Arch width and form: A review

Robert T. Lee, DOrth, MOrth, FDSRCS Eng, FDSRCPS Glasg
London, UK

A study of the literature reveals a variety of opinions on the potential for change in arch dimensions. The variations in sample sizes, treatment mechanics, and retention regimens may obscure relevant findings. These articles confirm some common findings, and a number of clinical cases are presented to illustrate these trends. It would seem that limited degrees of arch expansion can be produced regularly, but careful case selection is necessary. Arch expansion is most likely to be achieved in the growing patient with correction of crossbites, correction of a Class II malocclusion, and achievement of a good intercuspation without extractions. (Am J Orthod Dentofacial Orthop 1999;115:305-13)

The size and shape of the arches will have considerable implications in orthodontic diagnosis and treatment planning, affecting the space available, dental aesthetics, and stability of the dentition. These considerations, in association with anteroposterior movements of the dentition, will determine the requirements for extraction or otherwise.

In 1907, E H Angle[1] believed that each individual had the potential for normal growth and development with orthodontic therapy, stating that "The best balance, the best harmony, the best proportions of the mouth in its relation to the other features, requires that there shall be a full complement of teeth and that each tooth shall be made to occupy its normal position — normal growth."

In 1925, Lundstrom,[2] however, highlighted the need to consider the apical base in determining the occlusion: "Orthodontic experiments show that a normal occlusion attained by mechanical treatment is not necessarily accompanied by a development of the apical base in harmony with the position of the teeth, with the result that the occlusion obtained cannot be maintained."

In relation to arch shape, in 1955 Hawley[3] proposed a geometric method for predetermining the dental arches; the ideal arch was based on an equilateral triangle with a base representing the inter intercondylar width. The lower anterior teeth were arranged on the arc of a circle with a radius determined by the combined width of the lower incisors and canines, with the premolars and molars aligned with the second and third molars turned toward the center. Various authors have used different curved mathematical models since, but the stability of these arch forms has not been established.

Instability in arch wire changes can result in periodontal breakdown,[4] recurrence of crowding of the buccal segments, or increased crowding of the labial segments particularly where the lower intercanine width has been expanded. Bishara et al[5] examined 30 first premolar extraction cases that were on average 1.2 years out of retention. They reported that 71.4% of any expansion produced in the lower intercanine width resulted in relapse, with less likelihood of relapse of the upper.

Subsequently, Little et al[6] reported on the long-term follow-up of 65 cases with extraction of first premolars. The lower intercanine width had been increased by more than 1 mm during treatment in 60% of the cases but, after treatment, constriction in the intercanine width occurred in 60 of 65 cases, usually more than 2 mm.

There are clearly therefore a number of features in arch dimensional changes that should be considered in treatment planning.

NORMAL GROWTH AND DEVELOPMENT

Arch dimensions change with growth. It is therefore necessary to distinguish changes induced by appliance therapy from those that occur from natural growth.

Moorrees[7] has pointed out that considerable individual variation in arch form will occur with normal growth, with a general tendency toward an increase in the intermolar width during the changeover from the deciduous to the permanent dentition.

It is difficult therefore to predict the growth potential in individual patients, but information is available on the average changes in arch dimension in untreated samples. The average changes achieved in a sample reported by Moyers et al[8] are shown in Tables I and II.

[a]Director of Orthodontics, Royal London Hospital, London, UK
Reprint requests to: Mr R. T. Lee, Consultant Orthodontist, Orthodontic Department, The Dental Institute, The Royal Hospitals NHS Trust, New Road, Whitechapel, London, E1 1BB, United Kingdom

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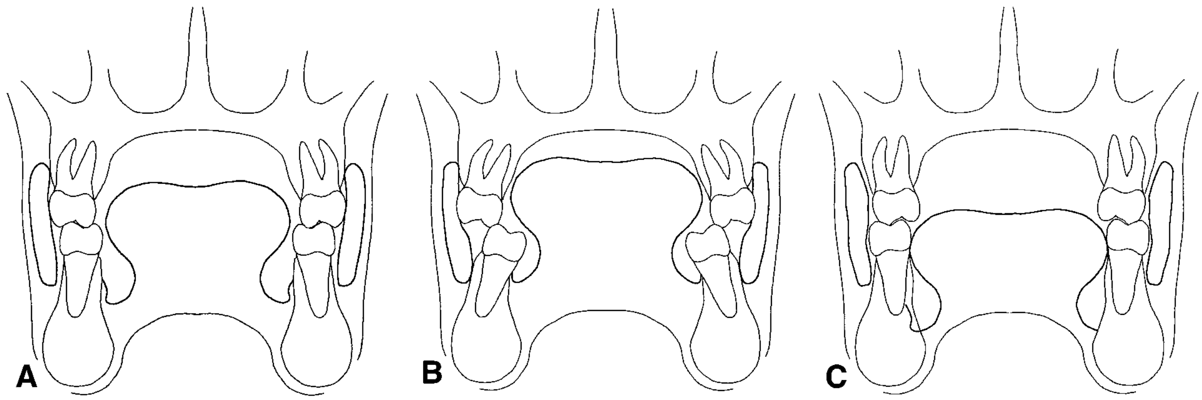

Fig 1. A, Diagrammatic representation of buccal dentition, cheeks, and tongue in the coronal plane. **B**, Scissorbite results in a different spatial relationship of teeth buccolingually associated with a requirement for the tongue adopting a higher position in the coronal dimension and the cheek position unaltered. **C**, Crossbite of the upper buccal teeth will be associated with a downward displacement of the tongue.

It is apparent that changes in arch width vary between males and females and that more growth in width occurs in the upper than the lower arch; this growth occurs mainly between the ages of 7 and 12 years of age and is approximately 2 mm in the lower arch and 3 mm in the upper. After the age of 12, growth in arch width is seen only in males.[9,10]

Sillman[11] looked at 65 normal white children from birth to over 25 years of age, including those with malocclusions, and found a progressive increase in arch width especially in males. Sinclair et al[12] have confirmed that the increase in molar width after the age of 12 is statistically different in males and females, without an increase in arch length or perimeter. Arch width continues to increase to a lesser extent in the third and fourth decades, but this is associated with arch length shortening.[13]

It seems therefore that:

- Male arches grow wider than female arches.
- The lower intercanine width increases significantly in the changeover dentition but does not increase in the permanent dentition after 12 years of age.
- The upper and lower intermolar widths increase spontaneously to a considerable extent between ages of 7 and 18 especially in males.
- Little change in arch width occurs in the premolar region after the age of 12.
- Changes in arch width may not be accompanied by changes in arch length; there is a tendency toward a decrease in arch depth in the third and fourth decades.

APPLIANCE-INDUCED GROWTH

A number of clinicians favor orthodontic treatment in the deciduous or early permanent dentition to try and induce growth. It is difficult to determine the contribution of appliances, as a normal growth change would be expected for each individual. McNamara and Brudon[14] state that "It seems logical to consider increasing arch size at a young age so that skeletal, dental alveolar, and muscular adaptations can occur before the eruption of the permanent dentition." If an appliance is inserted in an actively growing patient, a favorable response can be expected. However this response may have occurred in the absence of treatment, the relative contribution of the appliance being difficult to determine.

An earlier article by Spillane and McNamara[15] examined the records of those patients in the Michigan study who presented with narrow arch forms and compared them with the average in the sample. In the untreated sample of 74 cases aged 7 to 15 years, the average increase in transpalatal width between the upper first molars was 2.6 mm; in the narrow arch group, growth was 3.3 mm. The implication is that those with initially narrow arch forms tend to become more average, and appliance therapy is therefore more likely to achieve a stable change.

Individual clinical cases with considerable arch width change greater than would be expected with normal growth may have other factors contributing. The routine expansion of both arches in the permanent dentition has not been shown to produce stable change in arch dimension that is significantly greater than that which would have been achieved through normal growth.

CORRECTION OF CROSSBITES

The relevance of soft tissue balance and muscle forces on the facial and lingual sides of the teeth was well recognized by Angle[1] and others.

In some cases, however, it may be that the balance of forces on the dentition can be maintained while achieving significant dental movements without upsetting this equi-

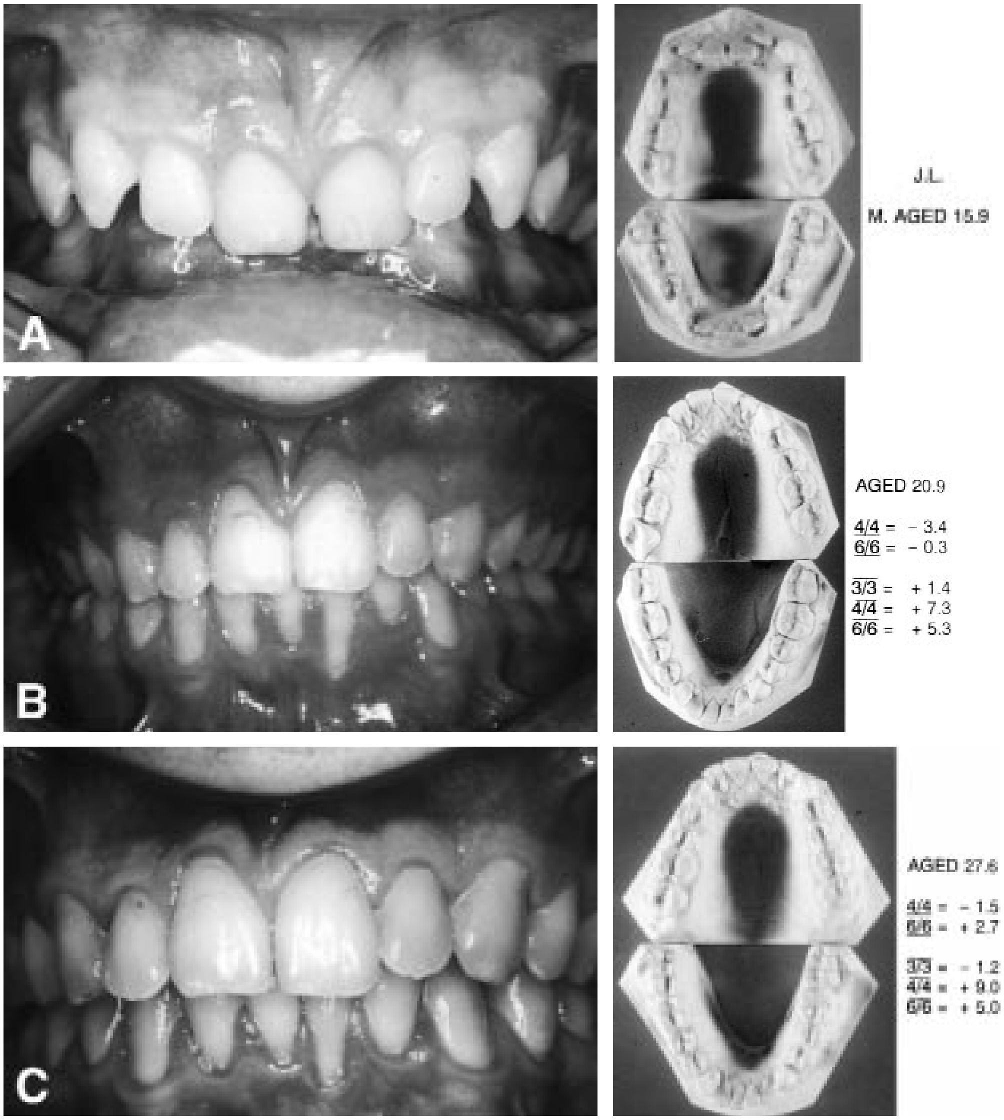

Fig 2. A, Deep overbite and scissorbite pretreatment. **B**, Corrected occlusion at the end of retention. **C**, Occlusion 6.7 years out of retention; overall changes in arch dimensions are shown.

librium. Selwyn-Barnett[16] hypothesized that the lower dentition can be induced to occupy space previously occupied by the upper incisors in Class II Division 2 cases without encroaching on the lips. It could be postulated similarly that correction of a crossbite with expansion of one arch and contraction of the other could be achieved without encroaching on the lips and cheeks (Fig 1).

An occlusion with a scissorbite will occupy a wider buccolingual space than a normal one, and a potential exists for the space of the upper dentition to be transferred to the lower dentition. Such a transfer would be more likely to occur in a growing individual where the vertical tooth movements required can be more readily achieved.

An example of such a case is shown in Fig 2. The correction of the scissorbite on the premolars has allowed stable expansion of the lower posterior teeth despite the recurrence of lower incisor crowding. An individual case report does not provide scientific evidence, but degrees of crossbite correction are regularly attained in orthodontic therapy, and these in turn allow satisfactory intercuspation of teeth with the associated functional benefits.

The interaction of all three planes of space is such that correction of crossbites will frequently be associated with anteroposterior movement of the arches.

ANTEROPOSTERIOR MOVEMENTS

Arch width changes must not be considered in isolation, and the interdependence of the arches has significant implications in arch width.

Because of the divergent shape of the dental arches

Table I. Mean changes (mms) in arch width in the mandible

Author	*Sample*	*No*	*Time (in years) (PR)*	*C|C, 3|3*	*D|D, 4|4*	*E|E, 5|5*	*6|6*
Moyers et al 1976	Males/untreated	Min 16	7-12	+1.78	+3.22	+1.26	+1.88
	Males/untreated	Min 11	12-18	–0.33	+0.31	+0.61	+0.88
	Females/untreated	Min 14	7-12	+1.84	+2.73	+2.99	+1.86
	Females/untreated	Min 5	12-18	–1.73	–0.69	–1.16	–0.12
Bishara et al 1973	11 Extractions/males		1.2 (PR)	+0.2	—	—	—
	19 Extractions/females						
Shapiro 1974	22 Nonextraction		10+ (PR)	–0.7	—	—	+1.0
	58 Extraction			–0.3	—	—	–2.1
Gardner et al 1976	74 Nonextraction		5.2	+0.51	+2.47	+1.24	+1.98
	29 Extraction		5.3 (PR)	+0.76		–2.95	–1.49
Mew 1983	16 Nonextraction		2.5 (PR)	—	—	—	+1.3
	Upper expansion						
Glenn et al 1987	14 Class I nonextraction		7.9 (PR)	–0.5	—	—	–0.3
	14 Class II nonextraction			–0.2		—	+1.1
Hine 1990	11 Nonextraction		4.4 (PR)	+1.25	+4.35	+2.30	+2.05
	Functional						
Tang 1991	15 Nonextraction		1+ (PR)	–0.12	+1.21	+0.93	`+0.24
	31 Extraction prospective		1+ (PR)	–0.08	+1.63	–1.78	–2.45
Sadowsky et al 1994	22 Nonextraction		6.3 (PR)	+1.2	+1.6	+1.5	+2.9
Elms et al 1996	42 Nonextraction		6.5 (PR)	–0.1	—	—	+1.6
	Class II Division 1						
Moussa et al 1995	55 Nonextraction RME		8.0 (PR)	+0.4	—	—	+2.5

PR, Postretention.
RME, Rapid maxillary expansion.

Table II. Mean changes (mms) in arch width in the maxilla

Author	*Sample*	*No*	*Time (years) (PR)*	*C|C, 3|3*	*D|D, 4|4*	*E|E, 5|5*	*6|6*
Moyers et al 1976	Males	Min 10	7-12	+3.84	+2.66	+3.08	+2.97
	Males	Min 10	12-18	–0.17	+1.00	–0.60	+1.35
	Females	Min 9	7-12	+3.53	+2.81	+3.13	+3.10
	Females	Min 6	12-18	–0.34	–0.47	–1.27	–0.70
Bishara et al 1973	30 Extraction edgewise		1.2 (PR)	+2.4	—	—	—
Mew 1983	22 Nonextraction Removable		2.3 (PR)	—	—	—	+3.37
Sadowsky et al 1994	22 Nonextraction Edgewise		6.3 (PR)	+2.9	+2.7	+4.0	+4.5
Elms et al 1996	42 Nonextraction Edgewise		6.5 (PR)	+1.5	—	—	+3.0
Moussa et al 1995	55 Nonextraction RME		8.0 (PR)	+2.7	—	—	+5.6

anteroposteriorly, movements of a whole arch require modification to the arch width to accommodate the opposing arch. This is most frequently seen in distal movement of the upper arch or forward movement of the lower arch; the upper arch is expanded in either case to accommodate the lower arch. It is possible that some of the upper arch expansion achieved could be maintained also in the lower arch.

A long-term study by Sadowsky et al[17] of 22 cases over 6.3 years after nonextraction treatment reported a mean expansion of 2.7 mm between the upper first premolars and 4.5 mm between the upper molars. This was accompanied by a lesser expansion in the lower arch of the premolars and molars by 1.6 mm and 2.9 mm, respectively. The mechanics used were conventional edgewise orthodontics with distal movement of both upper and lower arches using headgear and Class III traction. The majority of cases originally presented with a Class II malocclusion (Tables I and II).

Similarly, Elms et al[18] evaluated a sample of 42 patients with Class II Division 1 malocclusions that were on average 6.5 years postretention and in which the nonextraction treatment goals had been achieved with edgewise therapy and cervical facebows. The findings were similar to those of Sadowsky et al[17] in this nonextraction sample, with the upper molars maintaining an expansion of 3.0 mm, the lower molars an expansion of 1.6 mm, and the lower cuspids unchanged (Tables I and II).

An article by Glenn et al[19] contrasted the effects of nonextraction treatment in 14 Class I and 14 Class II cases

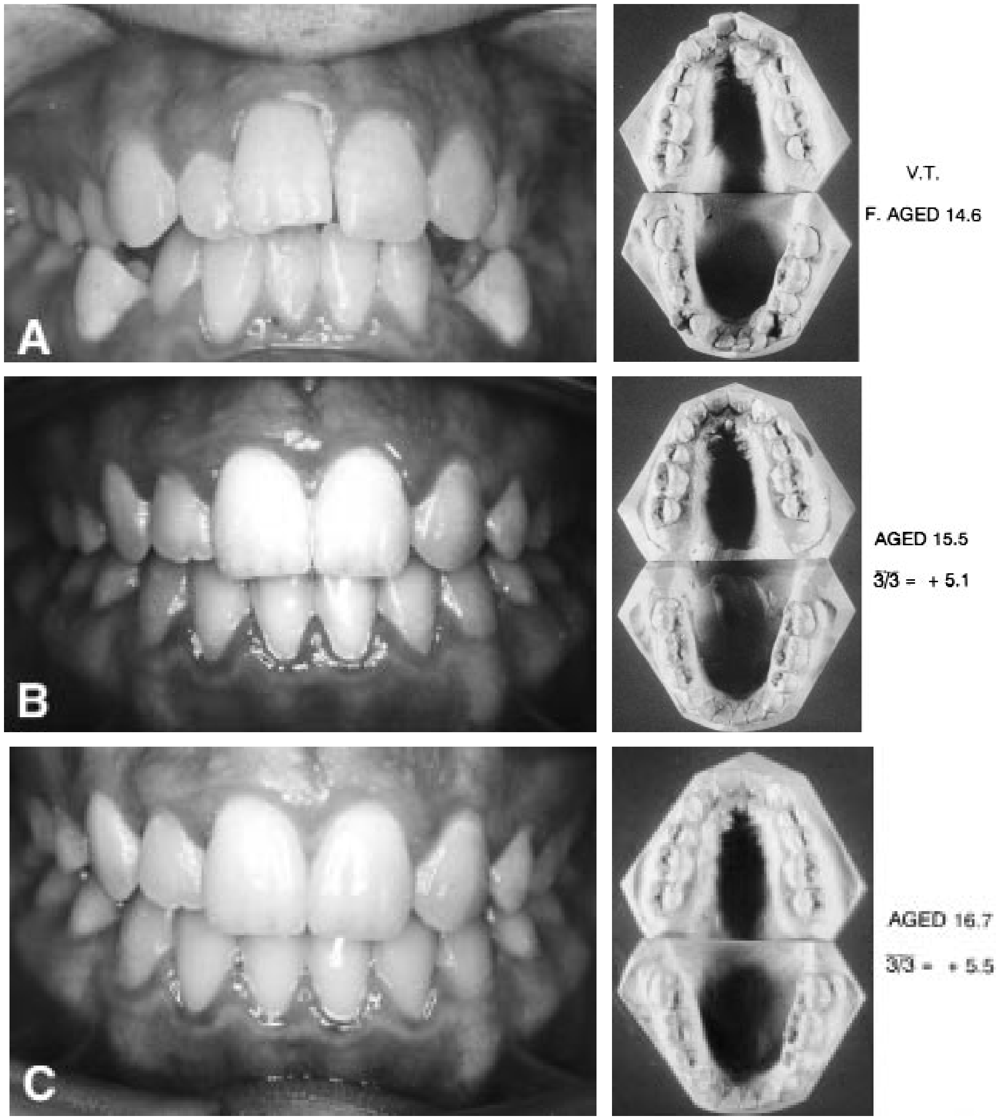

Fig 3. A, Pretreatment occlusion with instanding 3/-\3. **B**, Occlusion at the end of retention. **C**, Occlusion 1.2 years out of retention.

at least 3 years out of retention. In both groups, the intercanine width relapsed to its pretreatment value; only the Class II sample showed a stable expansion in the intermolar width—effectively a 1 mm expansion of the lower first molars (Tables I and II). Similar findings have been reported by Bishara et al[20] in nonextraction cases only.

Mew[21] reported on the use of expansion techniques with removable appliances in a group of 25 cases, 22 of whom were out of retention and 18 of whom were Class II malocclusions. The average age of the group was 11.8 years before nonextraction treatment, had an average retention of 2 years length, and were 18.8 years of age at final assessment. The upper intermolar width showed an average expansion of 3.44 mm, the lower an increase of 1.3 mm (Tables I and II). As these changes occurred over a considerable time period, normal growth would undoubtedly have been a contributor to them; the relative anteroposterior movements of the arches is likely also to have had an effect.

A study[22] of 11 patients treated nonextraction with the Frankel appliance and on average over 4 years out of retention showed that a degree of expansion was maintained in the lower arch. The gains were 1.25 mm, 4.35 mm, 2.30 mm, and 2.55 mm for 3|3, 4|4, 5|5, and 6|6, respectively, although the arch length tended to reduce.

Moussa et al[23] considered the effects of rapid maxillary expansion and nonextraction edgewise therapy in a mixed sample of malocclusions of 55 patients on average 6 years out of retention. An average expansion of 2.7 mm and 4.6 mm for the upper canines and molars was main-

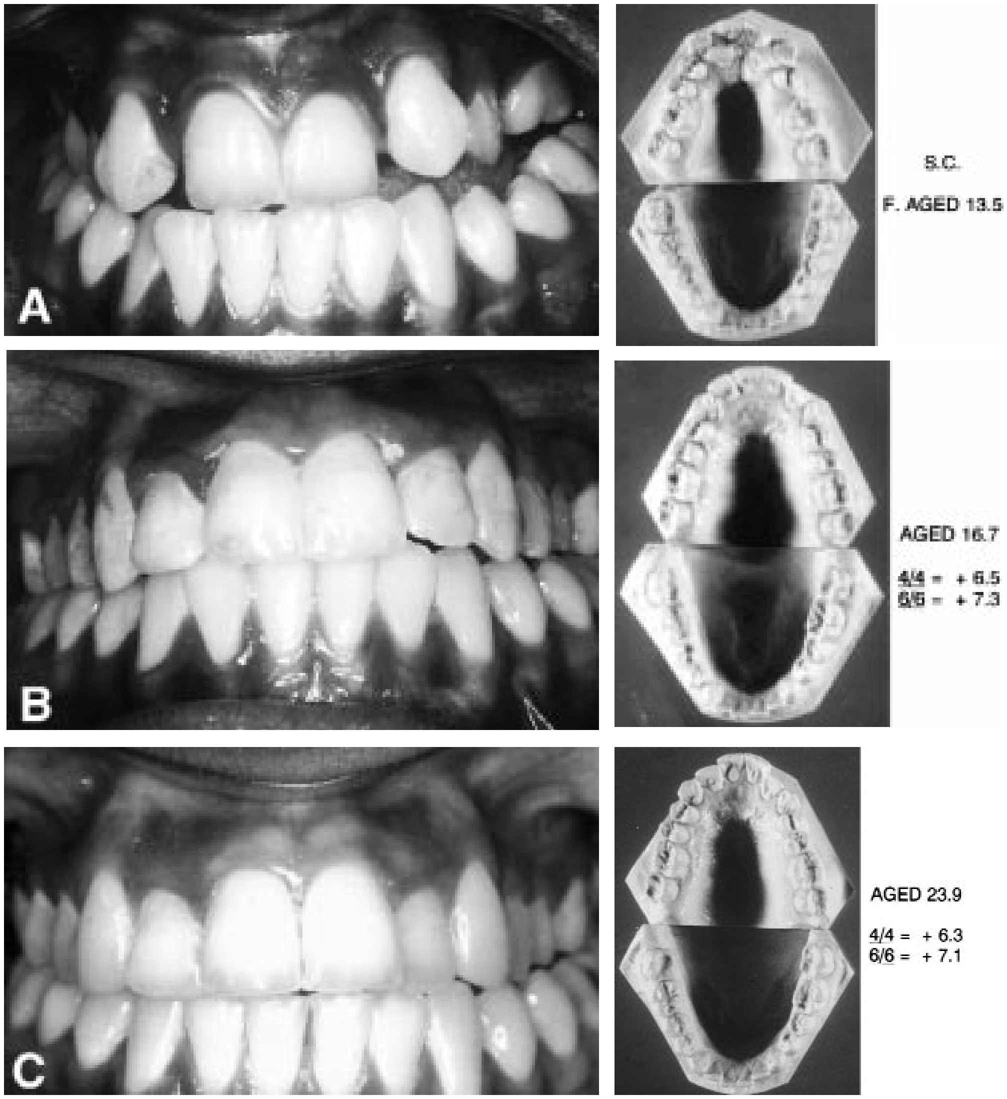

Fig 4. A, Pretreatment occlusion. **B**, Occlusion at end of retenion. **C**, Occlusion 7.2 years out of retention.

tained, with 0.4 mm and 2.5 mm maintained for the lower canines and molars (Tables I and II).

It would seem that in the correction of Class II malocclusion, approximately 3 mm stable upper molar expansion can be achieved; the lower molar equivalent would be around 1 mm beyond that which might have been expected with growth. The degree of expansion achieved will be affected by the type of malocclusion.

LOCAL FACTORS

Although the lower intercanine width in general will not withstand expansion, inevitably individual cases will exist where expansion can be maintained. In extraction cases, there is generally associated crowding with the canines frequently being buccally displaced. Retraction of these canines into extraction sites is not generally associated with stable expansion; their buccal position is likely to have been induced by crowding and their retraction into the space of the first premolars does not seem to allow for stable expansion.

Inevitably, however, cases exist where the canine is lingually displaced in association with crowding. In these cases, relief of crowding with expansion of the intercanine width may reasonably be expected once the crowding has been relieved and the local factor of the wedging of the canine teeth lingually has been eliminated. An example of such a case is shown in Fig 3.

Shapiro[24] noticed a difference in the varying malocclusions, his Class II Division 2 sample showed potential for slight increase in the lower intercanine width. This factor is likely to be related to the intrusion of the upper incisors and canines described by Selwyn-

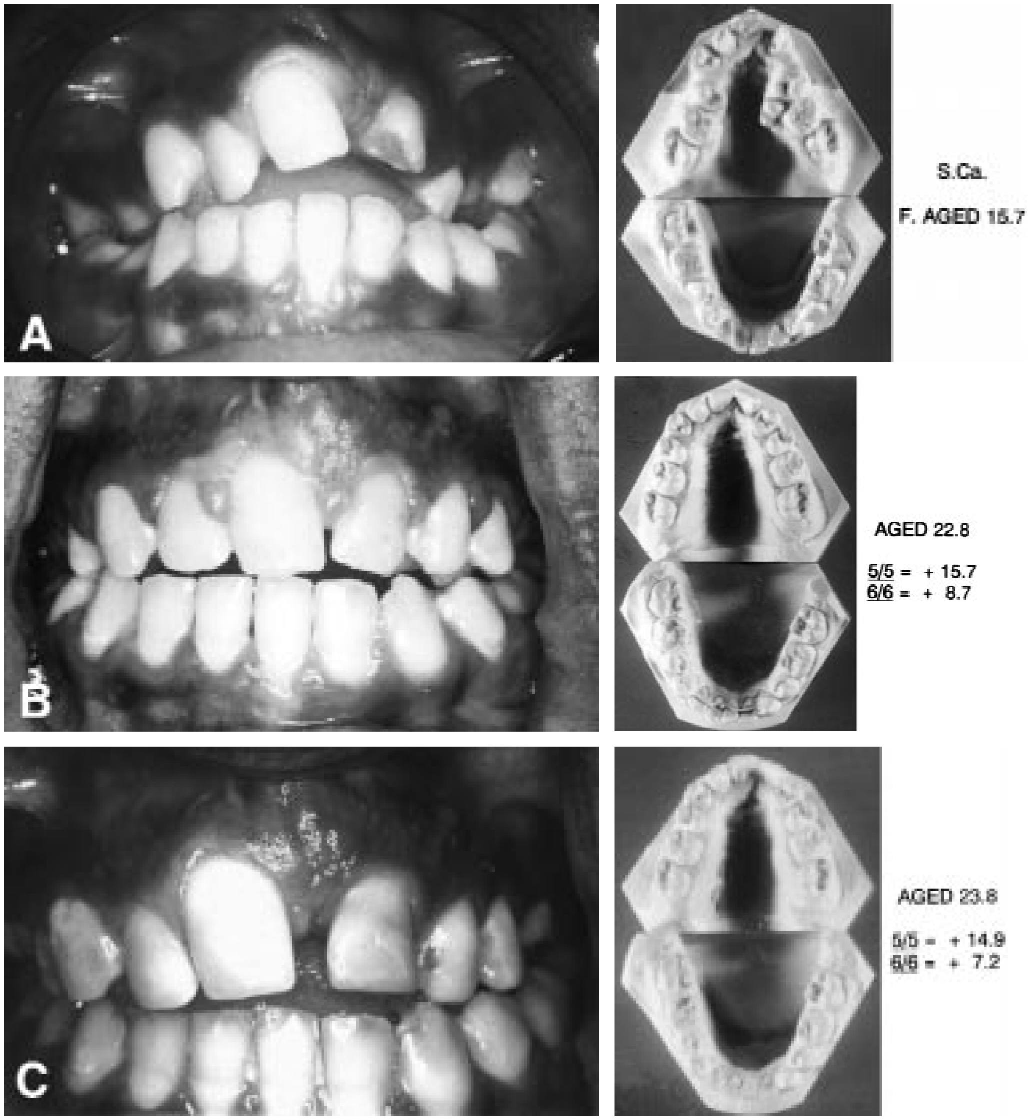

Fig 5. A, Pretreatment occlusion; patient is missing /*13*. **B**, Occlusion at end of retention. **C**, Occlusion 1 year out of retention.

Barnett,[16] the space occupied by 3|3 is vacated and made available for accommodation of expanded lower canines. This is another example of the interplay between two planes of space, in this case the vertical and transverse planes.

ADDITION OR EXTRACTION OF TEETH

The addition of teeth to be accommodated, either by prosthetic placement, transplantation, or orthodontic inclusion of a previously excluded tooth, will result in an increase in arch length and potential increase in arch width.

Conversely, extraction will reduce arch width. Thus, any expansion carried out in association with dental extractions is not generally likely to be a stable change. It is therefore essential to discriminate between extraction and nonextraction cases when assessing arch width and stability.

An article by Gardner and Chaconas[25] evaluated a sample of 70 Class II and 33 Class I cases; 74 were treated nonextraction and 28 with first premolars extractions. All cases were at least 1 year out of retention. Results show the various changes in arch dimension, in particular the nonextraction subsample showed a mean expansion of 2.47 mm in the lower first premolars with a lesser expansion of 1.24 mm in the second premolars and 1.98 mm for the lower molar. A stable expansion of the molars might be expected in the Class II correction cases where an anteroposterior movement was likely to have occurred (Tables I and II).

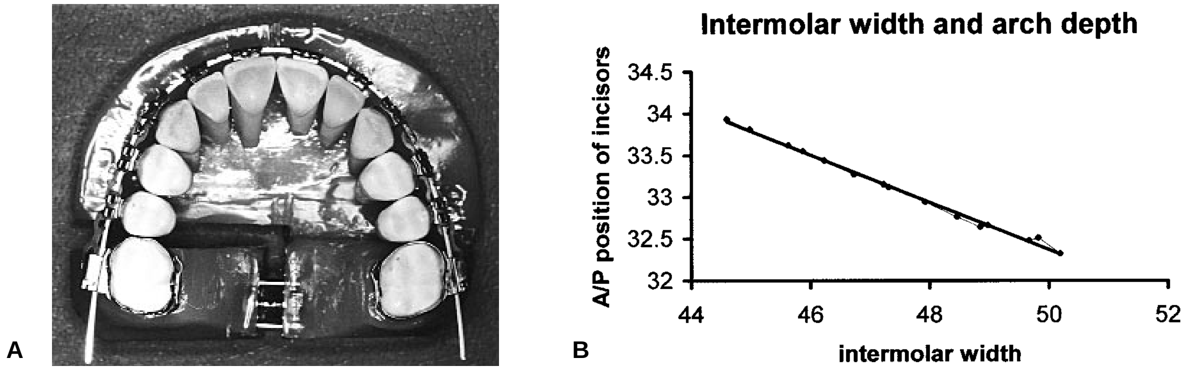

Fig 6. A, Model allows expansion of buccal segments while maintaining an intact arch. Arch depth anteroposteriorly is measured with a traveling microscope. **B**, Linear relationship exists between arch width and arch depth. Increase in arch width from 45.5 mm to 40.5 mm—a 4 mm expansion—is associated with a reduction in arch depth from 33.6 mm to 32.6 mm, equivalent to a 1 mm reduction in the overjet or approximately 1 mm on either side.

Extraction cases, however, showed a 2.95 mm reduction in the width of the second premolars as they moved forward and a similar reduction in the intermolar width of 1.49 mm. This was similarly highlighted by Shapiro[24] in a sample more than 10 years out of retention.

A prospective study[26] was carried out to consider changes achieved from treatment. The sample of 63 cases were all treated with identically shaped and sized arch wires regardless of the presenting arch form or extraction pattern. Twenty of these cases were treated without extraction, 26 with extraction of lower first premolars, and 17 with extraction of lower second premolars. The study found that the arch wires achieved full expression in archform in the lower anterior region and almost full expression in the posterior region. Forty-six of these cases were subsequently examined 1 year or more after removal of all retention appliances.[27] The mean changes were compared between extraction and nonextraction samples.

In the nonextraction sample, the arch wires were found to have little effect in the intercanine or intermolar width that were effectively unchanged and stable. Some expansion of the lower inter first premolar width was maintained, a mean of 1.21 mm, and the lower second premolar width was increased to a lesser extent, 0.93 mm.

In the extraction sample, the effect of the arch wires was to produce a small mean expansion in the intercanine width, which relapsed, and a contraction of the lower intermolar width, which remained stable.

It would seem therefore that expansion of the lower arch is likely to be stable only in the absence of extraction. Expansion of the lower arch is also more likely to be achieved when anteroposterior movement of the arches has been undertaken, with a potential for even greater expansion in the upper arch.

An example of a case in which teeth that had been excluded from the arch and were subsequently accommodated is shown in Fig 4. This expansion is likely to be significantly influenced by the intercuspation of teeth, the lower arch in this case being untreated.

ALTERED MUSCLE FUNCTION

The dentition is established in a position of balance between the muscles of the lips and cheeks and the pressures of the tongue. Although the forces are not equivalent,[28] the general effect of intermittent forces by the tongue and resting forces of the cheeks are likely to result in the final positioning of the teeth. It is unlikely that the lips and cheeks can be encroached on to a significant extent,[29] whereas the rest position of the tongue is potentially variable, with ready adaptation vertically and anteroposteriorly as seen when tooth loss occurs. Therefore the objective of orthodontic treatment might reasonably be to limit encroachment on the space occupied by the lips and cheeks. It is possible to limit such encroachment with redistribution of the dentition in space, utilizing space created in one arch for the accommodation of teeth from the opponent arch.

A diagrammatic representation of redistribution of space is shown in Fig 1. The dimensions of the teeth, cheeks, and tongue are equivalent in all cases; the dentition is effectively expanded in one arch while the other is contracted. The space occupied at the occlusal level is virtually unchanged.

This mechanism is particularly helpful in the treatment of many cases of patients presenting with an underlying skeletal III pattern, where upper arch expansion can be achieved with concurrent contraction of the lower, thereby allowing a normal functional relationship of the arches buccolingually. It could be presumed that upper arch expansion allows a higher position of the tongue, the space vacated by the tongue allowing lower arch contraction.

An unusual case with a narrow upper arch and severe crowding is shown in Fig 5. In this case the patient does not have an intact arch and the teeth fail to intercuspate after treatment. Nevertheless, considerable upper expansion has been maintained. The assumption must be that the increased upper arch width is maintained by the tongue adopting a new resting position within the upper arch in space which had not been available before treatment.

CLINICAL MANAGEMENT

Space Considerations

Expansion of the arches creates space, and an assessment of this space is critical. Overall arch expansion of the type achieved by splitting the midpalatal suture with a rapid expansion appliance screw would produce space equivalent to the amount of expansion achieved. In clinical practice, however, arch expansion usually is achieved unevenly throughout the arch, generally maintaining intact contact areas. A model was constructed to examine the relationship between arch width and depth. The posterior teeth were linked by an expansion screw whereas the anterior teeth were attached only by an arch wire. As the posterior width was increased, the spacing in the arch was closed to ensure intact contact areas were maintained (Fig 6). Arch width and depth were recorded with a traveling microscope measuring along the contact areas. The posterior segments were expanded more than the anterior segments, and the space created was expressed as incisor retraction, the space being proportionate to the degree of expansion but not in a one to one relationship. It is seen that 3 mm of posterior expansion results in 1 mm reduction of arch depth. Therefore a millimeter space is available on either side in association with 3 mm posterior expansion. This will vary depending on the initial shape of the arch and the morphology of the teeth.

CONCLUSIONS

1. The use of expansion can be considered applicable in the growing child. However, it is difficult to predict the degree to which this would have occurred from natural growth in any individual. There is no evidence that appliances can stimulate "growth" beyond that which would occur normally.
2. The presence of crossbites will affect the space available within the arches. The correction of such crossbites is generally achievable by a combination of arch expansion and contraction, intercuspation of teeth, and potential alteration in the vertical resting position of the tongue.
3. Arch expansion is more likely to be stable in the absence of extractions and is most effective in the posterior region. There is unlikely to be stable expansion of the lower intercanine width unless the canines are displaced lingually by the occlusion.
4. Expansion of the arches posteriorly can be achieved more readily where anteroposterior movement of the arches also takes place. An upper arch moved distally is likely to accommodate expansion and, in conjunction with this, some expansion of the lower arch may be achieved to a lesser extent.
5. Each individual should be assessed to identify any factors that might allow expansion either of the whole arch or of individual teeth. However, the space gain may be less than expected, with expansion posteriorly allowing a decrease in the arch depth of approximately one third the amount of expansion achieved.

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