

Aging in the Craniofacial Complex

Longitudinal Dental Arch Changes Through the Sixth Decade

Marcus M. Dager^a; James A. McNamara^b; Tiziano Baccetti^c; Lorenzo Franchi^c

ABSTRACT

Objective: To describe the dental arch changes occurring after adolescence through the sixth decade of life.

Materials and Methods: Longitudinal dental casts from 40 patients (20 male and 20 female) were digitized and analyzed. Measurements were recorded after the presumed cessation of circum-pubertal growth (T1), at approximately 47 years of age (T2), and at least one decade later (T3) were compared.

Results: The majority of the measurements were found to have a significant time effect, demonstrating at least some level of change throughout the aging process (T₁–T₃). Exceptions to this observation were the posterior maxillary arch width measurements, mandibular intermolar and interpremolar (as measured at the second premolars) widths, the maxillary incisor irregularity index, overjet, overbite, and curve of Spee. The T₁–T₃ changes reflected for the most part the T₁–T₂ changes, while the T₂–T₃ changes affected overall modifications only for the mandibular intercanine width and maxillary depth, as measured at the second premolars. All changes reflected a decrease in arch width, depth, and perimeter, with a significant increase in the mandibular incisor irregularity index.

Conclusions: The dental arches continue to change and adapt throughout life and into the sixth decade, though the degree of change decreases with time.

KEY WORDS: Dentition; Maturational changes; Dental casts; Digital imaging; Craniofacial growth

INTRODUCTION

It is a commonly held belief that the morphology of the dental arch is dictated by the supporting alveolar bone from which it arises¹ and that this form is modified further in all three planes of space by intraoral

functional forces and the circumoral musculature.^{2,3} Perhaps the most important factor in the observed changes in these somewhat malleable structures, however, is the fourth dimension (ie, time).

A number of recent studies^{4–8} have documented significant changes occurring in the dentofacial complex continuing into adulthood. The sum of these studies is that the form, function, size, and shape of the components continue to reflect small, but often statistically significant changes. Among these studies, only Harris⁸ has attempted to describe dental arch changes as late as the sixth decade. However, as this study measured subjects at approximately 20 years of age and again at approximately 55 years of age without intermediate measurements, it is impossible to isolate those changes occurring exclusively during the latest years of the investigation.

To meet the increasing need in an older orthodontic population,⁹ it is necessary to examine and describe the normal aging process of the dental arches contained within the adult craniofacial complex. Consequently, the present study was designed to detail the dental changes associated with aging, particularly

^a Private Practice, Indianapolis, Ind.

^b Thomas M. and Doris Graber Endowed Professor of Dentistry, Department of Orthodontics and Pediatric Dentistry, School of Dentistry; Professor of Cell and Developmental Biology, School of Medicine; and Research Professor, Center for Human Growth and Development, The University of Michigan, Ann Arbor, Michigan. Private practice of orthodontics, Ann Arbor, Mich.

^c Assistant Professor, Department of Orthodontics, University of Florence, Firenze, Italy, and Thomas M. Graber Scholar, Department of Orthodontics, University of Michigan, Ann Arbor, Mich.

Corresponding author: Dr James A. McNamara, The University of Michigan, Department of Orthodontics and Pediatric Dentistry, 1011 North University, Ann Arbor, MI 48109-1078 (e-mail: mcnamara@umich.edu)

Accepted: May 2007. Submitted: March 2007.

© 2008 by The EH Angle Education and Research Foundation, Inc.

Table 1. Distribution of Samples by Age

	Male Subjects				Female Subjects				Pooled Subjects			
	N	Age Range, y	Mean	SD	N	Age Range, y	Mean	SD	N	Age Range, y	Mean	SD
T ₁	20	14.9–18.0	17.0	0.9	20	14.8–18.1	16.9	0.8	40	14.8–18.1	17.0	0.9
T ₂	20	41.2–54.8	47.3	4.1	20	40.1–51.8	47.6	3.5	40	40.1–54.8	47.5	3.7
T ₃	20	52.3–66.7	58.4	4.2	20	51.4–62.9	58.7	3.3	40	51.4–66.7	58.6	3.8

those occurring after adolescence, with special attention to those changes occurring in the sixth decade of life.

MATERIALS AND METHODS

Patient Sample

The subjects for the current investigation were previous participants in the University of Michigan Elementary and Secondary School Growth Study (UMGS).^{10,11} Those subjects who had been successfully recalled in a previous survey in 1995^{5,7} and who also had diagnostic records available from the late teen years were targeted. Of these 65 subjects, nine could not be located, four declined to participate, and six could not make arrangements for their records to be obtained in a timely manner. Further, one subject was excluded due to multiple extractions, one had received extensive prosthodontic reconstruction, and four subjects were excluded whose records were damaged or incomplete. Therefore, the final number of subjects for the current study was 40 (20 male, 20 female; Table 1).

The sample originally was divided according to orthodontic treatment status. For the purposes of this study, "orthodontic treatment" was defined as any orthodontic intervention in either arch beyond space maintenance including expansion, functional appliances, active removable appliances, overbite/overjet correction appliances, or full orthodontic appliances. In all treated subjects orthodontic treatment and retention were completed prior to the time of first observation (T₁). Final samples comprised 12 male subjects and 10 female subjects in the untreated group, and 8 male subjects and 10 female subjects in the treated group.

Dental Cast Analysis

The dental casts of these subjects were measured using a digital imaging system (Bioscan OPTIMAS Imaging System, version 6.51.199; Seattle, Wash). This system was adapted to enable acquisition and measurement of dental cast data by Brust and McNamara,¹² and further modified for the adult dentition by Carter and McNamara.⁵ Methods for image capture and landmark acquisition have been described in detail in previous publications.^{5,12} Definitions of arch

depth, width, and perimeter reflect those described by O'Grady and associates.¹³

Due to the limitations of the OPTIMAS system, overbite, overjet, and curve of Spee were measured directly from the dental casts with the use of a digital caliper (Dentagauge 3, Erskine Dental, Marina Del Rey, Calif). Overbite was calculated by averaging the distance from the incisal edge of each maxillary incisor to the incisal edge of the corresponding mandibular incisor, measured perpendicular to the occlusal plane when the casts were oriented in centric occlusion. Overjet was calculated by averaging the distance from the labial surface of each mandibular incisor to the labial surface of its corresponding maxillary incisor measured parallel to the occlusal plane when the casts were oriented in centric occlusion. Curve of Spee, the perpendicular distance from a flat plane constructed over the incisal edges of mandibular incisors to the cusps of mandibular first molars, was calculated by averaging the greatest distances from cusp tips to the plane on the right and left sides.

At random intervals during digitization, measurements obtained through the OPTIMAS system were verified through the use of direct dental cast measurements. Comparison of these values found them to be consistent throughout the investigation.

Error of the Method

Ten dental casts were selected at random to duplicate measures. Intraclass correlation coefficient values ranged from 0.947 (maxillary incisor irregularity) to 0.999 (mandibular first interpremolar width, overbite). Dahlberg's formula¹⁴ yielded standard error values ranging from 0.07 mm (overjet) to 0.42 mm (maxillary incisor irregularity index).

Statistical Analysis

Descriptive statistics. Mean and standard deviation for each of the measured parameters were calculated at three time points: after the presumed cessation of circumpubertal growth (T₁), at approximately 47 years of age (T₂), and at least one decade later (T₃). Mean differences and standard deviations were calculated for changes over time (T₁–T₂, T₂–T₃, and T₁–T₃).

Inferential statistics. After confirming a normal distribution of the dental arch variables of the sample

Table 2. Pooled Sample: Descriptive and Inferential Statistics (N = 40)

Measurement, mm	T ₁		T ₂		T ₃		T ₁ -T ₂		T ₂ -T ₃		T ₁ -T ₃	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Maxillary arch width (centroid)												
First intermolar	42.0	2.5	41.8	2.5	41.9	2.7	-0.3	0.8	0.2	0.5	-0.1	1.1
Second interpremolar	37.3	2.1	37.1	2.3	37.3	2.4	-0.2	0.7	0.2	0.5	0.0	0.9
First interpremolar	32.8	1.8	32.6	2.0	32.6	2.2	-0.2	0.8	0.1	0.4	-0.2	0.9
Inter canine	29.0	1.4	28.4	1.5	28.4	1.7	-0.6**	0.6	0.0	0.4	-0.6**	0.8
Mandibular arch width (centroid)												
First intermolar	39.3	1.9	39.2	2.2	39.5	2.4	-0.1	0.8	0.2	0.6	0.2	1.0
Second interpremolar	34.0	1.9	33.6	2.0	33.7	2.2	-0.3**	0.7	0.1	0.5	-0.3	0.9
First interpremolar	29.4	1.4	28.8	1.5	28.7	1.7	-0.6**	0.6	-0.1	0.4	-0.7**	0.7
Inter canine	22.4	1.3	21.6	1.5	21.4	1.6	-0.8**	0.7	-0.2*	0.3	-1.0**	0.8
Maxillary arch depth												
First molar	25.1	2.0	23.8	2.1	23.7	2.0	-1.2**	0.8	-0.2	0.5	-1.4**	0.9
Second premolar	19.1	1.8	18.1	1.9	17.9	1.8	-1.1**	0.8	-0.2*	0.4	-1.3**	0.8
First premolar	13.1	1.4	12.2	1.4	12.0	1.4	-1.0**	0.7	-0.2	0.5	-1.2**	0.8
Canine	6.2	1.3	5.6	1.4	5.5	1.3	-0.6**	0.7	-0.1	0.5	-0.7**	0.6
Mandibular arch depth												
First molar	20.4	1.8	19.2	1.7	19.0	1.6	-1.2**	0.7	-0.2	0.7	-1.4**	1.0
Second premolar	14.4	1.8	13.3	1.7	13.2	1.6	-1.1**	0.8	-0.1	0.5	-1.2**	0.9
First premolar	8.5	1.3	7.7	1.2	7.6	1.3	-0.8**	0.7	-0.1	0.4	-0.9**	0.8
Canine	3.1	0.8	2.6	0.9	2.6	1.0	-0.5**	0.6	0.0	0.4	-0.5**	0.8
Arch perimeter												
Maxillary	69.2	3.8	67.1	3.7	66.9	3.7	-2.1**	1.6	-0.2	0.6	-2.2**	1.8
Mandibular	59.5	3.2	57.6	3.1	57.0	3.1	-1.8**	1.8	-0.6	1.5	-2.4**	1.3
Incisor irregularity index												
Maxillary	3.6	1.4	4.2	1.9	4.2	1.7	0.7	1.8	0.0	1.1	0.7	1.9
Mandibular	4.0	2.2	5.4	2.4	5.8	2.9	1.4**	1.8	0.4	2.2	1.8**	2.8
Overjet	4.4	1.4	4.4	1.5	4.4	1.6	0.0	0.7	0.0	0.4	0.0	0.8
Overbite	3.1	1.2	3.2	1.5	3.3	1.6	0.1	1.0	0.1	0.5	0.2	1.1
Curve of Spee	1.0	0.5	1.1	0.6	1.1	0.6	0.0	0.4	0.0	0.2	0.0	0.4

* $P < .05$; ** $P < .01$ using Bonferroni's correction for multiple comparisons.

through a Shapiro-Wilks test, data were analyzed through the use of repeated measures analysis of variance (RMANOVA) designed to test for the effects of time, orthodontic treatment, and gender. A nominal α level of .05 was selected and adjusted to $.05/3 = 0.017$ using Bonferroni's correction for multiple comparisons.

RESULTS

Analysis of Interactions

In an analysis comprising 23 arch parameters, only maxillary intercanine width demonstrated a statistically significant time \times treatment \times gender interaction ($P < .05$). No measurements in this investigation demonstrated statistical significance of either a treatment \times time or a treatment \times gender interaction, meaning that the study did not find differences in the way that orthodontically treated or untreated subjects age with respect to their dental alignments, and the effects of orthodontic treatment were not shown to differ based on

gender. The effect of gender consistently showed larger dimensions for male subjects compared with female subjects, without any qualitative consequence on the interpretation of the results. Thus, data from male and female subjects, as well as from treated and untreated subjects, were pooled for the purpose of analysis. Descriptive and inferential statistics for the pooled male and female samples are presented in Table 2.

Effects of Time (Aging)

The majority of the measurements examined were found to have a significant time effect, demonstrating at least some level of change throughout the aging process (T_1 - T_3). Exceptions to this observation were the posterior maxillary arch width measurements, mandibular intermolar and interpremolar (as measured at the second premolars) widths, the maxillary incisor irregularity index, overjet, overbite, and curve of Spee. The T_1 - T_3 changes reflected, for the most part, the T_1 - T_2 changes, while T_2 - T_3 changes affected overall mod-

ifications only for the mandibular intercanine width and maxillary depth, as measured at the second premolars. All changes reflected a decrease in arch width, depth, and perimeter, with a significant increase in mandibular incisor irregularity index (Table 2).

DISCUSSION

The purpose of this study was to describe the dental arch changes effected throughout adulthood, with a focus on those within the sixth decade of life. Subjects were selected from those who had participated in previous recalls of the University of Michigan Elementary and Secondary School Growth Study.

Overall, the changes observed from T_1 to T_2 are those that would contribute to crowding in the dental arches. Maxillary and mandibular arch width and depth decreased nearly universally, as did arch length. Accordingly, incisor irregularity increased in both arches, though this change was significant only in the mandible. Despite the significant changes in these arch dimensions, remarkable stability was observed in overbite, overjet, and curve of Spee during this time. The vast majority of statistically significant changes throughout the investigation occurred from T_1 to T_2 , representing the 30-year period from approximately 17 to 47 years of age.

In contrast to the preceding three decades, the period from 47 to 58 years of age was characterized by little change, if any. In general, arch depth and length continued to decrease from T_2 to T_3 , though to a lesser degree than observed from T_1 to T_2 , resulting in a change that often was not statistically significant during this time period. From T_2 to T_3 , only two arch width measurements (mandibular second premolar and first molar widths) showed significant changes (0.2 mm), though still probably below the definition of clinical significance.

Maxillary intercanine width was the only parameter in the present study that demonstrated a significant three-way interaction between time, gender, and treatment. No significant change was observed in untreated female subjects ($T_1-T_2 = -0.2$ mm; $T_1-T_3 = -0.1$ mm), while a significant decrease in intercanine width was apparent in untreated males ($T_1-T_2 = -0.8$ mm, $P < .01$; $T_1-T_3 = -0.9$ mm, $P < .01$). Ignoring the treatment effect, maxillary intercanine width decreased significantly in both male and female subjects between T_1 and T_2 (-0.8 mm and -0.5 mm, $P < .01$, respectively), as well as between T_1 and T_3 (-0.6 mm, $P < .01$, in both groups). On average, male subjects demonstrated a greater constriction of intercanine distance over time compared to female subjects, in agreement with findings published by Carter and McNamara,⁵ but in contrast to results presented by Harris.⁸ No signifi-

cant changes were noted between 47 and 58 years of age in the present study, an apparent continuation of the stability suggested by Bishara et al¹⁵ for this dimension. Maxillary intermolar width did not change significantly throughout the present study, in concordance with all studies with the exception of the 1997 investigation performed by Harris⁸ in which he describes significant increases in all maxillary dental widths through age 55 years.

The dental arches demonstrated a relative constriction in the anterior segment with time. It can be seen that both arches would take on a more rounded form through these changes in association with significant decreases in maxillary and mandibular arch depths. This result is in agreement with a study published by Henrikson and coworkers¹⁶ who found that the changes in arch form from adolescence into adulthood could be related to a decrease in arch depth, with greater increases over time of the premolar region with respect to intercanine width. The decrease in arch depth was accompanied by significant decreases in both maxillary and mandibular arch perimeters, and by a significant increase in incisor irregularity index limited to the mandibular arch.

The present investigation showed no significant changes in the curve of Spee between T_1 and T_2 or between T_2 and T_3 . Carter and McNamara⁵ described a decrease in the curve of Spee in untreated male subjects between 13.8 and 17.2 years of age, but determined the curve of Spee to be unchanged thereafter. Studies by Bishara and his groups¹⁷ demonstrated mild decreases in the curve of Spee. A striking majority of the sample utilized in this study demonstrated marked attrition of the mandibular incisors, a feature that would result in a decreased measurement of the curve of Spee. One could suggest that the incisor wear is secondary to traumatic occlusion due to incisor extrusion associated with the increased curve of Spee. It also could be hypothesized, however, that the incisors extrude secondary to incisal edge wear in order to reestablish occlusal contact with the opposing arch.

The present investigation noted no significant change in overbite throughout the course of the study. This observation is in agreement with the study by Harris⁸ and would appear to be a continuation of the trend toward stability described by Forsberg.¹⁸ A study by Tibana and coworkers¹⁹ suggests that overbite may increase during early adulthood, while investigations by Bishara and coworkers⁴ and Akgul and Toygar²⁰ found this increase to be significant only in female subjects. The small changes described in the existing literature and in the present study were of no clinical significance. Throughout the present investigation, overjet was found to remain essentially unchanged. None of the changes observed were statistically sig-

nificant. These results are in agreement with those of all longitudinal studies of overjet in early^{4,19,21,22} and middle adulthood^{5,7,8,21} that have shown agreement in their reports of stability of this measurement over time.

The present investigation revealed few statistically significant changes between the ages of 47 and 58 years. To make a claim of clinical significance of any of these changes may be unwise. The largest linear change observed was approximately 0.5 mm over a 10-year period (ie, 0.6 mm decrease in mandibular arch perimeter). However, a comparison of the values from T_2 to T_3 appears to reflect a continuation of the trends established between T_1 and T_2 , suggesting that while the arches are changing only slightly, these changes may be considered predictable to some degree.

CONCLUSIONS

- The dental arches continue to change throughout adulthood and into the sixth decade of life. These changes in arch width, depth, and length are decremental, and they reflect a continuation of those trends documented in the years prior to the sixth decade, though the degree of change decreases with time.
- There exists a tendency toward more rounded arch forms with age. This change in arch form results from a significant decrease in maxillary and mandibular arch depths.

REFERENCES

1. Brash JC. *The Aetiology of Irregularity and Malocclusion of the Teeth*. London, UK: Dental Board of the United Kingdom; 1956.
2. Weinstein S, Haack DH, Morris LY, Snyder BB, Attaway HE. On an equilibrium theory of tooth position. *Angle Orthod*. 1962;33:1–26.
3. Proffit WR. Equilibrium theory revisited: factors influencing position of the teeth. *Angle Orthod*. 1978;48:175–186.
4. Bishara SE, Treder JE, Jakobsen JR. Facial and dental changes in adulthood. *Am J Orthod Dentofacial Orthop*. 1994;106:175–186.
5. Carter GA, McNamara JA Jr. Longitudinal dental arch changes in adults. *Am J Orthod Dentofacial Orthop*. 1998;114:88–99.
6. Gormely JS, Richardson ME. Linear and angular changes in dento-facial dimensions in the third decade. *J Orthod*. 1999;26:51–54.
7. West KS, McNamara JA Jr. Changes in the craniofacial complex from adolescence to adulthood: a cephalometric study. *Am J Orthod Dentofacial Orthop*. 1999;115:521–532.
8. Harris EF. A longitudinal study of arch size and form in untreated adults. *Am J Orthod Dentofacial Orthop*. 1997;111:419–427.
9. Keim RG, Gottlieb EL, Nelson AH, Vogels DS. 2005 JCO Orthodontic Practice Study. Part 1: trends. *J Clin Orthod*. 2005;39:641–650.
10. Riolo ML, Moyers RE, McNamara JA Jr, Hunter WS. *An Atlas of Craniofacial Growth: Cephalometric Standards From The University School Growth Study, The University of Michigan*. Monograph 2. Craniofacial Growth Series. Ann Arbor, MI: Center for Human Growth and Development, The University of Michigan; 1974:1–4.
11. Moyers RE, van der Linden FPGM, Riolo ML, McNamara JA Jr. *Standards of Human Occlusal Development*. Monograph 5. Craniofacial Growth Series. Ann Arbor, MI: Center for Human Growth and Development, The University of Michigan; 1976:1–5.
12. Brust EW, McNamara JA Jr. Arch dimensional changes concurrent with expansion in mixed dentition patients. In: Trotman CA, McNamara JA Jr, eds. *Orthodontic Treatment: Outcome and Effectiveness*. Monograph 30. Craniofacial Growth Series. Ann Arbor, MI: Center for Human Growth and Development, The University of Michigan; 1995:193–225.
13. O'Grady PW, McNamara JA Jr, Baccetti T, Franchi L. A long-term evaluation of the mandibular Schwarz appliance and the acrylic splint expander in early mixed dentition patients. *Am J Orthod Dentofacial Orthop*. 2006;130:202–213.
14. Dahlberg AG. *Statistical Methods for Medical and Biological Students*. London: Bradford and Dickens; 1940:122–132.
15. Bishara SE, Jakobsen JR, Treder J, Nowak A. Arch length changes from 6 weeks to 45 years. *Angle Orthod*. 1998;68:69–74.
16. Henrikson J, Persson M, Thilander B. Long-term stability of dental arch form in normal occlusion from 13 to 31 years of age. *Eur J Orthod*. 2001;23:51–61.
17. Bishara SE, Jakobsen JR, Treder JE, Stasi MJ. Changes in the maxillary and mandibular tooth size-arch length relationship from early adolescence to early adulthood. A longitudinal study. *Am J Orthod Dentofacial Orthop*. 1989;95:46–59.
18. Forsberg CM. Facial morphology and ageing: a longitudinal cephalometric investigation of young adults. *Eur J Orthod*. 1979;1:15–23.
19. Tibana RH, Palagi LM, Miguel JA. Changes in dental arch measurements of young adults with normal occlusion—a longitudinal study. *Angle Orthod*. 2004;74:618–622.
20. Akgul AA, Toygar TU. Natural craniofacial changes in the third decade of life: a longitudinal study. *Am J Orthod Dentofacial Orthop*. 2002;122:512–522.
21. Bishara SE, Peterson LC, Bishara EC. Changes in facial dimensions and relationships between the ages of 5 and 25 years. *Am J Orthod*. 1984;85:238–252.
22. Forsberg CM, Odenrick L. Changes in the relationship between the lips and the aesthetic line from eight years of age to adulthood. *Eur J Orthod*. 1979;1:265–270.