlargement and distortion, landmark identification, and in superimposition of tracings. Correction of projection enlargement is not practical other than in the midsagittal plane. Generally speaking, there is no control of tracing error since only single tracings are made of each film.

We are fortunate in having access

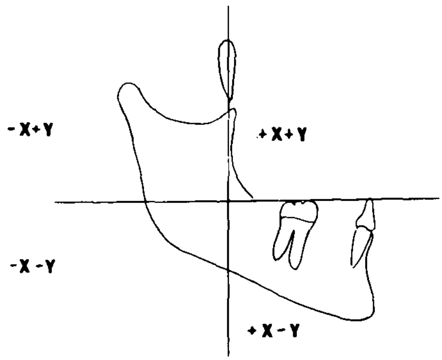


Fig. 2

to an outstanding computer program developed over the past decade by Baumrind: the University of California Craniofacial Measurement System. This is a computer-aided procedure developed for efficient and precise comparison of headfilms taken at different time points.[4] It has been designed to gain maximum accuracy and concòmitantly minimize human error in the mechanics of data imput. Four independent tracings are made of each headfilm, locating twenty-one dental and skeletal landmarks. Tracing, in the ordinary sense of the word, is not done except to identify anterior cranial base structures, palatal plane, and the lower border of the mandible as seen in the cephalogram. The remaining points of reference appear as fine dots in the acetate film. Each tracing is digitized yielding a two-dimensional array of coordinate values. The coordinate system is illustrated in Figure 2. Accordingly, negative and positive values for the X and Y axes appear in the printout locating a reference point in one of the four quadrants. The coordinate values for each landmark and for the anatomic reference planes of the independent estimates of the four tracings are averaged as a computer operation. This yields a single best estimate of the coordinates of each point on each headfilm. This procedure reduces the

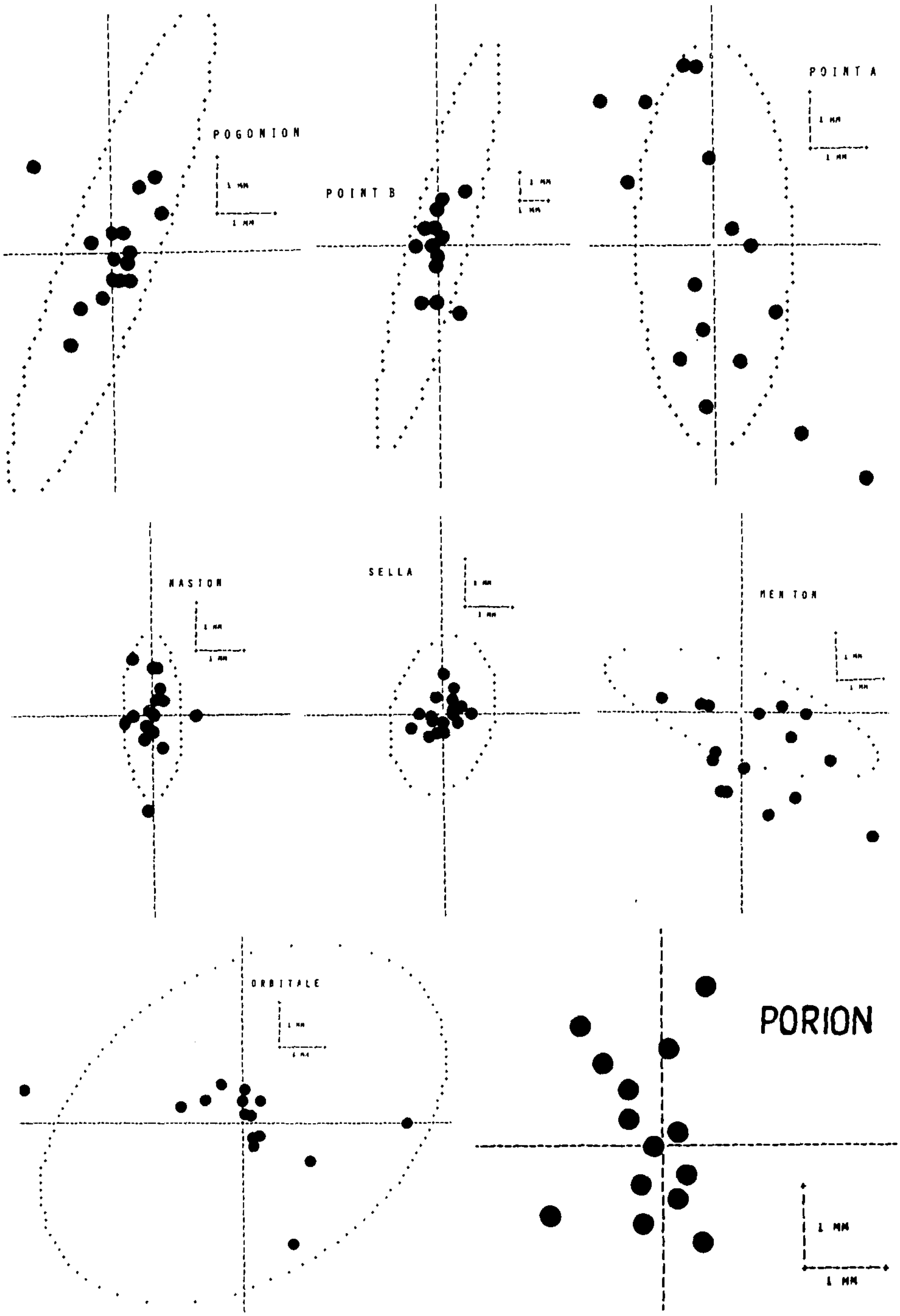
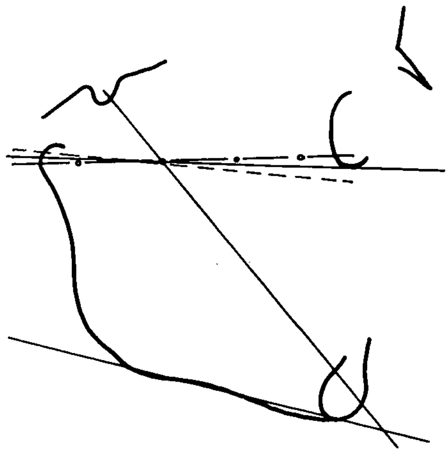

POGONION
POINT B
POINT A
NASION
SELLA
MENTON
ORBITALE
PORION
1 MM
1 MM

Fig. 3

measurement error inherent in landmark location by some fifty percent.[5] Additionally, it provides a considerable measure of protection against grossly outlying values. It is possible, as a computer operation, to rotate and translate the best estimates of each landmark for different time points and to superimpose on each of the three anatomic planes.

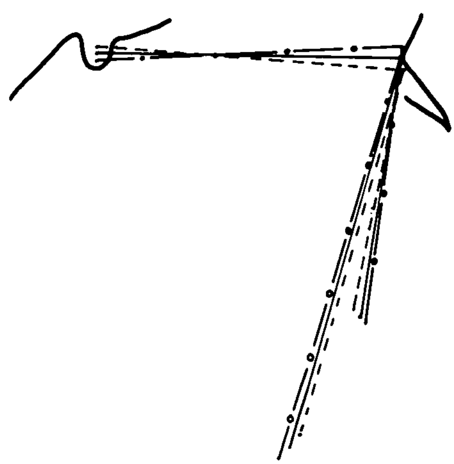
To illustrate the method, a duplicate headfilm of one individual was given to each of sixteen orthodontists experienced in conventional headfilm tracing. Each film was accompanied by a list of the twenty-one landmarks used in the study along with the definition of each landmark. All participant's tracings were digitized and a computer program used to produce scattergrams of each landmark. The scattergrams are dispersed around a mathematically averaged value producing a graphic display of the estimation error for each landmark among the sixteen orthodontists. The results of this effort can be seen in Figure 3. This should provide food for thought when one relates these findings to the level of accuracy in his own tracings. The results of the range of estimation error among the sixteen tracers as applied to landmarks used commonly in routine cephalometric analysis are shown. The total range of values for porion and orbitale have been selected to establish three possible alignments for Frankfort horizontal (Fig. 4). Similarly, values for the Y-axis and mandibular plane are seen. The smaller the angle being measured, the greater the percentage estimating error will be. Using cephalometric points, S, N, point A, and point B from the given test film (Fig. 5) discloses ANB angle values ranging from four degrees (acceptable maxillomandibular relationship) to ten degrees (indicating severe skeletal dysplasia). Unfortunate con-



TOTAL RANGE OF VALUES FOR Y - AXIS AND FRANKFORT HORIZONTAL PLANE TO MANDIBULAR PLANE USING DISPERSION AROUND LANDMARKS PORION AND ORBITALE.

Y - AXIS	49°	45°	53°
MP TO FH	12°	8°	15°

Fig. 4



TOTAL RANGE OF VALUES FOR SNA, SNB AND ANB USING DISPERSION AROUND LANDMARKS S, N, A, & B

S N A = 82°	83°	80°
S N B = 75°	79°	70°
A N B = 7°	4°	10°

Fig. 5

clusions could well be drawn depending upon which plane or angle is accepted as being correct. This example is illustrative of the value of replicate tracings in clinical headfilm analysis as well as lending increased confidence in evaluation of tooth movement and growth changes.

Four cases have been selected from the longitudinal growth study to provide examples of the application of the UCSF computer aided program. We have elected to follow the eruptive pattern of the lower incisor and the accompanying development of point B in children over a ten-year period presenting with Class I orthodontically untreated dentitions. It is apparent that the old theme of infinite morphologic variation in nature in general and in craniofacial growth in particular will be reflected in this small sample of children who could be judged to have "good faces." The first three of the four cases are male siblings with common genetic heritage. The fourth is an unrelated male. All present with favorable facial patterns and exhibit forward mandibular rotation and translation as defined by Björk.[5] It will be recalled that longitudinal material is best presented as a case-by-case method, thus avoiding the problems surrounding the average value in cross-sectional analysis. Unfortunately, there is no way at the present to present longitudinal material statistically in longitudinal fashion. Broad generalizations should not be made from this or other small selected samples, irrespective of the statistical method being employed.

Subsequent to the publication by Björk and Skieller[6] reporting the application of so-called natural registration points in the mandible, various authors may have led readers to believe that they represent fixed points of reference. Björk was quite clear in referring to natural mandibular reference points as being *relatively* stable.[7] In review, these points include pogonion, the inner lower cortical border of the mandibular symphysis, the mandibular canal, and the inner portion of the crown of the unerupted third molar *prior* to root formation. Attention will be directed to the level of stability of the lower aspect of the inner and outer cortical plates of the symphysis and pogonion. This paper will not be concerned with the mandibular canal or the crown of the unerupted molar as points of reference. Mathews and Ware[8] have remarked in another paper concerning the low level of reliability of these two points.

Implant methodology establishes fixed points of reference within a given bone unless they are lost through remodeling resorption or as the result of a pin having been placed improperly. Examples of both phenomena are seen in this longitudinal study and must be taken into consideration in evaluating a given film. For example, downward descent of the palate and maxillary complex through remodeling resorption may result in loss of palatally-placed pins into the maxillary sinus. Serial study involving tantalum implantation in this type of experimentation in man along with the accompanying radiation is no longer looked upon with favor.

One might ask rhetorically, does the tip of the lower incisor normally move smoothly upward in course of eruption until it is in occlusion? Does point B develop during the mixed dentition by differential resorption of bone in this area or does addition of bone at the point of the chin provide the answer? It is likewise rational to expect that both of these phenomena operate in concert. One should be reminded that while 45° oblique headfilms are excellent for analysis of the behavior of the buccal dentition they do not lend themselves well in studying the incisal region.

The implant method allows one to compare routine mandibular superpositioning with that obtained with tantalum implants. Theoretically, both methods of superpositioning should yield identical results. As one might suspect, they are not the same, particularly if one were to follow a series of films for the given patient. Three implant pins in a given bone, as the mandible, can be checked for stability at succeeding time intervals by triangulation. All of this, of course, is dependent upon the impossibility of interstitial bone growth.

Illustrations have been prepared to provide examples of the development of cephalometric point B and of the lower incisor tip eruption, comparing the customary anatomic superpositioning on Go-Gn registered on pogonion with that seen by superimposing on implants. It will be noticed that only two pins are shown in certain instances rather than the three to which reference has been made. In these cases, minor movement of the implant up to two millimeters over the ten-year period may have occurred, but is more often related to small rotational positioning errors of the head in the cephalometer. Graphs have been made from the computer printout to follow the lower incisor as well as the development of point B during the ten-year period. The computer program is very exacting, and since there is inevitable technician variability in positioning the patient in the headholder, one sees small perturbations in the graph pattern between the first and last point on a given graph. We have elected not to smooth the curves leaving it to the reader to follow the general pattern in each case.

Figure 6, one of the three brothers, patient B. H., seen in norma-lateralis, is superimposed on SN to demonstrate over-all facial growth during an approximate ten-year period beginning at eight and one-half years. The palate has descended in parallel fashion with a marked decrease in the mandibular plane angle, suggesting decreased lower facial height with the chin point having been translated forward and down. Mandibular superpositioning on implants seen in Figure 7 discloses forward ro-

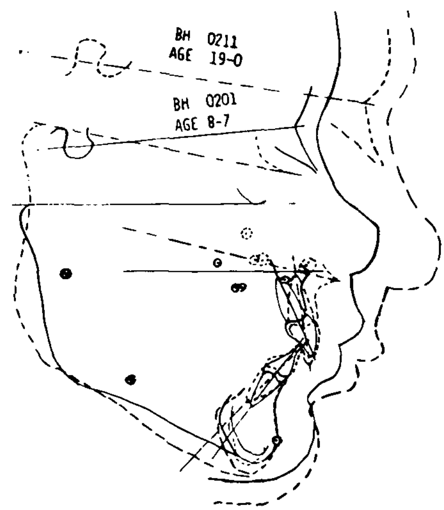


Fig. 6

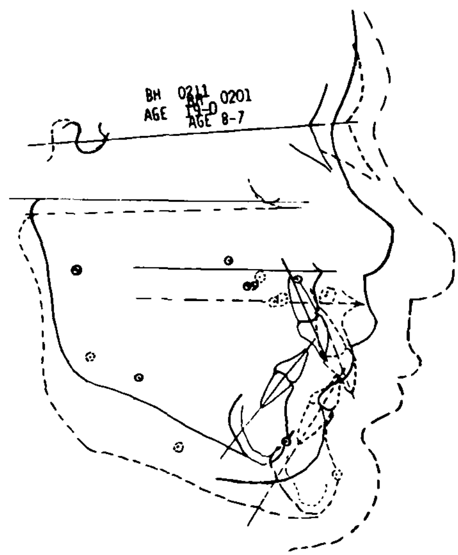


Fig. 7

tation with minimal change at the lower posterior border. Marked bony additions are seen at menton with symphyseal remodeling. Stability at pogonion is seen here as well as in the subsequent case examples.

Figure 8 for the same patient, B. H., is in the form of a graph. The initial point A and the final point A′ portray the first and last positions of the incisor tip using the customary mandibular registration which will be referred to henceforth as anatomic registration. Anatomically, the incisor appears to have erupted approximately six millimeters vertically and less than one millimeter lingually. Pin registration shows the actual vertical incisor tip movement from B to B′ to have been negligible while having moved some three millimeters lingually. What might appear to be an error in comparing vertical incisor eruption with both methods of registration is not, in reality, an error at all. The greater incisor tip eruption when superimposed anatomically is the result of bony additions at menton. This provides an excellent example of definitive error were one to rely on anatomic superpositioning over an extended growth period. In nearly every instance vertical movement appears appreciably greater with anatomic reference than with implant superpositioning, reflecting bony additions at menton.

Figure 9 for patient B. H. depicts the development of point B which has moved vertically upward about three millimeters in both methods of registration. Point B has moved lingually about three millimeters registered anatomically as contrasted with about one millimeter forward on pin registration. Point B is *not* determined consistently by different tracers as was seen earlier in this paper.

The next sibling, D. H., is presented in norma-lateralis superimposed on SN. Figure 10 demonstrates

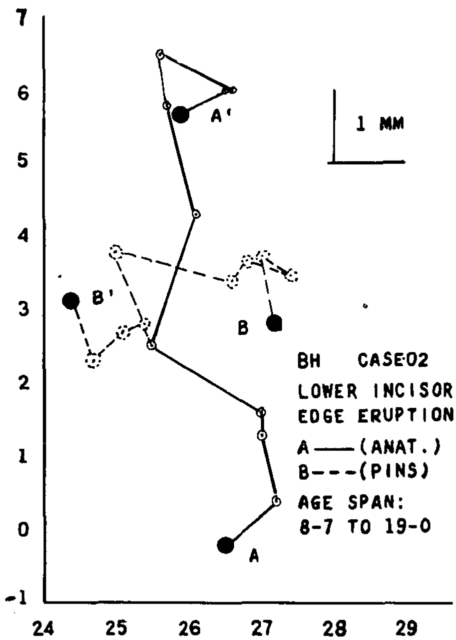


Fig. 8

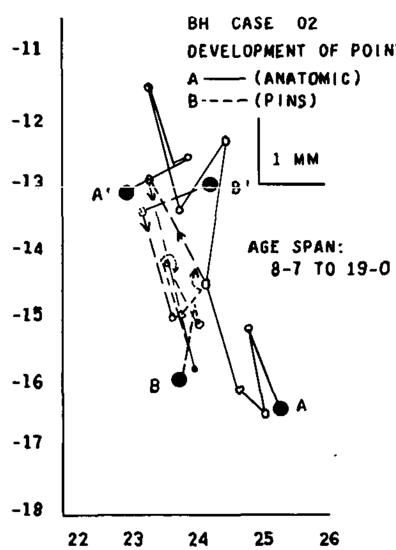


Fig. 9

over-all facial growth and development beginning at seven years of age. Superimposition on mandibular implants (Fig. 11) does not show the marked additions at menton as seen in patient B. H.

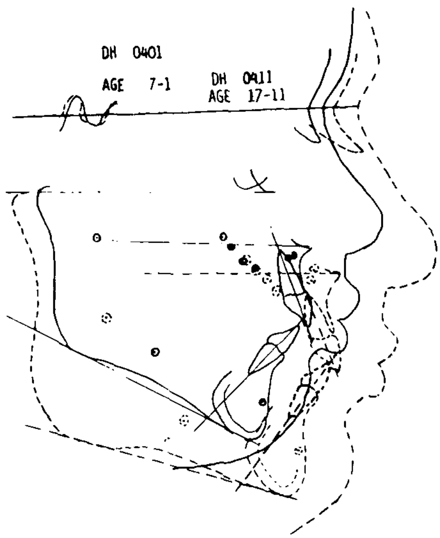


Fig. 10

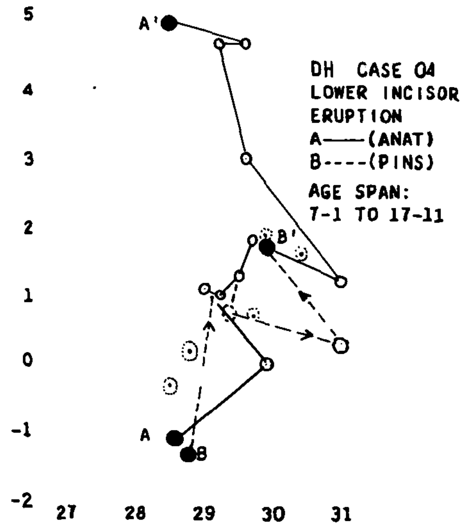


Fig. 12

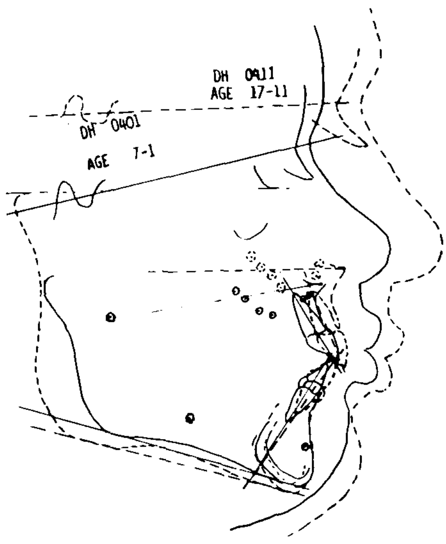


Fig. 11

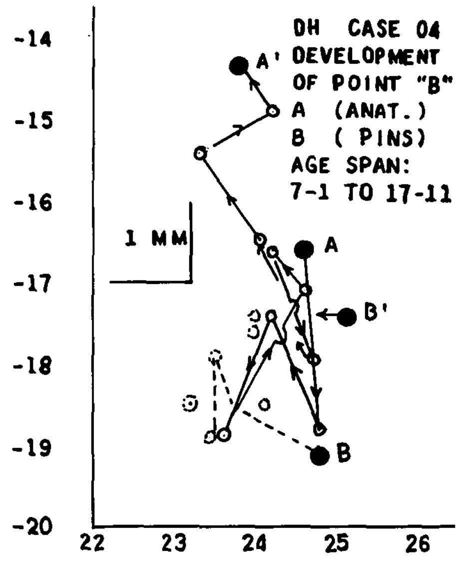


Fig. 13

Figure 12 presented as a graph follows the eruptive pattern for the lower incisor tip for D. H. over a ten year period. Anatomically, it has erupted approximately six millimeters as is seen from A to A′ on the graph. Pin registration discloses a lesser measure of three millimeters from B to B′. Again the graph is not smoothed and the perturbations have been maintained. Horizontal change during eruption is seen to be minimal with anatomic registration and about one millimeter forward with implant registration. The recognizable differences between the two methods of registration in this graph are in the vertical rather than the horizontal plane. Figure 13 follows the develop-

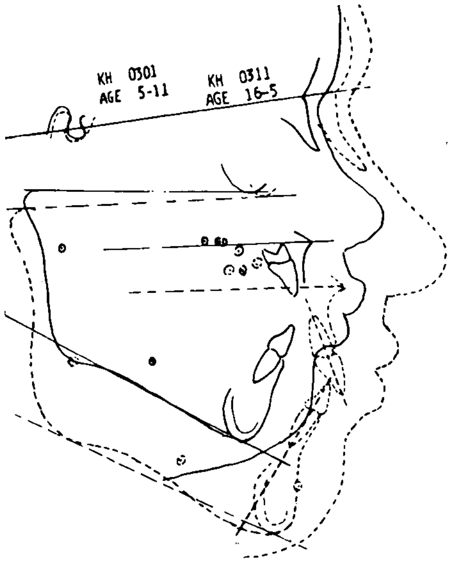


Fig. 14

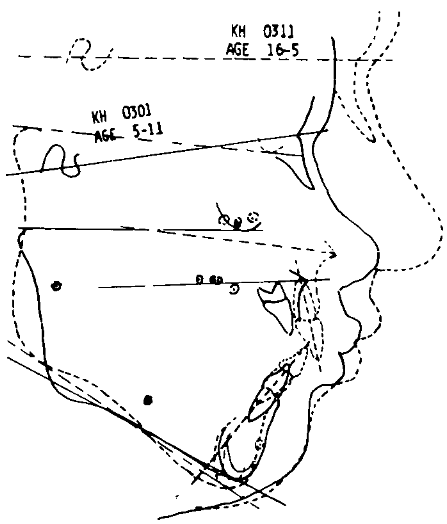


Fig. 15

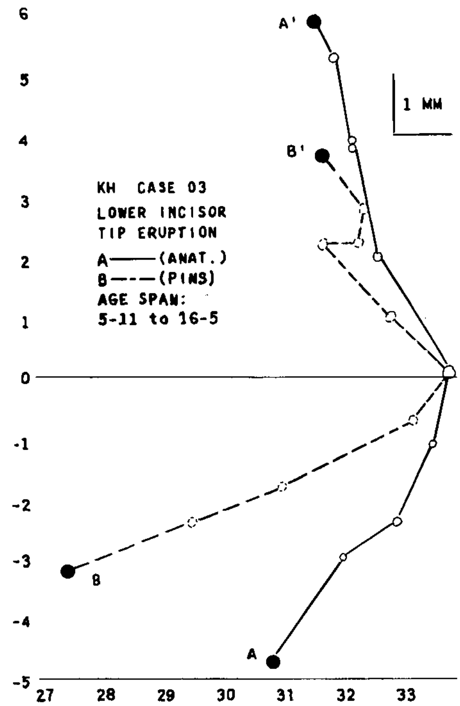


Fig. 16

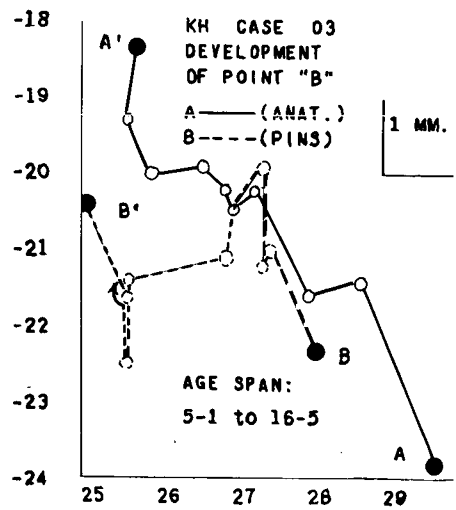


Fig. 17

ment of point B over the same time period. Anatomically, from position A to A′, marked irregularities are seen with a net vertical change of about two millimeters and one millimeter lingually. Implant registration shows one and one-half millimeters vertical development from B to B′ and no anteroposterior change. Again the difference between the two methods of superpositioning is the result of bony additions at menton.

The third sibling, K. H., the youngest of the three shown over the same ten year period, entered the study at age six years. Figure 14 for this boy in norma-lateralis is superimposed on SN. Maintenance of the facial pattern follows the constancy shown years ago by Brodie.[9] Mandibular implant superpositioning seen in Figure 15 discloses less growth of the mandibular corpus than was the case with the other two siblings. Growth at menton can be seen with the inner and outer cortical plates of the symphysis descending vertically. Bone apposition on the lingual aspect of the symphysis has been negligible in all three brothers. The lower border of the body of the mandible has remained stable in the course of remodeling resorption at gonion and corresponding additions at menton.

The eruptive pattern of the lower incisor edge displayed in Figure 16 is in marked contrast with the other two siblings. Following the solid line in the graph from A to A′, one sees the incisor to have erupted about eleven millimeters registered anatomically while only some six and one-half millimeters when superimposed on the implants as shown by following the broken line from B to B′. This incisor has followed the more classic pattern of early eruption forward and then dropped back as the face and jaw have grown markedly.

The lack of metric correspondence between the two methods of superpositioning in the vertical development of point B in K. H. is shown in Figure 17. Upon anatomic registration, following A to A′, cephalometric point B has moved some six millimeters vertically but only two millimeters when registered on the implants. Point B has moved lingually in both registrations but to a lesser degree in pin registration than when done anatomically.

The last patient, R. S., beginning at age seven years and extending over a ten-year period, is seen first in Figure 18, in norma-lateralis superimposed on SN. Marked over-all facial growth has been attained in good fashion with the chin point being translated well forward and down. Figure 19 for this patient superimposed on the mandibular implants demonstrates a marked bony addition at menton and a corresponding symphyseal remodeling. Stability at pogonion is seen in all four boys as has

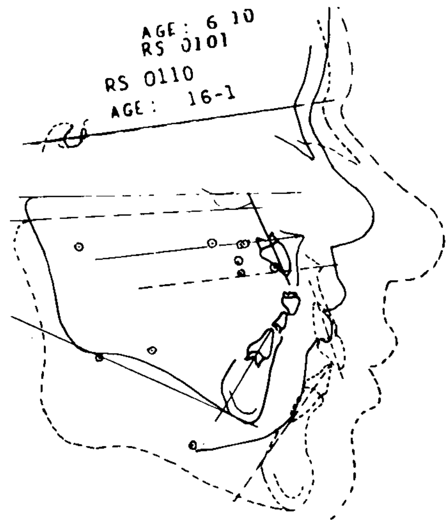


Fig. 18

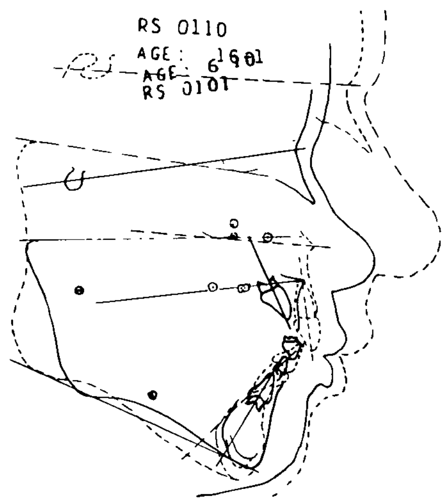


Fig. 19

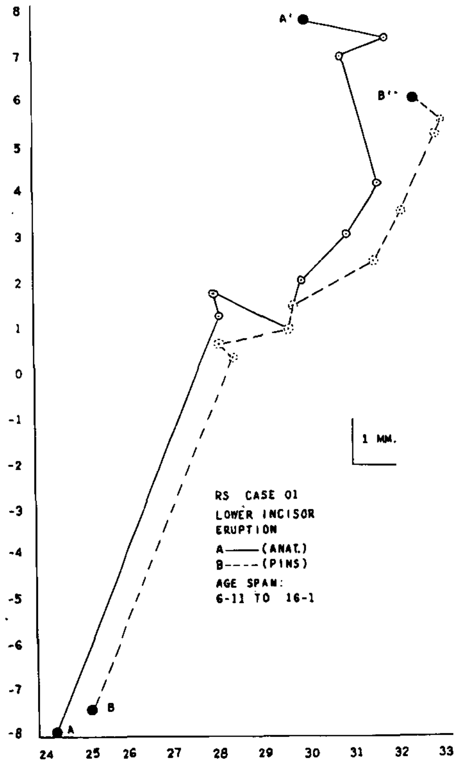


Fig. 20

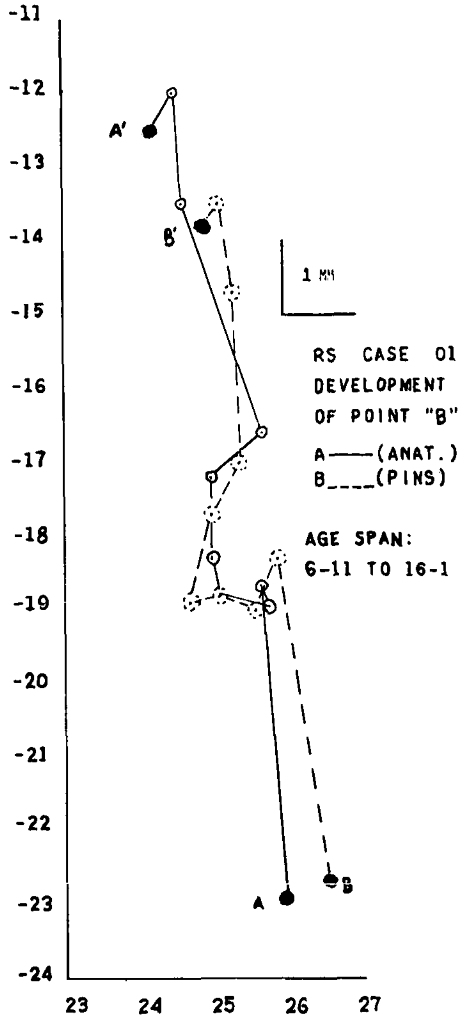


Fig. 21

been pointed out by Björk. The lack of stability of the lower border of the mandibular body, the lower aspect of the inner symphyseal cortical outline, and menton has been evident in all four cases with variation from boy to boy. The eruptive pattern of the lower incisor tip for R. S., seen in Figure 20, is interesting on a comparative basis. Vertical eruption is similar in both superpositionings, some fifteen and one-half millimeters with pin registration. A continuing forward eruption is seen with both registrations but somewhat greater with reference to the implants. The incisor tip has moved labially and forward in a more or less straight line. Development of cephalometric point B seen in Figure 21 needs little description. The migrational path has been essentially vertical with both registrations and only two millimeters lingually, being slightly more marked as viewed by pin registration.

Discussion

It seems quite clear that dentoalveolar morphologic change cannot be demonstrated with accuracy in the symphyseal area on a serial basis during the years when marked facial growth is occurring when one is forced to rely on customary anatomic superpositioning methodology. It suggests that prognostication of morphologic change for a given patient in the symphyseal area is suspect. Proposed subsequent analyses of midfacial growth, using material from the longitudinal study is likely to show much the same thing. Unfortunately, the so-called natural registration points might better be regarded as areas rather than points of registration. On the other hand, if the patient has not grown or the elapsed time between succeeding films is not particularly great, the customary registration mechanics should continue to serve. Nevertheless, this statement cannot be considered to be reliable during the adolescent growth spurt wherein the orthodontist has no control or knowledge of growth velocity and the length of time in which marked variation in growth rate may be expected.

The UCSF computer program is presented here as a research tool. In this, preconceived notions regarding dentofacial growth and morphologic change can be examined in retrospect to later be supported or discarded. The fluctuations seen in the graphs underline the difficulty in analysis and case presentation where one is attempting to quantify various morphologic growth changes when errors introduced both by the technician taking the film and the person tracing the film are very real. At least, for the present, no attempt is being made to prognosticate morphologic change for a given individual although such effort is undoubtedly as intriguing to the orthodontist as earthquake prediction must be to the geologist.

Summary

Computer aided interpretation of longitudinal growth data has been presented in summary fashion for four of thirty-six young patients with maxillary and mandibular tantalum implants employing the U.C.S.F. computer program. Broad generalizations of changes in mandibular morphology cannot be made from the small sample. Caution is the watchword in employing so-called natural reference points for superpositioning over an extended period of growth. Identification of cephalometric point B is difficult on a long-term serial basis. The direction of eruption of the lower incisor tip can be followed rather easily and accurately in patients with mandibular implants but varies considerably from patient to patient. Discrepancies arising between customary anatomic tracing methods and implant references have been demonstrated.

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