A COMPUTER AIDED STUDY ON THE SUPERIMPOSITION OF MAXILLARY AND MANDIBULAR IMPLANTS

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INTRODUCTION

The subject of craniofacial form and growth has intrigued investigators for many years. Prior to 1931, researchers were primarily limited to examination of dried skulls or external cranial measurements of living human beings. This type of data enabled investigators to derive crude cross-sectional data but was impractical for longitudinal research.

The introduction of the cephalometric technique in 1931 by Broadbent and Hoffrath[1,2] provided anthropologists and orthodontists with a far more viable and accurate investigative method than had previously existed. The method has been found to be of limited clinical usefulness in diagnosis and for describing gross changes (more than 1 mm.) in individuals during growth and treatment. Cephalometrics has also been useful in cross-sectional studies for describing average craniofacial changes. However, the method is severely limited due to the fact that errors inherent in the technique are often greater than the changes being described.

One of the greatest research problems has been, first of all, that of landmark location.[3] The second great dilemma of longitudinal cephalometrics has been how to superimpose subsequent radiographs of the same patient. In 1955, Bjork attempted to solve these problems through the use of metallic implants.[11] The implant method was meant to supply stable reference points upon which serial cephalograms could be accurately

superimposed and therefore make longitudinal craniofacial growth study more meaningful.

Although the implant method appears to be more accurate, it is, however, only minimizing a source of error. There are other problems still present such as:

1) Implant stability - tissue reactions or improper placement in areas of resorption or tooth eruption could well affect implant position.
2) The implants placed to date are not all in the same sagittal plane and are therefore subject to radiographic distortion relative to each other. This is due to the fact that we are representing a three-dimensional object on a two-dimensional film. It is also possible that differential growth within a single jaw could alter implant relationships.
3) Patient movement and the problem of repositioning patients in the same manner as previous films continue to be major sources of error.

The purpose of this pilot study is to establish parameters of implant stability for superimposition purposes. This should aid future studies in determining growth and treatment changes.

REVIEW OF THE LITERATURE

The choice of landmarks to use for reference points or planes has long been a source of controversy in craniofacial studies. The first attempt at a consensus opinion was addressed at the Frankfort Anthropological Conference in 1882, which was the origin of the frankfort horizontal plane.[4] Broadbent's[5] registration point and Brodie's[6] sella-nasion plane were two of the earliest attempts at a stable reference mode for cephalometric purposes.

The cranial base is still a very popular reference plane for superimposition of serial cephalograms although several authors including Bjork,[7] Bergesen,[8] and Ford[9] have noted changes in the pituitary fossa and nasion that occur during growth.

There are conventional methods for superimposing maxilla and mandible,[10] however, owing to resorption and apposition involved in bone growth, superimposition of individual bones on the basis of external bony contours is felt to be invalid.[11]

It has been determined that of all possible error sources involved in the cephalometric method landmark location is by far the largest.[12,13] In 1971 Baumrind and Frantz[3] demonstrated the landmark distribution patterns of 16 different landmarks using a computerized x-y coordinate locating procedure. The error residual patterns of these landmark

scattergrams were not random but were dependent as to x-y distribution upon which landmark was being located. For example, A point would be far more reliable in the x (horizontal) direction than in the y (vertical) direction.

The fact facing those involved in conventional cephalometric work is that so far research has been unable to identify any stable reference point or plane from which to measure. It has been possible only to determine change of one reference versus another as reference bases also alter during growth.[10]

The problem of achieving a stable reference mode was thought to be overcome by the use of metallic implant markers. Implants had been utilized as early as 1727 by Steven Hales[14] but never to record craniofacial growth in humans via cephalometrics until Bjork. He first published a study of five cases using tantalum implants in 1955.[11] A more complete study of 110 growing children detailing growth changes over 11 years was published in 1963.[15] In these studies Bjork claimed an ability to determine real changes within 1 mm or 1.5 mm in either direction.

In 1959 Krebs[16] used vitalum implants to record expansion in a rapid palatal expansion study. Other investigators involved in RPE implant research were Isaacson and Murphy.[17] In 1964 they recorded alveolar and basal bone changes in five patients undergoing rapid palatal expansion who also had cleft palate repairs. Their implants were silver endodontic cone tips placed with an 18-gauge needle under a raised mucoperiosteal flap.

In a 1965 study investigating changes in vertical dimension, Caccaro and Lloyd[18] used tantalum implants at points A and B in two adult denture patients.

It has been noticed by several researchers that implants do not maintain a perfect relationship to each other from one serial film to another.[15] Much of this apparent implant movement will be due to patient movement and the inability to reposition a patient in the exact same position in repetitive films on the same patient. It has been demonstrated that a five-degree head rotation can result in a landmark movement of 0-4.5 mm.[19] Bjork[20] used a cephalostat with a built-in image intensifier and a television monitor to accurately reposition the patient before a film is taken. A three-dimensional radiographic technique using two x-ray sources aimed simultaneously at a single film has also been demonstrated to minimize error.[21]

Biological factors also enter into implant movement from one serial film to another. Bjork felt that occasional implant movement was due to:[15]

1. placement of implant in pathway of erupting tooth.
2. placement of implant on bony surface undergoing resorption.
3. shallow placement of implant allowing periosteal drag.
4. electrolytic effects which stimulate fibroblastic activity.

Morris in 1972 examined the histologic reaction to implants made of tantalum and other metals.[22] After eight weeks he noticed tissue reactions as evidenced by:

1. macrophage activity.

2. degradation of adjacent cells.
3. osteoblastic activity.
4. formation of a collagenous capsule.

Therefore, it can be concluded that the most precise possible measuring methodology should be utilized as the magnitude of growth or treatment change is frequently very small.

MATERIALS AND METHODS

A sample of 15 Angle Class II male patients was selected from a group that had been implanted at the Oregon Health Sciences University Department of Orthodontics. All patients had been treated orthodontically. The criteria for sample selection was that all subjects had three implants in each jaw and retained them throughout the period of serial cephalograms. Each member also had to have at least four cephalograms covering a period of at least 30 months. Many subjects had more films over a longer period of time. The average number of films was 5.75 and the number of months covered by films averaged 62.2. The number of months covered ranged from 21 to 137.

The implants had been placed in the following positions:

maxilla

position 1 - most posterior maxillary implant

position 2 - middle maxillary implant

position 3 - anterior maxillary implant

mandible

position 1 - most posterior mandibular implant

position 2 - middle mandibular implant

position 3 - most anterior mandibular implant

Implant positions were digitized utilizing a system of high frequency microphones on an x-y axis sensing a high frequency spark. Four

fiducial points were punched on each film in order to spatially orient the computer for successive tracings on each film. Each implant position and fiducial point was digitized three times for each film producing a three-point scattergram for each point. A mean was produced for each point from the three estimates. Any estimate that was further away than 1 mm from the mean computed for the three implants was considered to be in error. This point was deleted and a new mean was then projected using the two remaining estimates.

A program was written that directed the computer, a PDP1170 utilizing a UNIX operating system, to superimpose serial radiographs. The implants, as a group of three, in each jaw were treated separately by the program. The triad of implants of one particular jaw were rotated and translated by the computer until a best fit was attained with the selected jaw's implants of the film being compared.

From this best fit situation residual errors were produced that signified the linear distance between each implant position. This method was designed to determine how closely one could superimpose one film of an implanted patient upon another or rather how stable are implants as reference points.

To attain a best fit for superimposition the computer rotates and translates the three implants until a least squares situation is attained for the error residuals. Another run for all films was also done employing a radiographic magnification, shrinkage, and head rotation correction procedure termed scaling. The scaling program not only rotates and translates the three implants as above but will also uniformly shrink or expand all three implants until a least squares situation is

achieved. This procedure compensates for cephalometric error to some degree but would also possibly disguise some linear implant movement. Current thought, however, maintains that interstitial bone growth does not occur. The majority of linear implant movement therefore may be due to cephalometric error that the scaling program will reduce.

Two different runs of implant superimposition were done using different films as the baseline reference point to which all the patients' successive films were compared. For the timepoint 1 data the first film in each patient's file was the film to which subsequent films were compared. A second data run used the second film in each file as the baseline reference. This was attempted in order to determine if there is a settling-in period required for implant stability. This could be due to the tissue reactions mentioned in the literature review. As the first film in each file was taken on the day of implant placement, it is possible that the second film might be a better reference base. The average time between first and second films was 10.4 months and ranged from one to 22 months. There was a total of 69 comparisons for the timepoint 1 data and 54 comparisons for timepoint 2 summed over all 15 patients.

Residual errors were summed for each implant position and means, variances, and standard deviations were calculated. This was done for all implants using timepoint 1 and timepoint 2, scaling and nonscaling for each timepoint. Therefore, there were four groups of data produced for all implant positions.

Statistically it was attempted to determine if any differences between groups existed at the P.05 confidence level. This was done

using a three-way analysis of variance and Schiffé tests. The three variables analyzed were: A) implant location, B) scaling versus non-scaling, and C) timepoint 1 versus 2. This analysis would show if any statistically significant difference existed between scaled or nonscaled data, timepoint 1 and timepoint 2 data, and if any one implant had a significantly different residual error mean and variance versus the other two in the same jaw. The three-way analysis of variance also enabled cofactors influencing implant residuals to be examined.

Due to limited time available at the University of California at San Francisco to digitize data points, there was no between or within operator measurement error data derived for this study.

FINDINGS

Maxilla

The mean differences for maxillary superimposition using nonscaled timepoint 1 data were: position 1 - .6 mm, position 2 - .7, position 3 - .5; for the scaled timepoint 1 data: position 1 - .3, position 2 - .6, position 3 - .4. For nonscaled timepoint 2 data the means were: position 1 - .5, position 2 - .5, position 3 - .5; means for the timepoint 2 scaled data were: position 1 - .2, position 2 - .5, position 3 - .3.

The three-way analysis of variance indicated that implant position, presence or absence of scaling, and whether timepoint 1 or 2 was used as the baseline, were all significant as individual factors. That is each of these factors, A, B, or C, were capable of significantly altering mean and variance. The combination factors of implant position--scaling (yes or no) and implant position--timepoint (1 or 2) were also significant. This indicates that factors B and C are each capable of altering the relationship of means and variances within factor A (implant positions).

The Schiffé test indicated that implant position number 2 was significantly different than positions 1 and 3. No difference could be discerned between positions 1 and 3. The residual means of the scaled data were significantly lower than the nonscaled. A significant difference also existed between means of timepoint 1 and 2 with timepoint 2 means being lower.

Mandible

The mean differences for mandibular superimpositions using nonscaled timepoint 1 data were: position 1 - 1.2, position 2 - 1.1, position 3 - .8; for scaled timepoint 1 data means were: position 1 - .4, position 2 - 1.0, position 3 - .6. The nonscaled timepoint 2 data produced means that were as follows: timepoint 1 - .9, timepoint 2 - 1.0, timepoint 3 - .7; for scaled timepoint 2 data the means were: timepoint 1 - .5, timepoint 2 - 1.0, timepoint 3 - .6.

The three-way analysis of variance of the three factors, A or implant position, B or scaling versus nonscaling, and C or timepoints 1 or 2 were not all significant in the mandible as they were for the maxilla. Factors A and B were significant but factor C, the timepoint factor, was not. This would mean that the analysis could not detect any difference between timepoint 1 or timepoint 2 data. For the combination factors only AB was significant. Only scaling was capable of altering mean end variance relationships among the implant positions. The fact that AC is not significant correlates with C (timepoint 1 or 2) being insignificant as an individual factor.

The Schiffé test for the mandibular analysis indicated that as in the maxilla, implant position 2 had a significantly higher mean residual than the other two positions. Also, as in the maxilla the scaled data had a significantly lower mean than the nonscaled. The Schiffé test backed up the initial impression given by the ANOVA that the timepoint 1 and timepoint 2 data were not significantly different.

DISCUSSION

The Schiffé test indicates that the second implant position has a statistically higher mean than the other two implants. The biological reasons behind this fact can only be guessed at. Implant number 2 was possibly more often placed in an area of developing alveolus during the mixed dentition. Although interstitial bone growth is not supposed to occur, if it did to any degree at all this could possibly be responsible for this implant's relative instability. The vector quantity for direction of implant movement is contained within the data gathered for this project. We chose not to deal with vectors in this paper but the direction of implant movement, especially implant number 2, would be of interest for future work.

A primary goal of this project was to determine how stable a reference base implants provide. As only two implants would be all that would be required for superimposition purposes, handling both translational and rotational movements, it may be beneficial at some future date to examine error residuals using only implants 1 and 3. It is well possible that this would eliminate much of the error in the process.

The effect of scaling was to significantly lower means and variances for implants in both jaws. The idea of having a correction ability for film errors such as magnification, shrinkage, and rotation

is attractive. The validity of using such a program and what implant movement is disguised by scaling is questionable. Future work using scaling with films containing calibrated fiducial points may be of aid in determining scaling's usefulness.

Implant position 1 in both jaws was most significantly affected by scaling. Mean and variance were drastically lowered for both timepoints. As to why this position, being closest to the central ray and therefore least affected by magnification and rotation, should be most affected by scaling is unknown. Perhaps future work may shed light upon this phenomena.

Statistical analysis reveals some interesting points concerning timepoint selection for future work using this sample. If one were superimposing maxillas it would be significantly beneficial to use timepoint 2 as the baseline in attempting to get a best fit of the implants. However, if one were superimposing mandibles it is statistically impossible to select if timepoint 1 or 2 is better. For purposes of attaining a larger sample size the use of timepoint 1 might be indicated.

Future work using only two implants may alter some of the relationships between the implants and the other factors of scaling and timepoint. It may be possible that timepoint selection becomes significant for the mandible with only two implants. It is difficult to reason why a settling-in period would be more beneficial for the maxilla than the mandible. Future work may possibly reveal this not to be true.

SUMMARY

1. Means, standard deviations, and variances were computed for residual errors between implant positions on superimposed maxillas and mandibles using serial radiographs of a 15-patient, male, orthodontically treated sample. The data were subjected to statistical analysis by ANOVA.

2. The middle implant position in the first molar and bicuspid region was found to have a significantly greater error residual than the other two implant positions.

3. Scaling as a radiographic error correction procedure was found to be significantly beneficial in providing lower error residuals between superimposed implants.

4. The use of the second film in the sample patient's file as the baseline reference for maxillary implants gave a significantly better fit than using the first film. This was not found to be true for mandibular implants.

5. It would be of value for a future study to determine within and between operator error for the digitizing process.

BIBLIOGRAPHY

1. Broadbent, B. H. "A New Z-ray Technique and Its Application to Orthodontia," Angle Orthod., 1:45-66, 1931.

2. Hofrath, H. "Bedeutung der Roentgenfern -und Abstandsoufnahme fur die Diagnostik der Kieferanomolien," Fortschr. der Ordhod., 1:232, 1931; from Brodie, A. G. "Growth of the Human Head from Three Months to Eight Years," Amer. J. Anat., 68:209. 1931.

3. Baumrind, S. and Frantz, R. "Reliability of Head Film Measurements, 1. Landmark Identification," Am. J. Orthod., 60:111-127, 1971.

4. Koski, K. and Virolainen, K. "On the Relationships Between Roentgenologic- Cephalometric Lines of Reference," Acta Odont. Scandinav., 14:23-32, 1956.

5. Broadbent, B. H. "The Face of the Normal Child," Angle Orthod., 7:183-208, 1937.

6. Brodie, A. G. "On the Growth Pattern of the Human Head from the Third Month to the Eighth Year of Life," Amer. J. Anatomy, 68:209-262, 1941.

7. Bjork, A. "Cranial Base Development," Am. J. Orthod., 41:198, 1955.

8. Bergersen, E. O. "A Comparative Study of Cephalometric Superimposition," Angle Orthod., 31:216-229, 1961.

9. Ford, E. H. R. "Growth of the Human Cranial Base," Am. J. Orthod., 44:498-506, 1958.

10. Salzmann, J. A. (ed.) Roentgenographic Cephalometrics, Philadelphia: Lippincott Co., 1961.

11. Bjork, A. "Facial Growth in Man Studied with the Aid of Metallic Implants," Acta Odont. Scand., 13:9, 1955.

12. Miller, P. A., Savara, B. S., and Singh, I. J. "Analysis of Errors in Cephalometric Measurements of Three-dimensional Distance on the Human Mandible," Arch. Oral Biol., 11:209-217, 1966.

13. Hatton, M. E. and Grainger, R. M. "Reliability of Measurements from Cephalograms at the Burlington Orthodontic Research Center," J. Dent. Res., 37:853-859, 1958.

14. Hales, S. Statistical Essays, Vol. 1, Vegetable Statistics, London: W. Innys and Others, 1727, p. 337.

15. Bjork, A. "Variations in the Growth Pattern of the Human Mandible: Longitudinal Radiographic Study by the Implant Method," J. Dent. Res., 42:400-411, 1963.

16. Krebs, A. "Expansion of the Midpalatal Suture, Studied by Means of Metallic Implants," Acta Odont. Scand., 17:491-501, 1959.

17. Isaacson, Robert J. and Murphy, Thomas D. "Some Effects of Rapid Maxillary Expansion in Cleft Lip and Palate Patients," Angle Orthod., 34:143-154, 1964.

18. Caccaro, P. J. and Lloyd, R. S. "Behavior of Points A and B in Denture Patients," Am. J. Orthod., 51:183-192, 1965.

19. Stackler, H. M. "An Evaluation of Error in Cephalometric Roentgenography Introduced by Variation in Position of the Head in the Broadbent-Bolton Cephalometer," M.S. thesis, Northwestern University, 1948.

20. Bjork, A. "The Use of Metallic Implants in the Study of Facial Growth in Children: Method and Application," Am. J. Phys. Anthropol., 29:243-254, 1968.

21. Cruikshank, D. and Nixon, M. "A Three Dimensional Cephalometric Technique," Certificate thesis, University of Oregon Dental School, 1970.

22. Morris, R. E. "Bone Healing Adjacent to Tantalum Implants," Certificate thesis, University of Oregon Dental School, 1972.

TABLE I

Maxillary Means, Standard Deviations and Variances

Maxilla

Timepoint #1

Implant Positions		1	2	3
	Mean	.640	.692	.461
No Scaling	SD	.553	.482	.368
	Variance	.306	.233	.136
	Mean	.305	.622	.417
Scaling	SD	.228	.416	.281
	Variance	.052	.173	.078

Timepoint #2

Implant Positions		1	2	3
	Mean	.544	.490	.540
No Scaling	SD	.425	.282	.417
	Variance	.181	.079	.174
	Mean	.231	.461	.320
Scaling	SD	.172	.247	.186
	Variance	.029	.061	.035

TABLE II

Mandibular Means, Standard Deviations and Variances

Mandible

Timepoint #1

Implant Positions		1	2	3
	Mean	1.150	1.08	.770
No Scaling	SD	1.18	.835	.539
	Variance	1.396	.697	.291
	Mean	.446	.976	.621
Scaling	SD	.390	.748	.452
	Variance	.152	.560	.204

Timepoint #2

Implant Positions		1	2	3
	Mean	.900	.992	.695
No Scaling	SD	.966	.820	.537
	Variance	.934	.673	.289
	Mean	.473	.958	.583
Scaling	SD	.475	.799	.452
	Variance	.226	.639	.204

TABLE III

ANOVA for Maxillary Implant Positions

Factors: A) Implant Position, B) Scaling (yes or no), C) Timepoint (1 or 2)

ANALYSIS OF VARIANCE (N FACTORS).

N = 3
n = 54
a = 3
b = 2
c = 2

CELL	MEAN	VAR.
1 1 1	.64000	.30600000
2 1 1	.69200	.23300000
3 1 1	.46100	.13600000
1 2 1	.30500	.05200000
2 2 1	.62200	.17300000
3 2 1	.41700	.07800000
1 1 2	.54400	.18100000
2 1 2	.49000	.07900000
3 1 2	.54000	.17400000
1 2 2	.23100	.02900000
2 2 2	.46100	.06100000
3 2 2	.32000	.03500000

SOURCE	SS	DF	MS	F
A	2.58785099	2	1.29392549	10.102216
B	4.59954450	1	4.59954450	35.910562
C	1.36620449	1	1.36620449	10.666528
AB	2.14236899	2	1.07118449	8.363184
AC	.80720100	2	. 40360050	3.151077
BC	.05746049	1	.05746049	.448618
ABC	.38994299	2	.19497149	1.522223
Error	81.46100000	636	.12808333	1.000000

TABLE IV

Schiffé Test for Maxillary Implant Positions

Factors: A) Implant Position, B) Scaling (yes or no), C) Timepoint (1 or 2)

MEANS OF VARIABLE A:

.4300000
.5662500
.4345000

MEANS OF VARIABLE B:

.5611666
.3926666

MEANS OF VARIABLE C:

.5228333
.4310000

MS = .12808333

DF = 636

CONTRASTS FOR MEANS OF CELLS:

Enter F(11,636): 1.830 Contrast = .3090198

CONTRASTS FOR MEANS OF A:

Enter F(2,636): 3.000 Contrast = .0843548

CONTRASTS FOR MEANS OF B:

Enter F(1,636): 3.840 Contrast = .0551003

CONTRASTS FOR MEANS OF C:

Enter F(1,636): 3.840 Contrast = .0551003

TABLE V

ANOVA for Mandibular Implant Positions

Factors: A) Implant Position, B) Scaling (yes or no), C) Timepoint (1 or 2)

ANALYSIS OF VARIANCE (N FACTORS).

N = 3
n = 54
a = 3
b = 2
c = 2

CELL	MEAN	VAR.
1 1 1	1.15000	1.39600000
2 1 1	1.08000	.69700000
3 1 1	.77000	.29100000
1 2 1	.44600	.15200000
2 2 1	.97600	.56000000
3 2 1	.62100	.20400000
1 1 2	.90000	.93400000
2 1 2	.99200	.67300000
3 1 2	.69500	.28900000
1 2 2	.47300	.22600000
2 2 2	.95800	.63900000
3 2 2	.58300	.20400000

SOURCE	SS	DF	MS	F
A	13.28822100	2	6.64411050	12.726149
B	10.53405000	1	10.53405000	20.176951
C	.87913800	1	.87913800	1.683903
AB	7.91135099	2	3.95567549	7.576712
AC	.11627099	2	.05813549	.111352
BC	.66355200	1	.66355200	1.270969
ABC	.45692099	2	.22846049	.437593
Error	332.04500000	636	.52208333	1.000000

TABLE VI

Schiffé Test for Mandibular Implant Positions

Factors: A) Implant Position, B) Scaling (yes or no), C) Timepoint (1 or 2)

MEANS OF VARIABLE A:

.7422500
1.0015000
.6672500

MEANS OF VARIABLE B:

.9311666
.6761666

MEANS OF VARIABLE C:

.8405000
.7668333

MS = .52208333
DF = 636

CONTRASTS FOR MEANS OF CELLS:

Enter F(11,636): 1.830 Contrast = .6238927

CONTRASTS FOR MEANS OF A:

Enter F(2,636): 3.000 Contrast = .1703074

CONTRASTS FOR MEANS OF B:

Enter F(1,636): 3.840 Contrast = .1112443

CONTRASTS FOR MEANS OF C:

Enter F(1,636): 3.840 Contrast = .1112443

Implant Positions

Fig. 1: Positions and Numbers of Maxillary and Mandibular Implants