European Journal of Orthodontics 23 (2001) 51–61 Published by Oxford University Press

Long-term stability of dental arch form in normal occlusion from 13 to 31 years of age

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SUMMARY Based on observations of longitudinal changes in dental arch dimensions, it has been stated that an individuality of arch form and an integrity of this form exists. However, longitudinal studies evaluating arch form changes have rarely been reported in the literature. The purpose of this investigation was to use a computer-assisted method for the description and analysis of maxillary and mandibular arch form in a sample of normal occlusion subjects, and to evaluate the long-term stability in dental arch form from the age of 13–31 years.

The study was carried out on 30 subjects of Scandinavian origin with normal occlusion, recorded at a mean age of 13.6 years and at follow-up at 31.1 years. Arch form analysis was based on a standardized photographic procedure, digitization of morphological landmarks, and a computerized form analysis in which arch form was described using eccentricity values of conics. No specific arch form could be found to represent the sample. Age changes occurred in arch form, although with large individual variations. For the mandible, a significant change to a more rounded arch form with age was found, which in males was accompanied by a significant increase in inter-molar distance and reduction in arch depth. There was also a significant correlation between change in mandibular arch form and increased irregularity of the lower incisors. These findings of lack of stability in arch form in normal occlusion subjects, when passing from adolescence into adulthood, further question the possibility of achieving stability post-orthodontically.

Introduction

Long-term changes in tooth positions and dental arch dimensions have been reported following orthodontic treatment (e.g. Shapiro, 1974; Gardner and Chaconas, 1976; Herberger, 1981; Little *et al.*, 1981, 1988; Udhe *et al.*, 1983), on untreated random samples (e.g. Moorrees, 1959; Sillman, 1964; Lundström, 1969; Moyers *et al.*, 1976; Harris, 1997), and on samples of untreated normal occlusion subjects (e.g. DeKock, 1972; Humerfelt and Slagsvold, 1972; Sinclair and Little, 1983; Bishara *et al.*, 1994). Longitudinal arch form changes have been described indirectly as dimensional changes of inter-canine and inter-molar distance, and arch length. However, these dimensional changes may not necessarily lead to a change in arch form.

Most studies evaluating arch form directly have been cross-sectional, and have tested methods to describe and find a specific arch form. Early methods (e.g. Hawley, 1905; Williams, 1917) were subjective and have been replaced by methods using mathematical equations such as 2nd to 8th polynomials (Lu, 1966; Pepe, 1975; Richards *et al.*, 1990), cubic splines (BeGole, 1980), parabolas (Jones and Richmond, 1989), ellipses (Currier, 1969), catenary curves (Pepe, 1975), beta function (Braun *et al.*, 1998), and conic sections (Biggerstaff, 1972; Sampson, 1981). Rudge (1981) has given a thorough review on the subject. Limitations in techniques to quantify arch form changes, as stated by Sampson (1981) and De La Cruz *et al.* (1995), could explain why methods for arch form description have rarely been used in longitudinal investigations. Hence, only a few longitudinal studies have evaluated arch form change directly.

Felton *et al*. (1987), who used 4th degree polynomials to assess dental arch form, found poor post-treatment stability in 70 per cent of a non-extraction sample, but did not report the method applied to quantify the changes in arch form. De La Cruz *et al*. (1995) adopted conic sections, a method described by Sampson (1981), to assess different arch forms (circles, ellipses, parabolas, and hyperbolas). Employing a geometric ratio allowed them to quantify the changes in arch form with time. They found that dental arch forms in subjects with Class I and II malocclusions treated with four premolar extractions, tended to return towards their pre-treatment forms in the post-treatment period. Recently, Davis and BeGole (1998) verified, with the use of cubic spline functions, that changes that occur during treatment tend to relapse during the post-treatment stage. The relapse appeared to be independent of whether the cases were treated by extractions or not, and a tested predictor model was found to be of limited use.

To what extent the post-treatment changes documented in referenced studies should be considered as relapse or normal change with time is unknown. It is generally believed that there is an individuality of the dental arch form and that an integrity of this form exists. Whether or not stability in arch form from the young to the adult permanent dentition is achievable by orthodontic treatment would be revealed by the stability of untreated normal occlusion samples. The purpose of this study was therefore to employ the method used by Sampson (1981) for the description and analysis of maxillary and mandibular dental arch form in a sample of normal occlusion subjects and to evaluate the long-term stability in dental arch form from the age of 13 to 31 years.

Subjects and methods

The subjects

The sample consisted of 30 individuals with normal occlusion (11 males and 19 females), documented with dental casts at 13 years of age (T1; mean age 13.6, SD 1.1 years) and at 31 years (T2; mean age 31.1, SD 0.4 years). The 13-year-olds were part of a larger sample of 7–16-year-old Swedish children with normal occlusion, originally collected between 1964–1968 to establish values for a normal occlusion sample for cephalometric and occlusal analysis. The criteria for selection were a normal sagittal, transversal, and vertical occlusion, without premature tooth loss and with a straight facial profile (Thilander *et al*., 1982). The present sample of 30 individuals of the original sample of 51 13-year-olds was made up by those who still were living in the district as adults and thus were able to take part in a re-examination.

Most subjects at T1 presented with fully erupted permanent teeth except for third molars. However, in a small number of subjects, second molars were still only partially erupted (two mandibular and seven maxillary). No loss of the permanent teeth, i.e. 17–27 and 37–47, occurred between T1 and T2 except in one case where there was loss of a maxillary second premolar, but without secondary occlusal changes.

Cast preparation and photographing

A sharp pencil was used to mark anatomic landmarks on the maxillary and mandibular casts from T1 and T2. The landmarks used were the buccal cusp tips of the canines, premolars, and molars, and the mid-points on incisal edges of the incisors (Figure 1). To ensure identical longitudinal location of the landmarks, casts from T1 and T2 of each individual were marked at the same time. The prepared casts were mounted in a camera stand (Docudent®; Lindqvist *et al*., 1998) in a standardized fashion for photographing. The

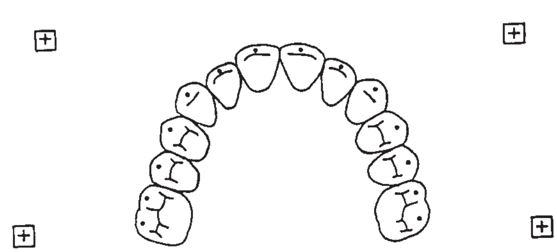

Figure 1 Schematic drawing of a dental cast showing the landmarks and four fiducial points used for digitizing.

occlusal plane of the casts, defined as a plane made up by landmarks on the first molars and central incisors, was positioned at the level of four reference objects (Figure 1). This ensured a consistent distance and orthogonality between the camera and the occlusal surfaces. A Yashica 108 Multiprogram camera with Tamron SP 90 Macro lens, and Agfapan APX 25 black and white film was used for the photographic recording.

Computer-generated measurements

Landmarks on the casts and the reference objects were digitized from the photographs using a Scriptel RDT Graphics Tablet (Scriptel Corp.®, Ohio, USA). Inclusion of the four reference objects in the Docudent equipment enabled correction for magnification and for photographic distortion. A computer program was developed for the calculation of arch form based on landmark co-ordinates and the description of arch shape as a mathematical function.

A mathematical method similar to that described by Sampson (1981) was used to fit conics to each set of data points from the dental casts. A conic is a curve obtained by taking a plane section through a cone. By varying the angle of cut, four main types of conics can be obtained: circle, ellipse, parabola, and hyperbola. A conic can also be described as the locus of a point that moves so that the ratio of its distance from a fixed point (the focus), to its distance from a fixed line (the directrix) is constant. The calculated ratio is called the eccentricity (*e*) of the conic (Figure 2). The variation of eccentricity determines the above mentioned main types of conics, i.e. the circle ($e = 0$), the ellipse ($0 < e < 1$), the parabola ($e = 1$), and the hyperbola ($e > 1$). Eccentricity values decrease as the arch becomes more rounded and increase as it becomes tapered. In this study, eccentricity was used to quantify the shape of the conics specific for each dental arch.

The digitized maxillary and mandibular landmarks also enabled the calculation of the inter-canine distance (the distance between the right and left canine cusp tips), the inter-molar distance (the distance between the mesio-buccal cusp tip of the permanent right and left first molars), and the dental arch depth (the perpendicular distance between a line crossing the mesio-buccal cusp tip of the first permanent molars to a mid-point positioned between the central incisor landmarks; Figure 3).

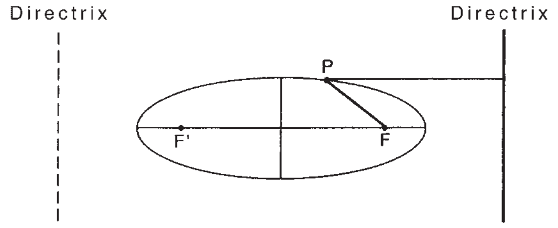

Figure 2 The principle for calculation of eccentricity of an ellipse. The eccentricity is the ratio between the distance of any point (*P*) on the curve from the focus (*F*) and the distance of the same point (*P*) to the directrix.

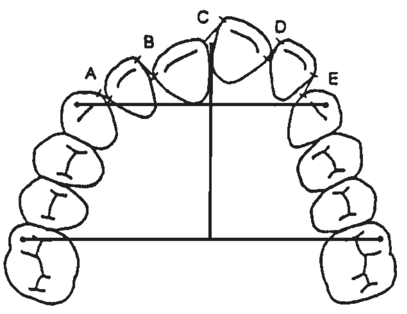

Figure 3 Linear measurements; lines for inter-canine distance, inter-molar distance and arch depth. A + B + C + D + E = Irregularity index.

Manual measurements

Little's irregularity index (Little, 1975) was used for the assessment of the alignment of the maxillary and mandibular six anterior teeth. The linear displacement of the anatomical contact points was recorded with an electronic sliding calliper (C. E. Johanssson AB, Eskilstuna, Sweden) and summed for each dental cast (Figure 3).

Statistical analysis

Means and standard deviations of eccentricity (arch form), and linear measurements at T1 and

T2 were calculated separately for the maxillary and the mandibular dental arches within the total sample, and for males and females. Differences in eccentricity and linear measurements between T1 and T2 and between maxillary and mandibular eccentricity at T1 were tested with the Wilcoxon matched-pairs signed-rank test. The Mann–Whitney *U*-test was used to determine any arch form gender differences at T1 and T2, for age changes from T1 to T2, and to test for gender differences with regard to linear changes with age. Pearson's product moment correlation coefficient was used to evaluate associations between: (a) arch form and linear changes, (b) different linear changes, and (c) maxillary and mandibular arch form changes. Correlations between arch form and linear changes for males and females separately were also calculated. The level of statistical significance was determined at $P \leq 0.05$.

Table 1 Mean and SD of eccentricity value (ratio) for the maxillary and the mandibular arches at 13 (T1) and 31 (T2) years of age, and eccentricity changes between T1 and T2; given for the whole sample ($n = 30$), and for females ($n = 19$) and males ($n = 11$) separately.

	T1 Mean (SD)	T2 Mean (SD)	T1–T2 Mean diff. (SD)
Maxilla,			
all	0.83 (0.08)	0.81 (0.09)	–0.02 (0.05) NS
females	0.84 (0.06)	0.82 (0.09)	–0.03 (0.06) NS
males	0.80 (0.09)	0.78 (0.10)	–0.02 (0.04) NS
Mandible,			
all	0.87 (0.08)	0.82 (0.14)	–0.04 (0.09) *
females	0.87 (0.06)	0.84 (0.09)	–0.03 (0.07) NS
males	0.85 (0.09)	0.79 (0.19)	–0.07 (0.12) NS

NS, not significant; $^*0.01 < P < 0.05$.

Methodological error

To evaluate the methodological error, 10 pairs of dental casts from another group of individuals with mild Class I malocclusions were selected from patient files in the clinic. Landmarks on the casts were routinely marked, photographed, erased, and digitized from the photographs. The procedure was repeated two weeks later. The mean difference between the two landmark registrations was 0.19 mm (SD 0.21) and the mean eccentricity difference 0.01 (SD 0.01). The methodological error between repeated measurements with the sliding calliper for assessment of incisor irregularity revealed a mean difference of 0.17 mm (SD 0.22). The plausibility of the utilized mathematical dental arch form descriptions was checked by comparing obtained arch form print-outs with the photographic records.

Results

Initial arch forms

These were expressed by the eccentricity value at the age of 13 years (T1) and varied from 0.68 to 0.98 in the maxilla and from 0.71 to 0.98 in the mandible. All maxillary and mandibular arches were thus elliptic with an eccentricity below 1. The mean eccentricity value at T1 (Table 1) for the maxilla was 0.83 (SD 0.08) and for the mandible 0.87 (SD 0.08). The tendency for a slightly more tapered arch form in the mandible was statistically significant ($P = 0.05$). No gender differences could be found with regard to eccentricity in the maxilla ($P = 0.116$) or in the mandible ($P = 0.636$). When the subjects were stratified into three groups (A, B, C) based on their eccentricity values (A: $e \leq 0.78$; B: $0.78 < e \leq 0.88$; C: $e > 0.88$), they were found to be quite evenly distributed with regard to the maxilla, but the mandibular arches showed a tendency to shift towards higher eccentricity values. The median arch shape and distribution at T1 for each group is illustrated in Figure 4.

Adult arch forms

At 31 years of age, maxillary and mandibular arch form (T2) showed an increased individual variation, with an eccentricity range from 0.65 to 1.01 in the maxilla, and from 0.44 to 1.04 in the mandible. No gender differences could be found at T2 with regard to eccentricity in the maxilla ($P = 0.220$) or in the mandible ($P = 0.576$).

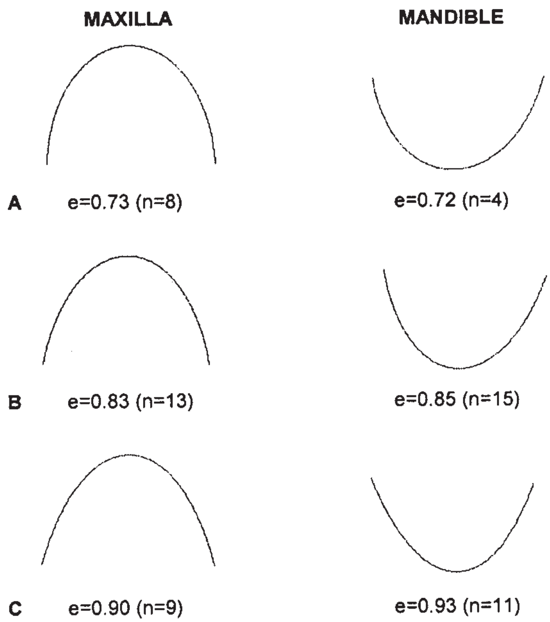

Figure 4 Median maxillary and mandibular arch form for the three stratified subgroups (A, B, C) at T1 and the distribution between the groups.

Arch form changes

Between 13 and 31 years of age (T1–T2) arch-form changes occurred both in the maxilla and in the mandible (Figure 5 a,b). A significant pattern in the sample as a whole was, however, only found in the mandible (Table 1), where the significant reduction in eccentricity revealed a tendency for a more rounded shape with age. No gender differences could be found with regard to arch form changes with age in the maxilla ($P = 0.914$) or in the mandible ($P = 0.518$). The extent of individual variation in arch form change is illustrated with a case from the sample in Figure 6.

Linear arch changes

Dimensional arch changes as expressed by inter-molar and inter-canine distance, and arch depth occurred between 13 and 31 years (Table 2a, 2b). A statistically significant reduction in upper as well as lower inter-canine widths and arch depths was found. An accentuation of lower incisor

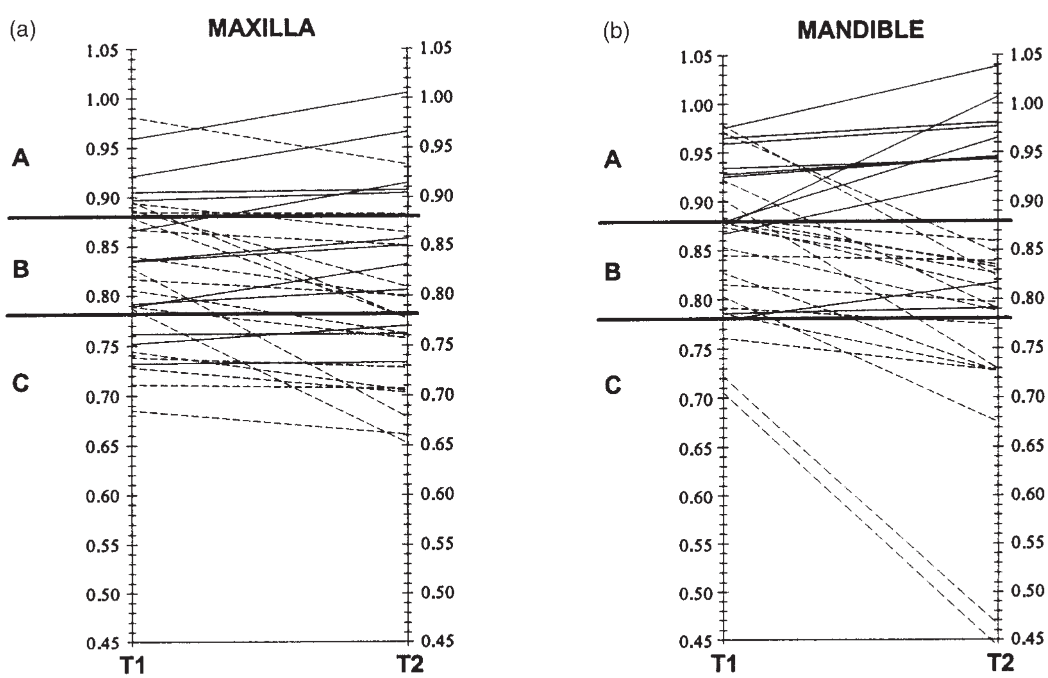

Figure 5 (a) Eccentricity value changes from 13 to 31 years of age (T1–T2) for the maxillary arch ($n = 30$). (b) Eccentricity value changes from 13 to 31 years of age (T1–T2) for the mandibular arch ($n = 30$). Continuous lines depict subjects with increased tapering of the arch, and dotted lines those with more rounded arches with age. Bold lines indicate boundaries between the subgroups (A, B, C).

Figure 6 Mandibular arches (case no. 9, male) superimposed, illustrating extreme eccentricity (*e*) change between T1 and T2. Thin line depicts arch form at T1 ($e = 0.71$) and bold line at T2 ($e = 0.44$).

crowding with age was also obvious by the significant increase in Little's irregularity index. Significant gender differences were found with regard to mandibular inter-molar distance change ($P = 0.0003$), where males showed increased values with age. Males also showed a significantly higher reduction in mandibular arch depth ($P = 0.01$) than females.

Linear arch changes and arch form (eccentricity) changes

Correlation between linear arch changes and arch form (eccentricity) changes from 13 to 31 years in the sample are summarized in Table 3. A significant correlation was found in the maxilla between the change in arch form and the reduction in inter-canine width, in the sample as a whole and in females. Although no such correlation was found in the mandible, mandibular arch form changes, were correlated with the increase in mandibular incisor irregularity as expressed by Little's index. This was also found in males. The correlation between mandibular inter-molar distance and mandibular arch form change was significant in both males and females. However, in males there was a negative correlation and the opposite in females, as a consequence of dissimilar changes in inter-molar distance (Table 2b). A test of correlation between different linear changes showed lower incisor irregularity to correlate with reduced mandibular dental arch depth ($r = -0.36$, $P = 0.047$). No correlation was found between maxillary and mandibular arch form changes with age ($r = 0.32$, $P = 0.086$).

Discussion

In this study, a method using conic sections as described by Sampson (1981), was employed to

Table 2a Mean and SD for maxillary inter-molar distance, inter-canine distance, arch depth, and for Little's irregularity index at age 13 (T1) and 31 (T2), as well as differences between T1–T2; for the whole sample ($n = 30$), for females ($n = 19$), and for males ($n = 11$) separately.

Maxillary linear measurements (mm)	T1 Mean (SD)	T2 Mean (SD)	T1–T2 Mean diff. (SD)
Inter-molar dist,			
all	51.0 (2.2)	50.9 (2.6)	–0.2 (1.3) NS
females	50.4 (2.1)	50.1 (2.4)	–0.2 (1.0) NS
males	52.2 (2.0)	52.1 (2.4)	–0.1 (1.7) NS
Inter-canine dist,			
all	33.7 (1.6)	33.2 (1.9)	–0.4 (0.8) **
females	33.1 (1.5)	32.6 (1.5)	–0.5 (0.7) *
males	34.6 (1.5)	34.3 (2.1)	–0.3 (1.0) NS
Arch depth,			
all	27.5 (1.7)	25.7 (1.8)	–1.8 (0.6) ***
females	27.7 (1.4)	25.9 (1.5)	–1.8 (0.7) ***
males	27.2 (2.3)	25.5 (2.4)	–1.8 (0.5) **
Irregularity index,			
all	1.8 (1.4)	2.0 (1.2)	0.2 (1.2) NS
females	1.7 (1.3)	1.8 (1.0)	0.1 (1.2) NS
males	1.9 (1.7)	2.3 (1.4)	0.5 (1.3) NS

NS, not significant; *$0.01 < P < 0.05$; **$0.001 < P < 0.01$; ***$P < 0.001$.

Table 2b Mean and SD for mandibular inter-molar distance, inter-canine distance, arch depth, and for Little's irregularity index at age 13 (T1) and 31 (T2), as well as differences between T1–T2 ; for the whole sample ($n = 30$), for females ($n = 19$), and for males ($n = 11$), separately.

Mandibular linear measurements (mm)	T1	T2	T1–T2
	Mean (SD)	Mean (SD)	Mean diff. (SD)
Inter-molar dist,			
all	44.2 (2.6)	44.5 (3.3)	0.4 (1.4) NS
females	43.3 (2.0)	43.0 (2.3)	–0.3 (1.2) NS
males	45.7 (3.0)	47.2 (3.1)	1.6 (0.9) **
Inter-canine dist,			
all	25.5 (1.3)	24.8 (1.7)	–0.7 (0.8) **
females	25.2 (1.4)	24.4 (1.8)	–0.8 (0.8) **
males	26.2 (1.0)	25.6 (1.4)	–0.6 (0.8) **
Arch depth,			
all	23.6 (1.2)	22.0 (1.8)	–1.6 (1.2) ***
females	23.6 (1.1)	22.4 (1.3)	–1.2 (1.0) ***
males	23.6 (1.4)	21.3 (2.3)	–2.2 (1.4) **
Irregularity index,			
all	2.4 (1.7)	3.8 (2.2)	1.4 (1.4) ***
females	2.0 (1.5)	3.4 (1.5)	1.4 (1.3) ***
males	3.1 (1.9)	4.5 (3.1)	1.4 (1.7) *

NS, not significant; *$0.01 < P < 0.05$; **$0.001 < P < 0.01$; ***$P < 0.001$.

Table 3 Correlations between maxillary eccentricity (Max ecc) and maxillary linear changes, and between mandibular eccentricity (Mand ecc) and mandibular linear changes; for the whole sample ($n = 30$), for females ($n = 19$) and for males ($n = 11$), separately between T1 and T2. Correlation coefficient (r).

	Inter-molar distance	Inter-canine distance	Arch depth	Irregularity index
Max ecc				
all	$r = 0.11$ NS	$r = –0.54$ **	$r = 0.22$ NS	$r = 0.11$ NS
females	$r = 0.36$ NS	$r = –0.59$ **	$r = 0.24$ NS	$r = 0.20$ NS
males	$r = –0.09$ NS	$r = 0.15$ NS	$r = 0.17$ NS	$r = –0.11$ NS
Mand ecc				
all	$r = –0.05$ NS	$r = –0.09$ NS	$r = 0.19$ NS	$r = –0.47$ **
females	$r = 0.61$ **	$r = 0.05$ NS	$r = 0.14$ NS	$r = –0.29$ NS
males	$r = –0.70$ *	$r = –0.19$ NS	$r = 0.12$ NS	$r = –0.62$ *

NS, not significant; *$0.01 < P < 0.05$; **$0.001 < P < 0.01$.

achieve a numerical value (eccentricity) of arch form change. It is recognized that this method may be limited by the fact that symmetrical dental arches may not necessarily be present (Pepe, 1975), although this is less likely in a normal occlusion sample.

This method could allow for a continuing search for correlations between possible aetiological factors and changes in arch form.

Various definitions of the dental arch have been used in studies of arch form. Currier (1969) defined three curves, an outer curve based on cusp tips and incisor edges, a middle curve based on fossae, fissures and cinguli, and an inner curve based on lingual aspects of teeth. Arch shape will thus vary according to the landmarks chosen to represent the teeth. The landmarks may represent an outer 'bracket slot curve' as in commercially available arch wires, an outer 'bucco-labial surface curve' (Brader, 1972), a middle curve or a modification thereof (Jones and Richmond, 1989), another middle curve, a 'contact point curve' (Battagel, 1996), or a modified outer curve excluding premolars (Raberin *et al*., 1993). As each definition generates a different shape, general comparisons between various studies on arch form should be made with caution. In addition, the validity of each defined arch type is related to the purpose of its use. Thus, it is likely that landmarks and arch form descriptions based on peripheral occlusal surface structures, as used in this study, are more sensitive to changes in tooth position over time than structures closer to the roots.

The findings of a large variation in eccentricity values verify earlier observations that the dental arch has no single and universal form (Felton *et al*., 1987; Raberin *et al*., 1993). These observations are strengthened by the rather even distribution of cases in the three stratified groups in this investigation. Raberin *et al*. (1993), who studied mandibular arch form in subjects with normal occlusion, concluded that at least five different forms are among those most frequently seen. Whether gender may influence arch form is unclear and earlier observations are contradictory. Kawata *et al*. (1974) revealed such a difference between Japanese males and females, but Raberin *et al*. (1993) did not find any gender differences in a French sample. In the light of the large individual variation in arch form in the present sample, it is not surprising that no gender differences in arch shape were revealed. Arch dimension, on the other hand, has been found to be related to gender in several earlier studies and, more recently, by Ferrario *et al*. (1994) with smaller linear values in women as in the present investigation, and differences therefore seem to reflect more a size discrepancy than a shape difference.

The stability of arch form has long been a subject for controversial opinions, although the discussion has mainly focused on stability following orthodontic reshaping (Strang, 1949; Felton *et al*., 1987; De La Cruz *et al*., 1995; Davis and BeGole, 1998). Bennet (cf. Knox *et al*., 1993) recognized that the arch form of non-treated normal occlusion subjects is often broader than that of orthodontically treated patients. This statement would be in line with observations that individuals with normal occlusion tend to have more brachy- than dolicofacial patterns with wider dental arches (Christie, 1977). The present study indicates a change in untreated 'normals' towards a more rounded mandibular arch form with age. Whether these observations of arch form changes from 13 to 31 years represent a linear relationship with age or predominately an early maturing dentition in the late teens cannot be answered. However, a remarkably stable period has been observed in the late teens by Richardson (1992), contrasting to larger changes observed during earlier teenage years, and small, although sometimes clinically significant beyond the age of 20 years (Richardson and Gormley, 1998; Bishara *et al*., 1994; Carter and McNamara, 1998).

A correlation between changes in arch form and linear distance, i.e. a reduction in inter-canine width, was found only in the maxilla. Mandibular arch form changes were significantly correlated with an increase in lower incisor irregularity, which in turn correlated with a decrease in mandibular arch depth. Moreover, all males demonstrated an increase of mandibular inter-molar distance, which was correlated with change in arch form. This may be interpreted as different factors regulating arch form changes in the two arches, and an increased disparity in breadth dimension between upper and lower arches has, in fact, been noted in boys (Moorrees, 1959; Brown *et al*., 1983). Brown *et al*. (1983) stated, following longitudinal studies in Aboriginals, that dimensional arch changes, such as depth and breadth, were relatively independent of each other within and between dental arches. It is recognized that factors may operate differently, not only between subjects, but also between dental arches in the same individual. An example of this is given in Figure 7, where the casts of an individual in the sample at 13 and 31 years of age demonstrate how dentoalveolar compensatory changes in the upper arch adjust for late mandibular growth, which would otherwise disrupt the normal occlusion.

A late and surprisingly large increase of maxillary and mandibular inter-molar distance

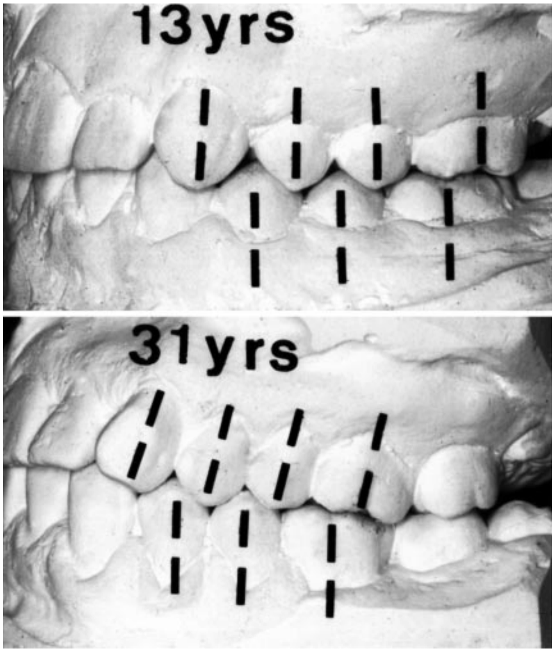

Figure 7 Casts of an individual in the sample (case #13, male) at 13 and 31 years of age illustrating dentoalveolar compensatory changes in the upper arch to adjust for a slight mandibular overgrowth, i.e. the maxillary teeth have become more anteriorly inclined with age.

has recently been reported to occur in adults between 20 and 55 years of age (Harris, 1997). He concluded, based on the finding of a wider inter-molar distance, but unchanged inter-canine width, that arch form tends to become more tapered with age. On the other hand, he also found a change towards a shorter, broader arch when using a principal component analysis, thus illustrating the limitations in using dimensional measurements when describing arch form.

The finding in this study of a shorter and more rounded dental arch in the mandible, associated with increased incisor irregularity, could be explained by incisor uprighting and/or mesial tooth migration. The investigation covers a period of intense facial growth during adolescence and adulthood, when facial growth is slower. Different dentoalveolar changes may be seen during these periods with regard to mandibular incisor inclination. Watanabe *et al.* (1999) observed that mandibular incisors procline between pre- and mid-adolescence, and retrocline thereafter. Bishara *et al.* (1994) studied adults and demonstrated small, but significant skeletal changes, as well as an increased inter-incisal angle, in a sample of subjects with normal occlusion between 25 and 46 years. In the average growing individual changes in lower incisor inclination, as well as mesial tooth migration would be in agreement with the dentoalveolar changes that occur in the forward rotating facial growth pattern as described by Björk and Skieller (1972, 1983). However, it should be recognized that incisor inclination changes, recorded in relation to stable structures, differ markedly from those observed relative to a reference in conventional cephalometrics and may explain different observations in several studies (Björk and Skieller, 1983). The relationship between facial growth pattern and dentoalveolar changes and the influence of soft tissue stretching on face and jaw shape (Solow and Kreiborg, 1977) also strongly supports an association between dental arch shape and facial form, and requires further study. Many factors influence arch form and, in agreemant with Brown *et al.* (1983), it must be concluded that the relative importance of many determinants involved and the way they interact is still not clear. De La Cruz *et al.* (1995) stated that it is difficult, if not impossible, to predict the post-retention consequences after orthodontically induced changes in arch form. The arch form changes observed in the untreated, normal occlusion subjects in this study underline this difficulty.

Conclusions

In a longitudinal sample of normal occlusion subjects, age changes in dental arch form occur from adolescence to adulthood, with large individual variation, and in several subjects on a clinically visual level. For the mandible, a more rounded arch form with age was found to be statistically significant, which in males was accompanied by a significant increase in inter-molar distance and reduction in arch depth. Lack of stability in arch form in most untreated normal occlusion subjects when passing from adolescence into adulthood further questions the possibility of achieving post-orthodontic stability.

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Acknowledgments

Assistance in the development of the computer program for the dental arch form analysis by Mr Roger Mähler, previously at the Demographic Data Base, Umeå University, is gratefully acknowledged. This study was supported by grants from the Swedish Dental Society.

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