Original Article

Changes in Arch Width
A 20-year Longitudinal Study of Orthodontic Treatment

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Abstract: The changes in the dental arch dimensions that occur as a result of growth and treatment are of interest to the orthodontist and require careful consideration during treatment planning. A greater understanding of these changes could influence the patient's expectations from treatment as well as the formulation of the treatment and retention plans by the clinician. A retrospective study of the maxillary and mandibular canine and molar arch width changes in 60 patients over 20 years was carried out. Approximately half were treated orthodontically, and measurements were made on dental casts taken at four time points during the study: 1981, 1985, 1989, and 2001. Between baseline and final follow-up, the treated group demonstrated a statistically significant increase in maxillary intercanine arch width and statistically significant decreases in maxillary intermolar and mandibular intercanine and intermolar widths. No significant changes were observed for the untreated group. When comparing the orthodontically treated group with the untreated group, there was a significantly greater increase in maxillary intercanine width and a significantly greater reduction in mandibular intercanine width in the treated group over the duration of the study. No significant difference was observed between treated and untreated groups for maxillary and mandibular intermolar width changes. Sex had no statistically significant effect on these treatment differences. Type of orthodontic treatment had no effect on arch width changes within the treated group; however, the effect of tooth extraction needs further investigation. (*Angle Orthod* 2006;76:6–13.)

Key Words: Intercanine width; Intermolar width; Sex; Tooth extraction; Orthodontic appliance

INTRODUCTION

Dental arch changes resulting from growth and treatment are important to the orthodontist. An understanding of these changes is useful in treatment and retention planning by the clinician.[1] The literature focuses on a number of important factors in relation to arch width including the effect of extraction vs nonextraction[2–8] and the general effect of orthodontic treatment and normal growth on arch width.[9] Arch dimensions change with growth; therefore, it is necessary to distinguish changes induced by appliance therapy from those that occur from natural growth. These naturally occurring changes in untreated individuals should be used as comparative ''gold standards'' against which the dental arch changes produced by orthodontic treatment are evaluated.[10]

Shapiro[11] found that intermolar width responded differently in extraction and nonextraction orthodontically treated cases. In a study by Uhde et al,[12] mean intercanine widths increased in the maxillary and mandibular arches with treatment in all types of malocclusion and decreased after treatment toward the original values. Gardner and Chaconas[13] concluded that the type of treatment had little effect on the net change in intercanine arch width, although this disagreed with other authors.[14] The review article by Lee[7] on arch width and archform immediately brings to attention the variation in results and conclusions and the wide range of study types and methods that have been carried out during the past few decades. The breadth of literature indicates orthodontic interest in assessing changes in

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TABLE 1. Measurement Problems and Adopted Conventions

Problem	Convention Adopted
Crowns/bridges	Where crowns/bridges replaced reference teeth, we estimated the point on the prosthesis.
Deciduous canines	Deciduous canines were used if present.
Attrition	Where attrition of the cusp was evident, the central outermost point of the wear facet was used.
Rotation	Not included in study.

arch width, with and without treatment. However, a range of evidence exists regarding the size and timing of such changes and, as a result, further investigation is required.

This study aims to compare the fundamental arch width change with and without treatment and investigates whether orthodontic appliance type, extraction status, and sex have any significant influence on these results.

MATERIALS AND METHODS

This study used information collected from the longitudinal Cardiff Survey, which commenced in 1981.[15] The initial sample consisted of 1018 eleven-year-old Caucasian school children. A total of 331 individuals attended the latest examination in 2001 (aged 31). Sixty individuals, selected as part of another study assessing facial attractiveness,[16] were used in the study described here. Inclusion was based on a complete set of records for each year of the assessment and groups approximately equally divided with regard to sex and orthodontic treatment. Dental casts were collected at 11, 14, 20, and 31 years of age.

Measurement techniques

The intercanine and intermolar widths were measured using electronic vernier calipers accurate to 0.005 mm. All measurements were performed blind, ie, the examiners had no knowledge of the treatment status of the models. The two examiners were calibrated on a different set of 30 casts before measuring 30 casts each for this study.

Measurement protocol and conventions

The following measurement protocol was used.

- Intermolar width: the distance between the mesiobuccal cusp tips of the right and left first permanent molars.
- Intercanine width: the distance between the cusp tips of the right and left canines.
- A number of complicating factors were encountered during preliminary intra- and interexaminer reliability assessments, which required the development of conventions to deal with certain situations (Table 1).

Study subjects

In the study sample, 28 subjects were orthodontically treated, and 32 were untreated. Of those who were treated, 12 subjects were treated with a removable appliance and 16 with fixed alone or fixed + removable, or both. Of the whole sample, 31 were female and 29 male. Regarding tooth extraction status, 26 subjects had no teeth extracted, and 34 subjects had between one and six teeth extracted.

Statistical analysis

Bland Altman plots were used to examine inter- and intraexaminer variability for the calibration study.[17] Arch width changes with time were evaluated using repeated measures analysis of variance (ANOVA) over all four time points. Orthodontic treatment, extraction status, and sex were investigated in relation to these changes. The type of appliance used in the treated group was also investigated. Statistical significance was determined at the 0.05 level throughout.

RESULTS

Visual inspection of all Bland Altman plots indicated no significant departures from acceptable agreement. Figure 1A through C shows the inter- and intrarater reliabilities for upper canine arch width measures. Similar plots were obtained for all arch width measures but are not shown. Average biases ranged from −0.007 to 0.432 mm for all interrater differences and from −0.028 to 0.160 mm for all intrarater differences. Limits of agreement were within acceptable limits for all arch widths.

Table 2 shows the mean intercanine and intermolar distances for the four assessment time points in orthodontically treated and untreated groups. The largest change between baseline and final assessment observed in the treated group was an increase in mean upper canine width from 32.66 to 34.12 mm. All other changes in this group were decreases in width. Changes in the untreated group were all smaller than those in the treated group. Lower canine widths decreased slightly from 25.18 to 25.14 mm, whereas all other widths increased. The changes over the duration of the study are illustrated in Figure 2A through D.

Table 3 summarizes the changes in arch width mea-

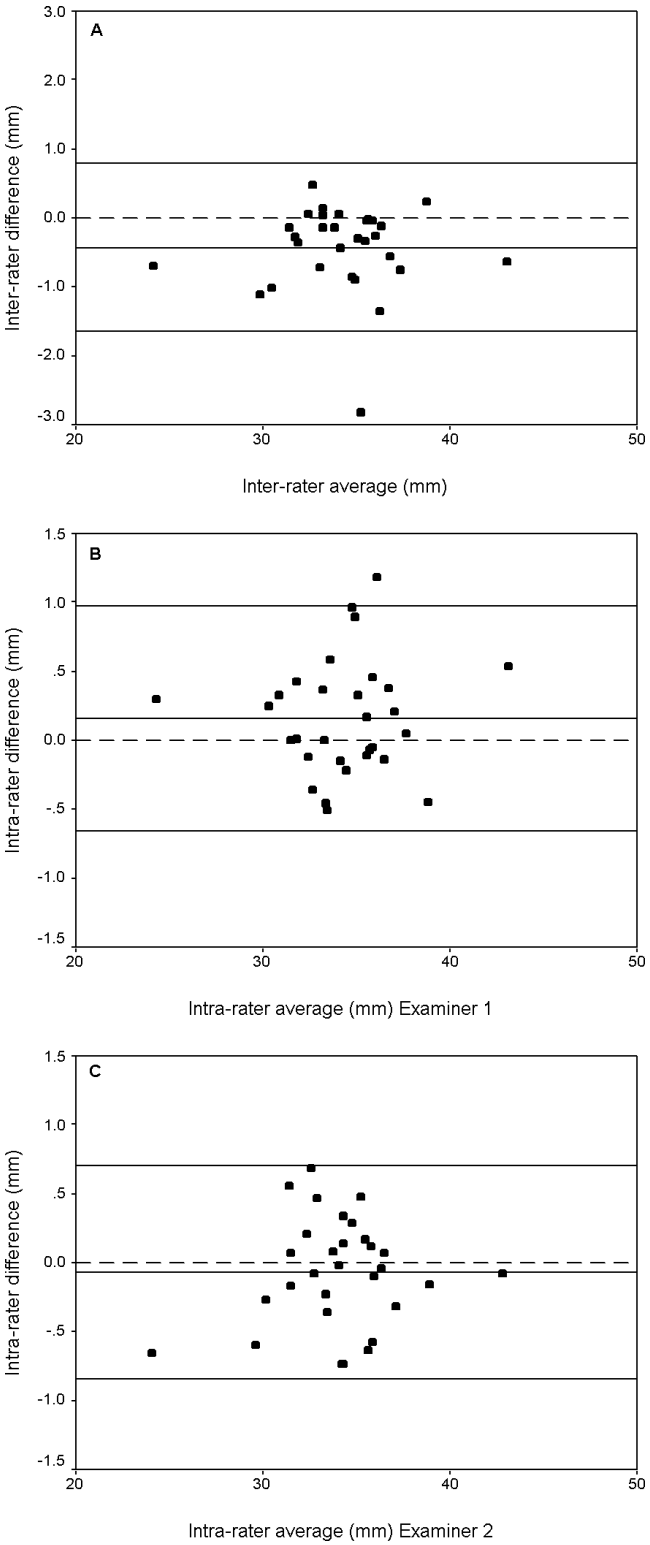

FIGURE 1. (A–C) Bland Altman plots for inter- and intrarater reliability for upper canines.

sures between the start and the end of the study and gives 95% confidence intervals for the change. The confidence intervals indicate that changes in the treated group were statistically significant, whereas changes in the untreated group did not reach statistical significance. Variation in the median levels of arch widths over time in treated and untreated groups is shown in Figure 3A through D. They illustrate the large amount of variation in arch widths observed in the groups.

To analyze changes in arch width over all four time points between treated and untreated groups, repeated measures ANOVA was used. This type of analysis gives both within and between subjects effects. Within subjects time effects represent changes in arch widths over time. Between subjects effects represent differences in average widths between groups (treated vs untreated) for each of the four arch widths. In the absence of interactions, this suggests changes that are paralleled over time in each group. However, if there are significant time $\times$ group interactions, the changes over time differ as well as the average levels. Thus, these interactions imply significant group (treatment) effects within each arch, and it is these results that are shown in the following tables.

Table 4 summarizes the results of repeated measures ANOVA. It can be seen from Table 2 and Figure 2 that there were differences in arch width between treated and untreated groups at baseline. Because these initial differences may affect the interpretation of the results, they were adjusted for in all ANOVA models.

Statistically significant differences over time between treated and untreated groups were found for upper and lower canine arch widths. The differences for molar arch widths were not statistically significant, although the *P* value for the lower molar arch width measures was close to conventional levels of significance. To examine the effect of tooth extractions on these treatment differences, an extra covariate was added to the ANOVA model. There were no statistically significant differences in the arch width changes over time between treatment groups after adjusting for extraction status. This suggests that extraction status may account for the treatment differences observed previously. However, of the 32 untreated subjects, 23 had no teeth extracted, whereas only three of the 28 treated subjects had no teeth extracted (all other subjects had 1–6 teeth extracted). Because these numbers are unbalanced, the results of this analysis may be unreliable and require further confirmation.

The effect of sex on treatment differences was also examined. Eleven males and 17 females were included in the treated sample and 18 males and 14 females in the untreated sample. The differences in the changes over time for upper and lower canines between un-

TABLE 2. Mean (SD) Intercanine and Intermolar Distances (in mm)

	1981		1985		1989		2001	
	Not Treated	Treated	Not Treated	Treated	Not Treated	Treated	Not Treated	Treated
Upper								
Canine	33.06 (3.33)	32.66 (2.45)	32.97 (3.31)	34.28 (2.11)	33.30 (3.44)	34.38 (1.60)	33.52 (3.37)	34.12 (1.87)
Molar	50.14 (2.41)	47.99 (2.94)	49.95 (2.46)	46.93 (2.35)	50.56 (2.72)	46.88 (2.84)	50.62 (2.90)	46.62 (3.38)
Lower								
Canine	25.18 (1.68)	25.67 (2.04)	24.80 (1.68)	25.67 (1.82)	25.09 (1.90)	25.24 (1.74)	25.14 (2.03)	24.91 (1.57)
Molar	44.29 (1.78)	43.27 (2.88)	44.09 (2.10)	42.47 (2.77)	44.76 (1.98)	42.22 (2.69)	44.96 (2.12)	42.21 (2.91)

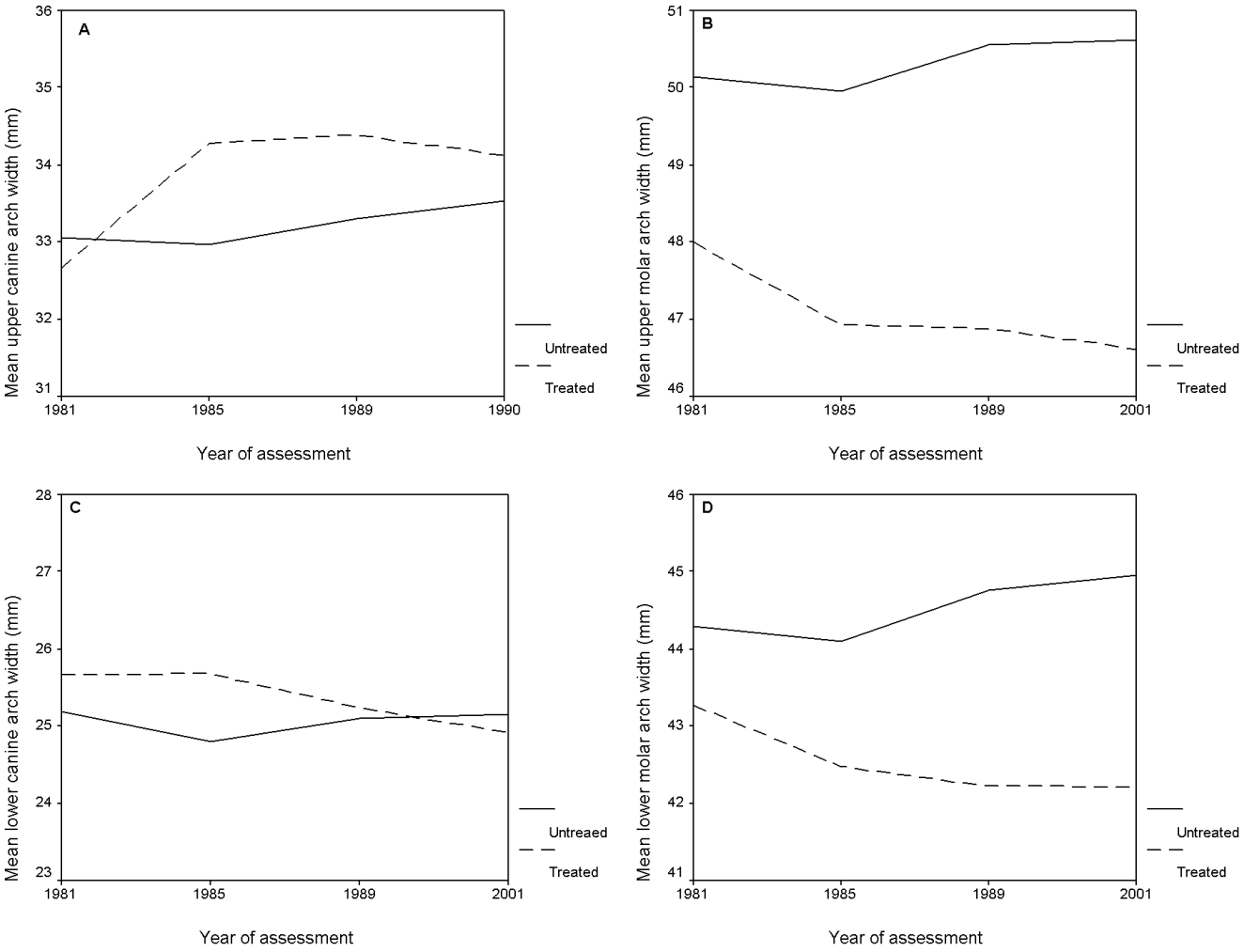

FIGURE 2. (A–D) Mean upper and lower canine and molar arch widths by year for treated and untreated groups.

TABLE 3. Mean Changes in Arch Width (mm) Between 1981 and 2001 (95% Confidence Interval)[a]

	Not Treated	N	Treated	N
Upper				
Canine	0.46 (1.10 to −0.17)	26	1.46 (2.50 to 0.42)	17
Molar	0.48 (1.15 to −0.18)	30	−1.38 (−0.04 to −2.72)	24
Lower				
Canine	−0.04 (0.49 to −0.57)	28	−0.76 (−0.20 to −1.32)	22
Molar	0.67 (1.37 to −0.02)	28	−1.06 (−0.08 to −2.04)	24

[a] Missing data are due to excessive attrition or absence of deciduous canines.

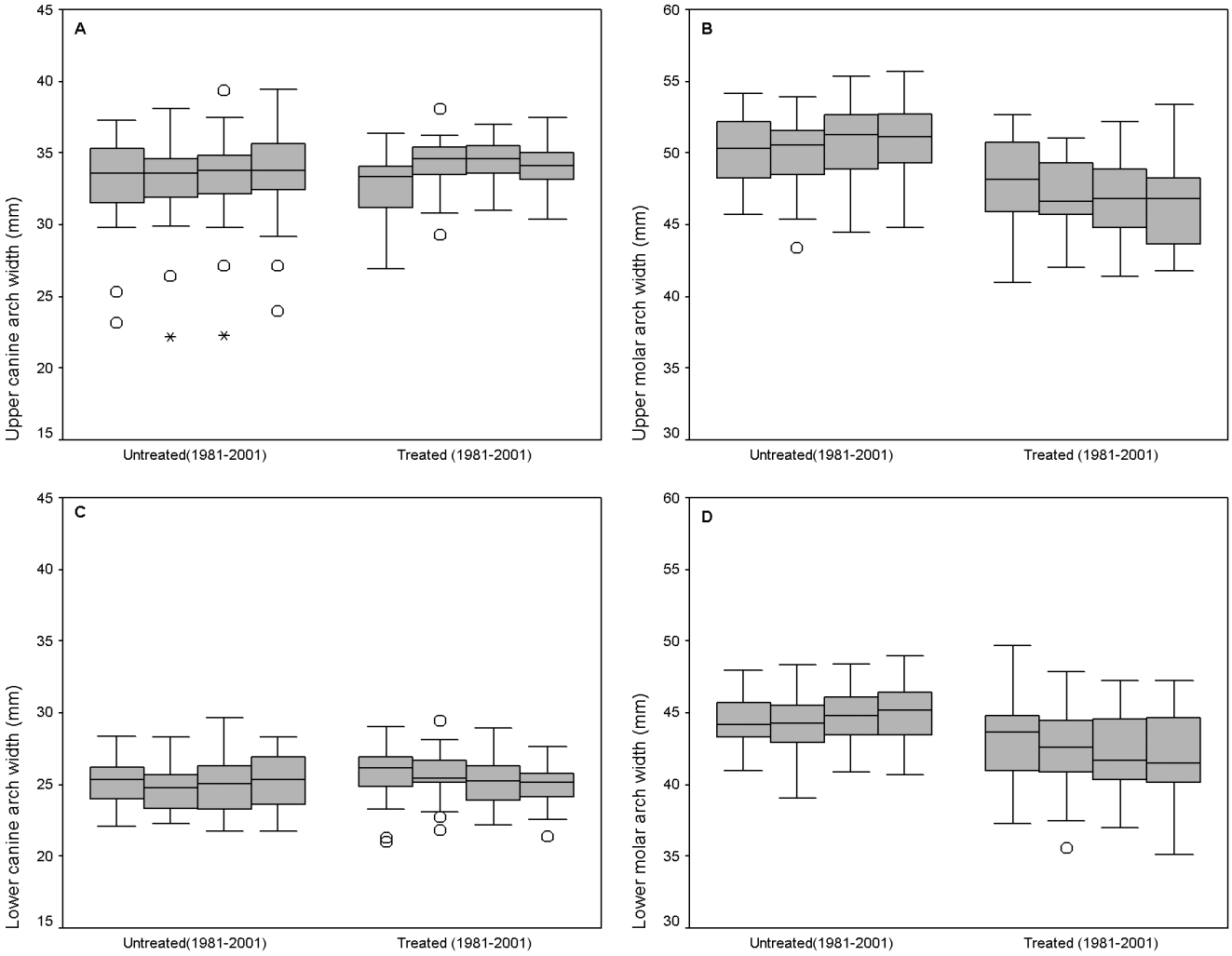

FIGURE 3. (A–D) Upper and lower canine and molar boxplots of arch width for treated and untreated groups, 1981–2001.

TABLE 4. Summary of Repeated Measures ANOVA Models for Orthodontically Treated and Untreated Groups[a]

	Treatment vs Nontreatment: Arch Width Difference *P* Values		
Arch Width	Unadjusted	Adjusted for Extraction Status	Adjusted for Sex
Upper canine	.045	.685	.049
Upper molar	.255	.452	.327
Lower canine	.011	.267	.019
Lower molar	.060	.190	.087

[a] ANOVA indicates analysis of variance.

TABLE 5. Summary of Repeated Measures ANOVA Model for Appliance Type in the Orthodontically Treated Group Only[a]

Arch Width	Removable vs Fixed or Removable (or both) (Arch Width Difference *P* Values)
Upper canine	.518
Upper molar	.747
Lower canine	.568
Lower molar	.527

[a] ANOVA indicates analysis of variance.

treated and treated groups remained statistically significant after adjusting for sex. This indicates that sex does influence treatment differences.

Table 5 gives the results of the ANOVA for the comparison of appliance types within the treated group alone. No statistically significant differences in arch width over time between appliance types were observed.

DISCUSSION

In this study, when comparing end and start points of treatment, all treated interarch widths demonstrated a significant reduction in width except the upper canine, which significantly increased. The untreated cas-

es all demonstrated an increase except lower molars, which demonstrated a small decrease (all nonsignificant). Using repeated measures ANOVA, we examined differences between treated and untreated patients regarding these changes in arch widths during the study. Maxillary intercanine widths increased to a significantly greater extent in the treated group, and mandibular intercanine widths decreased to a significantly greater extent than in the untreated group. There were no significant differences in change over time in the maxillary or mandibular intermolar widths between treated and untreated groups.

Arch widths naturally change with age during adulthood, but the magnitude of changes can be small and variable amongst samples.[18] It is important when analyzing changes in arch width that we compare orthodontically treated patients with a representative sample of untreated individuals. In the untreated UMGS (University of Michigan Growth Series) and a similar Iowa growth study, the maxillary and mandibular intercanine widths decreased significantly.[19–21] This trend was observed for our mandibular results but not for our maxillary results. It may be argued that the current results appear to support the conclusions of Knott[22,23] and Moorrees and Chadha[24] that untreated intercanine width appears to remain relatively stable. Carter and McNamara[10] stated that any change in intercanine width of <0.50 mm between treated and untreated subjects over a 30-year period may be clinically insignificant. Although we did not have access to postretention time periods, on the basis of this hypothesis, it could be stated that our lower canine results (-0.76 mm difference) and upper canine results ($+1.46$ mm difference) were significant changes in this respect.

De La Cruz et al[9] carried out a study on 45 patients with Class I malocclusion and 42 Class II division 2 patients, all of whom had undergone four premolar extractions. Averaged interarch changes across the various malocclusions for both treated groups from 16 to 33 years produced results similar to this study. This included values for maxillary intercanine width when postretention factors were taken into consideration: 1.1 mm compared with our value of 1.46 mm. However, interpretation and direct comparison should be made with some caution because this study compared treatment ''with and without'' extractions with nontreatment and not just cases involving extractions.

Other studies also supported the current findings, demonstrating increases in maxillary canine width,[25,26] whereas Shapiro[11] and Glenn et al.[27] found decreases in mandibular canine width. Gardner and Chaconas,[13] however, published differing results, showing an increase in mandibular intercanine width of 0.51 mm during nonextraction treatment and 0.76 mm during extraction therapy. In these cases though, it was noted that expansion had a strong tendency to return to its original pretreatment width in both extraction and nonextraction cases. As always, different study techniques make these comparisons illustrative at most. The review article by Lee[7] demonstrates the differing degree of results in this area of orthodontic research.

For years, the use of extraction therapy in orthodontic treatment of malocclusions has been discussed with both the pro- and antiextraction groups arguing the case for their treatment plans. Some authors such as Bishara et al[2] have concluded that extraction groups and nonextraction groups show similar overall trends in some width parameters (intercanine) and different trends in other parameters (intermolar). Bishara et al[3] went on to conclude that the extraction/nonextraction decision on the basis of good diagnostic criteria does not have a detrimental effect on the facial profile.

More specifically, Lee[7] stated that extraction will reduce arch width and the inclusion of teeth, eg, by orthodontic inclusion of a previously excluded tooth, will increase arch length and leads to a potential increase in arch width. An article by Gardner and Chaconas[13] was cited in this respect in this review article. Burke et al,[5] however, concluded that mandibular intercanine width increased in the order of 0.8 to 2.0 mm regardless of whether the treatment was extraction or nonextraction. More recently, in 2003, Gianelly[6] reported mandibular intercanine dimension to be 0.94 mm larger in the extraction sample than the nonextraction sample. In this study, the results of the analysis adjusting for extraction were inconclusive and require further study.

Although a large quantity of the literature has contributed to the extraction debate, a lesser amount of work has examined the effects of appliance type on arch width outcomes. McNamara and Brudon[28] argue the case for increasing arch size at a young age so skeletal, dental alveolar, and muscular adaptations can occur before the eruption of the permanent dentition. Appliances, if placed in an actively growing patient, may produce a widening of the dental arch. However, it can be difficult to ascertain the degree, if any, of the contribution of the appliance because normal growth is occurring concurrently. No statistically significant differences in profile were encountered when the two different orthodontic treatment regimes were used. Nevertheless, it is an interesting and relatively unexplored area of research that requires more investigation.

So what is responsible for the increase in upper intercanine width and the decrease in lower intercanine width in this study? One possible contributing factor is sex. A number of authors noted that changes in arch

width vary between males and females, with male arches reportedly having an increased width.[3,10,19] Including sex in the repeated measures ANOVA models did not change the findings of the study and no differential treatment differences were observed between males and females.

It is possible that other unaccounted factors may have influenced results such as the degree of crowding, amount of overjet, presence of displaced canines, and the variability in arch shape. Local factors and archwire type may also play a role. Other influential factors that may modify treatment outcome are variations in the archwire and the nature and length of retention. These factors may affect intercanine stability, but the specifics of treatment and retention were not known.

Considerable individual variation in archform occurring with normal growth and the high degree of variability observed in the postretention response to treatment changes make it difficult for the clinician to predict the consequences, if any, of altering or not altering the shape of the dental arch.[29] In addition, it is also important to consider that changes, although statistically significant, would be imperceptibly small on examination, and such a change is only detectable on measurement, not visual comparison.

CONCLUSIONS

- Orthodontic treatment caused an increase in the maxillary canine and a decrease in the mandibular canine widths.
- Appliance type did not have any differential effect on arch width changes.
- Sex had no significant influence on the results of the study.
- The effects of tooth extraction require further study.

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