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Cephalometric Superimpositions

A Comparison of Anatomical and Metallic Implant Methods

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ABSTRACT

Objective: To test the hypothesis that there is no difference between the information produced by superimposition of serial lateral headfilms on anatomical structures and that produced by superimposition on metallic implants according to the protocols of Björk.

Materials and Methods: Serial cephalograms of 10 untreated subjects who had tantalum implants placed in the maxilla and mandible during childhood were analyzed. Headfilms taken at six consecutive stages of cervical vertebral maturation (CS1-CS6) for six female and four male subjects were used. Tracings were superimposed according to the methods of superimpositions advocated by the American Board of Orthodontics (ABO). In addition, superimpositions along the inferior border of the mandible were performed. Finally, superimpositions of serial tracings on stable intraosseous implants were made to determine the actual growth and remodeling patterns of the maxilla and mandible.

Results: The ABO maxillary superimposition method underestimates the vertical displacement and overestimates the forward movement of maxillary landmarks. Superimposing on the internal cortical outline of the symphysis and the inferior alveolar nerve canals generally approximates the mandibular superimposition on implants, although the lower anterior border of the symphysis may be a preferable area of superimposition. Superimposition on the lower border of the mandible does not reflect accurately the actual pattern of growth and remodeling of the mandible.

Conclusions: When analyzing serial headfilms, erroneous information concerning patterns of bone growth and remodeling can be obtained if convenient, but biologically incorrect superimposition protocols are used. In addition, tooth movements measured can be distorted significantly depending on the method of superimposition.

KEY WORDS: Cephalometrics, Superimposition, Metallic implants, Maxilla, Mandible, Cervical vertebral maturation method.

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INTRODUCTION Return to TOC

Superimposing tracings of serial lateral cephalograms has facilitated knowledge about normal craniofacial growth and development as well as knowledge about the treatment effects produced by various orthodontic, orthopedic, and surgical procedures. The superimposition of serial headfilms on metallic implants is considered the most precise and reliable technique to monitor growth and adaptation in the craniofacial region.[1] With the use of such metallic implants (pins) as reference points in longitudinal cephalometric investigations, Björk and coworkers[2–7] have provided basic information as to the pattern of craniofacial growth in humans. Unfortunately, there have been few studies of orthodontic treatment outcomes that have used this protocol,[8–12] presumably because of the invasiveness of tantalum implant placement solely for research purposes.

In that artificial landmarks such as tantalum pins rarely are available, several relatively stable structures have been suggested as substitutes for maxillary and mandibular superimposition.[3,7,13–16] Commonly used maxillary superimposition techniques include Björk and Skieller's[6,7] structural method, an anatomic method in which the films are registered on the anterior surface of the zygomatic process of the maxilla. Previous investigations have shown that Björk and Skieller's structural method matched closely with that of implants.[17–19] This method, however, is dependent on the quality of cephalograms with regard to optimal contrast and density.[17] Other recommended superimposition protocols include palatal plane superimposition registered at the anterior nasal spine (ANS), posterior nasal spine (PNS), and the pterygomaxillary fissure (Ptm), and superimpositions on the superior or inferior surface of the hard palate.[15,16] The American Board of Orthodontics (ABO) has adopted the maxillary anatomical method by recommending registering “on the lingual curvature of the palate and the best fit on the maxillary bony structures to assess maxillary tooth movement.”[20]

Mandibular superimposition on stable, naturally occurring structures also has gained wide acceptance. These techniques include superimposition on outline of the inferior border of the mandible and along the mandibular plane, as well as Björk's and Ricketts' structural methods.[14,21] Based on serial studies of implant subjects and patients, Björk observed that the mandibular canal, the developing molar crypts, and the inner cortical structure of the inferior border of the symphysis could be reasonable substitutes for mandibular implant superimposition.[21] The mandibular superimposition method advocated by the ABO is to “register on the internal cortical outline of the symphysis with the best fit on the mandibular canal to assess mandibular tooth movement and incremental growth of the mandible.”[20]

The current study assumes that the “implant method” is the most accurate method of superimposition to determine growth and treatment changes in the maxilla and mandible. Therefore, the primary purpose of this investigation is to test the hypothesis that there is no difference between the information produced by superimposition of serial lateral headfilms on anatomical structures and that produced by superimposition on metallic implants according to the protocols developed by Björk. This evaluation is based on the analysis of maxillary and mandibular growth data gathered from the cephalograms available at the six consecutive stages of cervical vertebral maturation and superimposed on metallic implants located within the maxilla and mandible. Cervical vertebral staging was selected because the rates of growth and remodeling are known to vary over time, with the maximum growth velocity occurring during the CS-CS4 interval in most individuals.[22,23] By evaluating a subject longitudinally both before and after the peak in mandibular growth velocity, patterns of mandibular growth and remodeling can be determined.

MATERIALS AND METHODS Return to TOC

Sample

The sample of serial headfilms was obtained from Mathews and Ware's implant study,[24,25] a growth study conducted at the University of California San Francisco in the 1970s. This growth study was similar to that of Björk and coworkers, and was comprised of longitudinal cephalometric records of 10 untreated subjects (6 female, 4 male). The cephalograms were available at the six consecutive stages of cervical vertebral maturation (CS1 through CS6).[23] The average interval between stages ranged from 13 to 19 months. The mean ages for the 10 subjects at each cervical vertebral maturation stage are shown in Table 1.

Cephalometric Analysis

Lateral cephalograms were hand traced by one investigator, and the landmark identification, anatomical outlines, and tracing superimpositions were verified by another; any differences were resolved by mutual agreement. The tracings were digitized by way of a specialized software program (Dentofacial Planner Plus, Toronto, Ontario).

Skeletal maturation assessed on cervical vertebral maturation stage according to the method of Baccetti and coworkers[23] was performed by two independent calibrated examiners. Agreement as to the cervical vertebral maturation (CVM) stage was reached on each film. Landmarks were defined as used in traditional cephalometric analyses[26–28] and in the study of McNamara and Graber concerning mandibular growth in the rhesus monkey.[29]

The six tracings for each subject were superimposed according to the method recommended by the ABO for maxillary and mandibular superimpositions that involved (1) superimposition of serial tracing by hand on the lingual curvature of the palatal plate and achieving a “best fit” on the internal bony structures of the maxilla, and (2) registration on the internal cortical outline of the symphysis and the inferior alveolar nerve canals. In addition, mandibular superimposition on the best fit of the inferior border of mandible was performed. Finally, superimpositions of the maxilla and mandible based on stable intraosseous implants were made to determine the actual pattern of growth and remodeling.

To evaluate remodeling and landmark displacement, an occlusal reference line “X” was drawn along the functional occlusal plane, and a perpendicular line “Y” was constructed through the pterygomaxillary fissure (Ptm; Figure 1). This “template”[29] provided a means of quantifying the maxillary landmarks displacement and mandibular remodeling determined by the superimposition methods examined.

Statistical Analysis

Statistical analyses were carried out with SPSS 14.0 (SPSS Inc, Chicago, Ill). Because of the limited sample size, female and male subjects were pooled. Descriptive statistics were calculated and one-way analysis of variance (ANOVA) was performed to compare the significant difference of landmark displacement and remodeling among different superimposition methods during five CVM intervals.

Method Error

Fifty lateral cephalograms randomly chosen from different superimposition methods were traced and remeasured twice by the same examiner to determine whether any intraexaminer error resulted from landmark selection, tracing, and measurement error. Statistical analysis was performed and no significant differences were noted.

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Overall differences in horizontal and vertical displacement of the maxillary and mandibular landmarks, as well as mandibular remodeling from CS1 to CS6, are shown in Tables 2 and 3, respectively. Statistical comparisons among the different superimposition methods were performed to determine the differences of landmark displacements in each of the five CVM intervals; the results are shown in Tables 4 through 7.

Maxilla

Horizontal Displacement. Horizontal displacements of three landmarks (point A, ANS, and PNS) considered during five intervals are shown in Tables 4 through 6, respectively. Generally speaking, point A and ANS were relatively stable in the horizontal direction when superimposed on intraosseous implants; the overall forward displacement of point A was only one-third of that indicated by the ABO superimposition method, with average values of 0.6 mm and 1.7 mm, respectively (Table 2). The ABO method revealed much more forward movement of the ANS, with the overall displacement of ANS from CS1 to CS6 1.5 mm, compared with negligible displacement of ANS with implant superimposition method (Table 2). Much backward growth (−5.6 mm) of PNS was noted when the tracings were superimposed on stable implants compared with superimposition on ABO method (−4.1 mm), with a difference of −1.5 mm from CS1 to CS6 (Table 2).

Vertical Displacement. Significant downward displacement of point A, ANS, and PNS was noted when the implant superimposition was used compared with the ABO method (Table 2). During the study intervals, the amount of vertical displacement of the three maxillary landmarks was similar (slightly less than 4 mm) when superimposed on implants; minimal vertical displacement was indicated with the ABO superimposition method (Table 2).

The differences between the two methods of maxillary superimposition are indicated graphically by the cephalometric tracings of the two subjects shown in Figures 2 and 3.

Mandible

Condyle. Three methods of superimposition were evaluated, with superimposition on the mandibular implants used as the gold standard (Figures 4A and 5A). Superimposing along the lower border of the mandible is shown in Figures 4B and 5B; the ABO superimposition method is shown in Figures 4C and 5C.

During the overall period, significant growth occurred at condylion (19.7 mm) when the mandibular pins were used for superimposition (Table 3). When the ABO method was used, the increase in condylar length was nearly the same (19.2 mm), but superimposing on the lower border of the mandible underestimated the overall amount of condylar growth by 1.3 mm.

The apparent direction of condylar growth was affected by the method of superimposition. Accepting the implant superimposition data as the gold standard, the other two methods underestimated the amount of superior condylar growth by 2–3 mm and overestimated the amount of condylar growth posteriorly by about 1 mm (Table 3). The ABO method was superior to superimposing on the lower border of the mandible in determining the direction and amount of condylar growth during the overall observation period.

Ramus and Corpus. Both anatomical methods of superimposition overestimated the amount of deposition along the posterior border of the mandible and underestimated the amount of resorption in the antegonial region (Table 3; Figures 4 and 5). In addition, deposition along the lower border of the mandible posterior to the symphysis was noted in almost all subjects.

Symphysis. When superimposition on implants and the ABO method are compared, similar amount of bone remodeling was observed at menton and pogonion during the growth interval studied (CS1 to CS6; Table 3). The anterior border of the symphysis was relatively stable with implant superimposition except in the region of point B, where resorption was noted in 6 of the 10 subjects studied. Significant forward movement of pogonion was noted when superimposition with the implant method was compared with superimposition along the inferior border of mandible, with the average value of 0.3 mm and 2.3 mm, respectively (Table 3, $P < .05$). This significant difference occurred mainly in the interval CS4 to CS5 (Table 7).

DISCUSSION Return to TOC

The results of this study indicate that there are major differences in the analysis of serial headfilm tracings, depending on the method of superimposition used. It is well accepted that the best way to determine how a bony structure grows and remodels is to place radiopaque markers in the bone. As long as the implants are stable and because bone grows by apposition only,[30] the patterns of localized bone deposition and resorption can be identified in standardized serial radiographs. On the other hand, if convenient anatomical landmarks (eg, lower border of the mandible) are used for superimposition, erroneous data are derived. This study also demonstrated that the measurement of tooth movements occurring during orthodontic treatment can be influenced greatly depending on the methods of superimposition used. This same conclusion was reached by Isaacson and coworkers[31] in their 1976 reanalysis of the cephalometric tracings of four of the subjects originally studied by Björk and Skieller[6] in 1972.

Maxillary Superimpositions

The findings of the present study suggest that the ABO superimposition method overestimated the forward displacement of point A, which was as much as three times that observed when serial tracings were superimposed on implants (Table 2, Figures 2 and 3). Great difference in the horizontal displacement of point A between two superimposition methods occurred in the interval CS4 to CS5, which coincides with the larger downward movement of ANS (Tables 4 and 5).

The results further indicate that the ABO superimposition method underestimates the vertical displacement of point A, ANS, and PNS significantly due to the pattern of descending remodeling occurring in the maxilla (Figures 2 and 3), observations that confirm the findings of Nielsen.[17] The relative amount of downward movement of ANS and PNS was similar in the current study, an observation that is not in agreement with the findings of other studies that indicated a greater inferior movement of ANS than PNS.[7,17,32]

The ABO method also underestimates the posterior deposition of bone in the posterior nasal spine region; when implant superimposition is used, about 20% further posterior relocation of PNS is observed. Other studies also have shown that concomitant with the resorptive modeling of the nasal floor, there is apposition on the hard palate.[30] Therefore, superimposition on the ANS-PNS line masks the downward remodeling of both the superior surface of the maxilla and the palate.[17,33,34]

Mandibular Superimpositions

The ABO recommended method of superimposition, as registered on the internal cortical outline of the symphysis with best fit on the inferior alveolar canals, seems to offer greater validity and reliability than does the “best fit” superimposition along the inferior border of mandible. In the current study, the lower anterior border of the symphysis below the point B region was relatively stable according to the implant superimposition method. A similar finding has been reported by Björk.[3]

When comparing superimposition on the inferior border of mandible with superimposition on implants, the condyle will appear to grow in a backward and upward direction (Figures 4C and 5C) instead of in a forward and upward direction (Figures 4A and 5A); horizontal displacement of landmarks will increase and vertical displacement will decrease when an implant superimposition protocol is used.

Enlow[30] stated that the gonial region of the human mandible becomes relocated posteriorly and that osseous tissue formerly in this area becomes successively relocated into the area of the antegonial notch, and the antegonial notch gradually becomes incorporated into the body of the mandible with further bone deposition in that region. The composite tracings in the current study (Figures 4 and 5) demonstrate Enlow's findings; apposition on the anterior part and resorption on the posterior part of the lower border lead to a shape change of the mandibular corpus with time (Figures 4 and 5). Thus, if a “best fit” superimposition of serial films is attempted along the inferior border of the mandible, successive tracings have a tendency to move forward (relative to tracings of earlier films) due to the change in the curvature of the inferior border of mandible. This latter superimposition method should not be used.

CONCLUSIONS Return to TOC

- The method of maxillary superimposition currently recommended by the ABO on their Web site underestimates the vertical displacement of maxillary structures and overestimates the forward movement of maxillary skeletal landmarks.
- Although there are subtle differences between methods of superimposition, the current mandibular superimposition method advocated by the ABO is an acceptable substitute for the implant superimposition method. The anterior symphyseal outline below the region of point B also can be used.
- Superimposition on the lower border of the mandible does not reflect accurately the actual pattern of mandibular growth and remodeling and should not be used.

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TABLES Return to TOC

Table 1. Summary of Mean Age for 10 Subjects at Each Cervical Vertebral Maturation Stage

	CS1	CS2	CS3	CS4	CS5	CS6
Mean age, yrs	8.9 ± 1.1	10.5 ± 0.9	11.9 ± 0.9	13.1 ± 0.7	14.5 ± 0.7	15.3 ± 0.8

Table 2. Difference of Maxillary Landmarks Displacement From CS1 to CS6 Between Two Superimposition Methods (mm)[a]

	Point A		ANS		PNS	
CS1-CS6	Horiz	Vert	Horiz	Vert	Horiz	Vert
Implant superimposition	0.6 ± 1.1	−3.9 ± 1.7	0 ± 0.8	−3.5 ± 1.8	−5.6 ± 2.2	−3.9 ± 1.9
ABO (maxilla)	1.7 ± 2.0	−1.0 ± 2.6*	1.5 ± 1.7*	−0.4 ± 2.5**	−4.1 ± 1.6	0 ± 1.2***

[a] ANS indicates anterior nasal spine; PNS, posterior nasal spine; Horiz, horizontal; Vert, vertical.
* $P < .05$; ** $P < .01$; *** $P < .001$.

Table 3. Difference of Mandibular Remodeling From CS1 to CS6 Among Three Superimposition Methods (mm)

CS1-CS6	Implant		Mandibular Lower Border		ABO (Mandible)	
	Mean	SD	Mean	SD	Mean	SD
Condylion	19.7	3.1	18.4	4.0	19.2	4.3
Superior condylion	17.1	2.6	14.2	3.4	15.2	3.5
Posterior condylion	6.6	1.9	7.8	2.5	7.8	1.8
Posterior border	5.0	1.7	6.0	1.9	6.0	1.4
Antegonial region	−2.7	1.7	−1.4	0.7	−1.8	2.4
Menton	1.4	1.1	−0.2*	0.4	1.0	0.9
Pogonion	0.3	0.3	2.3*	1.0	0.7	1.1

* $P < .05$; ** $P < .01$; *** $P < .001$.

Table 4. Difference in Point A Displacement in Five Cervical Vertebral Maturation Intervals Between the Two Superimposition Methods (mm)

Point A	CS1-CS2 (19 mo)		CS2-CS3 (17 mo)		CS3-CS4 (14 mo)		CS4-CS5 (17 mo)		CS5-CS6 (13 mo)	
	X	Y	X	Y	X	Y	X	Y	X	Y
Implant superimposition	0.3 ± 0.8	−1.1 ± 1.8	−0.2 ± 0.7	−0.9 ± 1.2	0 ± 0.8	−0.3 ± 1.6	0.2 ± 0.7	−1.4 ± 1.6	0.1 ± 0.7	0.2 ± 1.2
ABO (max)	0.7 ± 1.1	−0.1 ± 1.8	0.2 ± 2.1	−0.1 ± 1.8	−0.1 ± 1.1	−0.1 ± 1.3	0.8 ± 1.4	−0.5 ± 0.8	0.3 ± 1.9	−0.2 ± 1.7

Table 5. Difference in ANS Displacement in Five Cervical Vertebral Maturation Intervals Between Two Superimposition Methods (mm)[a]

ANS	CS1-CS2 (19 mo)		CS2-CS3 (17 mo)		CS3-CS4 (14 mo)		CS4-CS5 (17 mo)		CS5-CS6 (13 mo)	
	X	Y	X	Y	X	Y	X	Y	X	Y
Implant superimposition	0.3 ± 0.7	−1.1 ± 1.4	−0.3 ± 1.2	−0.7 ± 1.4	0 ± 0.9	−0.4 ± 1.8	0.1 ± 1.0	−1.3 ± 1.7	0 ± 0.6	0.3 ± 1.4
ABO (max)	0.8 ± 1.6	0.1 ± 1.7	0.1 ± 2.2	0 ± 1.9	−0.2 ± 1.1	−0.2 ± 1.4	0.7 ± 1.6	−0.2 ± 0.5	0.4 ± 2.0	−0.1 ± 1.2

[a] ANS indicates anterior nasal spine.

Table 6. Difference in PNS Displacement in Five Cervical Vertebral Maturation Intervals Between Two Superimposition Methods (mm)[a]

PNS	CS1-CS2 (19 mo)		CS2-CS3 (17 mo)		CS3-CS4 (14 mo)		CS4-CS5 (17 mo)		CS5-CS6 (13 mo)	
	X	Y	X	Y	X	Y	X	Y	X	Y
Implant superimposition	−1.0 ± 0.8	−0.5 ± 1.6	−1.8 ± 1.4	−1.1 ± 1.4	−1.3 ± 0.9	−1.1 ± 1.4	−1.2 ± 1.0	−0.2 ± 1.8	−0.1 ± 1.0	−1.0 ± 1.4
ABO (max)	−0.5 ± 1.0	0.3 ± 1.8	−1.1 ± 1.4	−0.5 ± 1.6	−1.7 ± 1.3	−0.2 ± 0.8	−0.6 ± 1.4	−0.2 ± 0.7	0.1 ± 1.6	0.5 ± 1.1*

[a] PNS indicates posterior nasal spine.
* $P < .05$.

Table 7. Difference of Mandibular Remodeling in Five Cervical Vertebral Maturation Intervals Among Three Superimposition Methods (mm)[a]

	CS1-CS2 (19 mo)			CS2-CS3 (17 mo)			CS3-CS4 (14 mo)		
	Implant Method	Lower Border	ABO[a] (Mand)	Implant Method	Lower Border	ABO (Mand)	Implant Method	Lower Border	ABO (Mand)
Co	5.2 ± 2.8	4.8 ± 3.4	4.9 ± 2.7	3.7 ± 1.4	3.1 ± 1.5	3.7 ± 1.6	3.8 ± 1.1	3.9 ± 1.2	3.2 ± 1.4
Super Co	4.6 ± 2.2	3.2 ± 3.4	4.0 ± 2.3	3.1 ± 1.4	2.7 ± 1.5	2.9 ± 1.6	3.3 ± 1.2	2.7 ± 1.2	3.1 ± 1.3
Post Co	1.5 ± 2.1	1.7 ± 2.4	1.7 ± 1.9	1.4 ± 1.1	1.4 ± 1.6	2.0 ± 1.1	1.5 ± 0.9	2.1 ± 1.3	1.4 ± 0.5
Posterior border	0.5 ± 1.0	1.1 ± 1.4	0.7 ± 0.8	1.3 ± 1.0	1.0 ± 1.2	1.6 ± 0.9	1.2 ± 0.8	1.6 ± 1.1	1.1 ± 0.6
Antegonial	−1.2 ± 0.5	−0.4 ± 0.8	−0.9 ± 0.8	−0.5 ± 1.1	−0.3 ± 0.7	−0.4 ± 0.8	−0.6 ± 1.1	−0.4 ± 0.8	−0.5 ± 1.1
Me	0.3 ± 0.6	0 ± 0.2	0.3 ± 0.5	0.3 ± 0.4	0 ± 0.1	0.2 ± 0.3	0.3 ± 0.5	0.1 ± 0.2	0.2 ± 0.5
Pg	0 ± 0.5	0.8 ± 0.9*	0.1 ± 0.3	−0.1 ± 0.6	0.2 ± 0.6	−0.1 ± 0.4	0.1 ± 0.4	0.1 ± 0.6	0.1 ± 0.4

[a] Co indicates condylion; Super Co, superior condylion; Post Co, posterior condylion; Me, menton; Pg, pogonion.
* $P < .05$.

Table 7. Extended

CS4-CS5 (17 mo)			CS5-CS6 (13 mo)		
Implant Method	Lower Border	ABO (Mand)	Implant Method	Lower Border	ABO (Mand)
4.7 ± 2.9	3.6 ± 2.5	4.3 ± 2.7	1.8 ± 1.3	2.3 ± 1.5	2.4 ± 1.3
4.3 ± 2.7	3.1 ± 2.0	3.5 ± 2.2	1.1 ± 0.9	1.7 ± 0.9	1.4 ± 2.0
1.1 ± 1.4	1.7 ± 1.7	1.0 ± 1.3	0.9 ± 1.2	0.7 ± 1.7	1.3 ± 1.2
1.2 ± 1.2	1.4 ± 2.0	1.3 ± 1.4	0.8 ± 0.7	0.7 ± 1.2	0.9 ± 0.9
−0.5 ± 1.1	0 ± 0.6	−0.4 ± 0.6	0.1 ± 0.2	−0.2 ± 0.6	0.2 ± 1.3
0.5 ± 0.4	−0.1 ± 0.6	0.4 ± 0.4	0 ± 0.4	0 ± 0.2	−0.2 ± 0.6
0.1 ± 0.5	0.9 ± 0.8*	0.2 ± 0.4	0.2 ± 0.4	0.2 ± 1.0	0.2 ± 0.7

FIGURES Return to TOC

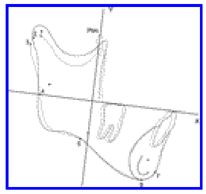

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Figure 1. Reference lines and reference points for mandibular remodeling analysis. (1) Superior condylion. (2) Condylion. (3) Posterior condylion. (4) Posterior border of ramus. (5) Antegonial region. (6) Menton. (7) Pogonion

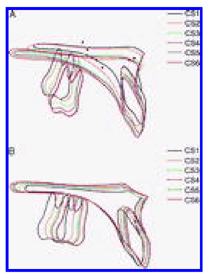

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Figure 2. Composite tracings of the maxilla. (A) Superimposition on intraosseous tantalum implants. Note that resorption of the nasal floor was less than the apposition on the hard palate during most of the intervals. Significant downward displacement of point A, ANS, and PNS was observed. Elongation of the posterior end of the palate at PNS and slightly backward movement of point A and ANS were noted. In addition, the maxillary central incisor erupted primarily in a vertical direction. (B) Superimposition according to the ABO method. Less elongation of the posterior end of the palate at PNS and forward movement of point A and ANS were observed. In addition, the maxillary central incisor erupted slightly anteriorly with minor downward movement. It is interesting to note that ABO superimposition method masked the resorption occurring along the nasal floor and made this surface appear to be appositional

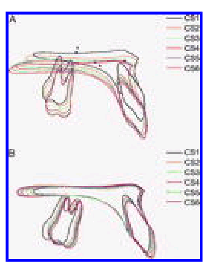

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Figure 3. Composite tracings of maxillary structures. (A) Superimposition on the tantalum implants. (B) Superimposition according to the ABO method

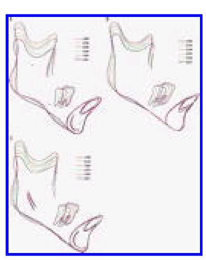

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Figure 4. Composite tracings of the mandible. (A) Superimposition on the tantalum implants: the largest increment of condylar growth occurred between stages CS3 and CS4.

Deposition along the anterior lower border of the corpus and resorption in the antegonial region can be observed. The condyle grew in an upward and slightly backward direction. (B) Superimposition is “best fit” along the inferior border of the mandible. Less resorption in the antegonial region was observed, and backward and upward growth of the condyle was noted. Also, there was greater bone apposition on the posterior border of the ramus and forward movement of the chin point at pogonion. (C) Superimposition according to the ABO method: less resorption in the antegonial region was observed

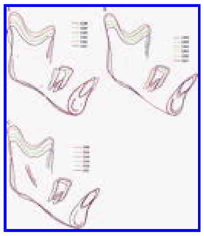

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Figure 5. Composite tracings of the mandible. (A) Superimposition of serial tracings on the tantalum implants. (B) Superimposition is the “best fit” along the inferior mandibular border. (C) Superimposition with the ABO method. The composite tracings are similar to those in Figure 5A

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