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Lower arch crowding in the third decade

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SUMMARY Lower arch crowding and dimensions were measured on study models of 46 untreated subjects, 20 male and 26 female, at age 18 years (T1), 21 years (T2), and 28 years (T3), and the changes during the observation periods calculated. Only very small changes, few of them detectable clinically, were found. The findings are discussed in relation to the changes reported in untreated subjects in other age groups and in orthodontically-treated subjects after retention.

Introduction

It is recognized that the human dentition is in a dynamic state, continually changing throughout life. Particularly noticeable in this respect is the change in alignment of the lower arch which may be crowded in the early mixed dentition, less so in the years between 8 and 12, and become more crowded after eruption of the second permanent molars, a process which is said to continue well into the third decade and beyond (Little, 1990). The cause of this late increase in crowding is obscured by its multifactorial nature. There are many factors acting singly or together, in different individuals, at different stages of development which may be implicated. Physiological mesial drift, the anterior component of the force of occlusion, mesial vectors of muscular contraction, a developing third molar, the amount and direction of late mandibular growth, skeletal structure and complex growth patterns, soft tissue maturation, occlusal changes, tooth morphology, periodontal forces, direction of eruption and degenerative tissue changes may be involved (Richardson, 1989, 1994b; Vasir and Robinson, 1991).

It is important to chart the progress of the crowding process to ascertain whether it is a continuous, gradual, slowly diminishing change, or whether it occurs rapidly at certain stages interspersed with periods of relative stability. Such information may have a bearing upon its aetiology.

In the untreated arch an increase in crowding between the ages of 12–13 and 17–18 years is well documented (Siatowski, 1974; Sakuda *et al.*, 1976; Moorrees *et al.*, 1979; Richardson, 1979; Sampson *et al.*, 1983). Other investigators have reported an increase in crowding between 12 and 21 years (Brown and Daugaard-Jensen, 1951), 9–19, and 23–32 years (Lundström, 1969), 11 and 25 years (Humerfelt and Slagsvold, 1972), 13 and 20 years (Sinclair and Little, 1983), 14 and 27 years (Meng *et al.*, 1985), 13 and 26 years (Bishara *et al.*, 1989), and 13 and 31 years (Persson *et al.*, 1989). Since no intermediate examinations were made in those studies it is not clear whether the crowding developed in the years immediately following second molar eruption or continued to increase up to the later age.

Information on changes in lower arch alignment in untreated subjects after the age of 18 years is sparse. Several studies have reported cephalometric changes in various dimensions of the face and jaws in adult life (Thompson and Kendrick, 1964; Forsberg, 1979; Sarnäs and Solow, 1980; Behrents, 1985; Lewis and Roche, 1988; Bishara *et al.*, 1994; Bondevik, 1995). Of these only Bishara *et al.* (1994) have included model analysis. They found increases in anterior lower arch crowding (0.57 mm in 15 females, 0.90 mm in 15 males) between 25 and 46 years, and in total lower arch crowding (0.65 mm in females, 0.94 mm in males).

Duterloo (1991) found dimensional arch changes on study models of 26 subjects between the mean ages of 17–28 years. Basic statistics were not calculated, but the changes were graded according to amount. The changes were, for the most part, small with none exceeding 1.5 mm and few reaching that level. In some cases the dimensions increased. Crowding was not measured but the illustrations showed slight crowding increases in three cases. The sample included some subjects younger than 17 years, with the starting age ranging from 14 to 18 years.

Richardson (1992) noted relative stability of lower arch alignment between the ages of 18 and 21 years, and clinically significant mean increases in total lower arch crowding in 11 men (1.1 mm), and five women (0.9 mm) between 18 and 50 years (Richardson, 1995).

In orthodontically-treated subjects a variable and unpredictable deterioration in lower arch alignment from 1 to 20 years after retention has been widely reported following various treatment regimes, both extraction and non-extraction (Stackler, 1958; Fastlich, 1970; Lombardi, 1972; Kaplan, 1974; Johnson, 1977; Little *et al.*, 1981, 1988, 1990a,b; Sadowsky and Sakols, 1982; Uhde *et al.*, 1983; Shields *et al.*, 1985; Glenn *et al.*, 1987; Little and Riedel, 1989; Persson *et al.*, 1989; Ades *et al.*, 1990; Kuitert and Prahl-Andersen, 1990; McReynolds and Little, 1991; Paquette *et al.*, 1992; Freeman, 1994; Sadowsky *et al.*, 1994; Dugoni *et al.*, 1995; Franklin *et al.*, 1995; Kahl-Nieke *et al.*, 1995; Moussa *et al.*, 1995; Årtun *et al.*, 1996).

It is often claimed that this is due to the normal physiological process of maturation which is found in untreated subjects (Little, 1990; Bishara *et al.*, 1994). Nevertheless, it is not unreasonable to expect that teeth which have been moved orthodontically might be more susceptible to the pressures which cause arch length reduction and crowding.

It seems likely that increased crowding in later life in untreated subjects may be due to degenerative changes associated with ageing or periodontal disease resulting in weakening of the supporting structures of the teeth so that they are less resistant to pressures which they previously withstood (Richardson, 1995).

Orthodontic tooth movement may accelerate this process by causing root resorption and reduced alveolar bone levels which may not recover their pre-treatment status (Sjølien and Zachrisson, 1973; Zachrisson and Alnæs, 1974; Hollender *et al.*, 1980; Hamp *et al.*, 1982; Kennedy *et al.*, 1983; Polson and Reed, 1984; Sharpe *et al.*, 1987; Øgaard, 1988). Arch width reduction following increase during treatment, the amount and direction of tooth movement, the inter-incisal angle and the relationship of the incisors to the soft tissues at the end of treatment, and the natural tendency for teeth to return to their original positions may also contribute to post-retention crowding.

In order to understand the relationship between natural developmental changes and factors associated with orthodontic tooth movement in post-retention crowding it is important to clarify the changes in crowding in untreated subjects after the age of 18 years.

The purpose of the present investigation was to examine changes in lower arch dimensions and crowding in the adult dentition.

Subjects and methods

Twenty males and 26 females were examined and recorded with study models at age 18 (T1), 21 (T2) and 28 (T3) years. The sample included normal and near normal occlusions and a variety of malocclusions. None was treated orthodontically. All had intact lower arches anterior to and including second molars. Third molar status was variable and included congenitally missing, extracted, erupted, and impacted teeth.

Measurements

On models at T1, T2, and T3 the following measurements of the lower arches were made using a travelling microscope (Baker, London).

Space condition. Arch perimeter minus tooth size. In a well aligned arch with all the teeth in contact, arch perimeter was equal to total tooth size (Figure 1A). Where spaces occurred, these were added to the total tooth size to find the arch perimeter (Figure 1B). Where teeth were crowded the space between adjacent teeth was measured and substituted for the tooth size to calculate

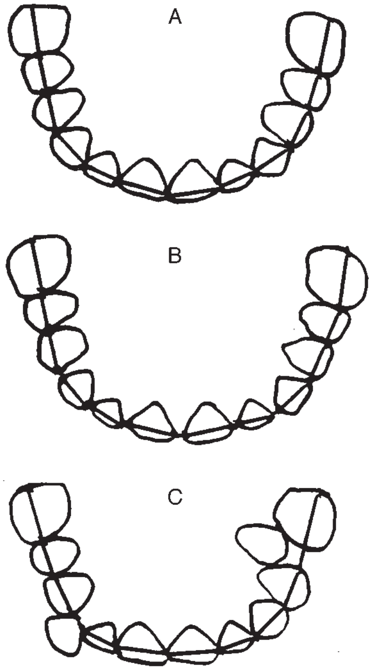

Figure 1 Measurement of space condition; arch perimeter minus total tooth size. (A) A well aligned arch, arch perimeter = sum of tooth widths = zero space condition. (B) Spaced arch = positive space condition. (C) Crowded arch = negative space condition.

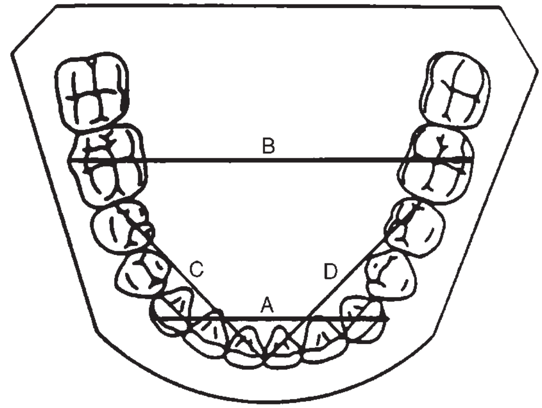

Figure 2 Measurement of arch dimensions. (A) Intercanine width. (B) Intermolar width. (C,D) Arch length.

arch perimeter (Figure 1C). Negative values indicated crowding (Richardson, 1965).

Inter-canine width. Between the widest points on the buccal surfaces of the canines (Figure 2).

Inter-molar width. Between the widest points on the buccal surfaces of the first molars (Figure 2).

Arch length. The sum of the distances from the mesial contact points of the left and right first molars to the mesial contact point of the central incisors measured diagonally (Figure 2).

The changes in measurements from T1–T2, T2–T3, and T1–T3 were calculated.

Negative values indicated an increase in crowding and a decrease in arch dimensions.

All measurements were made at least twice. If the difference exceeded 0.5 mm a third reading was made and the aberrant one discarded. The mean of the two closest measurements was used in the calculations. Means of the differences between replicate measurements were 0.04 mm for space condition, 0.20 mm for arch length, and 0.02 and 0.00 mm for intercanine and intermolar width, respectively. None were statistically significant when tested with the one sample *t*-test. Reliability coefficients (Houston, 1983) between pairs of measurements were 0.98 or 0.99.

Means and standard deviations for all measurements at T1, T2, and T3 were calculated for males and females and the pooled sample. The significance of the changes in measurements between T1 and T2, T2 and T3, and T1 and T3 was tested with the one sample *t*-test.

Differences in parameters and changes between males and females were tested with the independent samples *t*-test. Significance was set at the 5 per cent level.

Results

Means and standard deviations for lower dental arch parameters at T1 (18 years) and the changes from T1–T2 (18–21 years), T2–T3 (21–28 years), and T1–T3 (18–28 years) are shown in Table 1. At T1 there was no significant difference in space condition between males and females. Arch width and length dimensions were significantly larger in males.

From T1 to T2 there was a significant mean increase in crowding in the pooled sample (0.1 mm). Width dimensions did not change

Table 1 Means and standard deviations for lower dental arch parameters at T1 (18 years) and the changes from T1–T2 (18–21 years), T2–T3 (21–28 years), and T1–T3 (18–28 years).

	N	T1			T2–T1			T3–T2			T3–T1		
		Mean (mm)	SD	Range (mm)	Mean (mm)	SD	Range (mm)	Mean (mm)	SD	Range (mm)	Mean (mm)	SD	Range (mm)
Space cond.													
M	20	–0.6	2.6	–5.5, 6.6	–0.1	0.3	–0.8, 0.7	–0.2*	0.4	–1.2, 0.4	–0.3*	0.5	–1.3, 0.3
F	26	–1.3	1.8	–5.2, 2.5	–1.2	0.4	–1.3, 0.4	–0.2**	0.4	–1.4, 0.2	–0.4**	0.5	–1.6, 0.5
M + F	46	–1.0	2.2	–5.5, 6.6	–0.1*	0.4	–1.3, 0.7	–0.2***	0.4	–1.4, 0.4	–0.3***	0.5	–1.6, 0.5
M – F		0.7			–0.1			0.0			–0.1		
Arch width 3–3													
M	20	31.9	1.9	28.6, 37.1	–0.1	0.2	–0.6, 0.5	0.0	0.3	–0.6, 0.5	–0.1	0.4	–0.8, 1.0
F	26	30.5	1.7	26.5, 33.6	–0.1	0.2	–0.6, 0.4	0.0	0.3	–0.4, 0.5	0.0	0.3	–0.6, 0.7
M + F	46	31.1	1.9	28.6, 37.1	–0.1	0.2	–0.6, 0.5	0.0	0.3	–0.6, 0.5	0.0	0.3	–0.8, 1.0
M – F		1.4*			0.0			0.0			0.1		
Arch width 6–6													
M	20	56.4	3.2	51.1, 62.8	0.1	0.5	–0.6, 1.0	0.2*	0.4	–0.6, 1.2	0.3*	0.5	–0.6, 1.2
F	26	52.3	2.2	46.7, 56.8	–0.1	0.4	–0.4, 0.5	0.0	0.3	–0.5, 0.5	–0.1	0.5	–1.0, 0.8
M + F	46	54.0	3.4	46.7, 62.8	0.0	0.4	–0.6, 1.0	0.1	0.3	–0.6, 1.2	0.1	0.5	–1.0, 1.2
M – F		4.1***			–0.1			–0.2*			–0.4*		
Arch length													
M	20	60.3	2.7	56.5, 66.6	–0.2	0.5	–1.2, 1.1	–0.3*	0.7	–1.2, 1.5	–0.6**	0.7	–1.9, 0.9
F	26	57.1	3.1	48.6, 61.9	–0.2**	0.4	–1.0, 0.7	–0.5***	0.5	–1.7, 0.6	–0.7***	0.7	–2.0, 0.3
M + F	46	58.5	3.3	48.6, 66.6	–0.2**	0.5	–1.2, 1.1	–0.4***	0.6	–1.7, 1.5	–0.6***	0.7	–2.0, 0.9
M – F		3.1***			0.0			–0.2			–0.1		

T1, pre-treatment; T2, post-treatment (including retention); T3, post-retention.
**P* < 0.05; ***P* < 0.01; ****P* < 0.001.

significantly on average. Arch length decreased by 0.2 mm, significant in females and the pooled sample.

From T2 to T3 crowding increased significantly by approximately 0.2 mm in all groups. Arch width did not change significantly except for an increase in molar width, 0.2 mm in males. Arch length decreased significantly, 0.3 mm in males, 0.5 mm in females, and 0.4 mm in the pooled sample.

The cumulative changes from T1 to T3 resulted in significant increases in crowding of 0.3–0.4 mm, and in molar width in males (0.3 mm) and decreases in arch length of 0.6–0.7 mm. None of the changes differed significantly between males and females except for molar width.

Discussion

The increases in lower arch crowding, although statistically significant, were for the most part small, averaging at most 0.4 mm from T1 to T3 with a maximum increase of 1.6 mm. In only seven cases did the increase exceed 1.0 mm (Figure 3) and in two of these the negative change in space condition was due to space closure. Figure 4 shows models of a girl whose lower arch crowding increased by 0.6 mm from T1 to T2, and 0.7 mm from T2 to T3. The cumulative change from T1 to T3 is only just perceptible. Increases in crowding of less than 1.0 mm are scarcely visible to the naked eye and are of little clinical significance.

Considerably larger increases in crowding averaging approximately 2.0 mm and ranging up to 6.0 mm have been reported during a period of more active growth between the ages of 13 and 18 years (Richardson, 1979; Sampson *et al.*, 1983) and slightly greater increases (mean = 0.9 mm in males and 0.7 mm in females, ranging up to 2.0 mm) between 26 and 46 years (Bishara *et al.*, 1994) when degenerative changes may supervene.

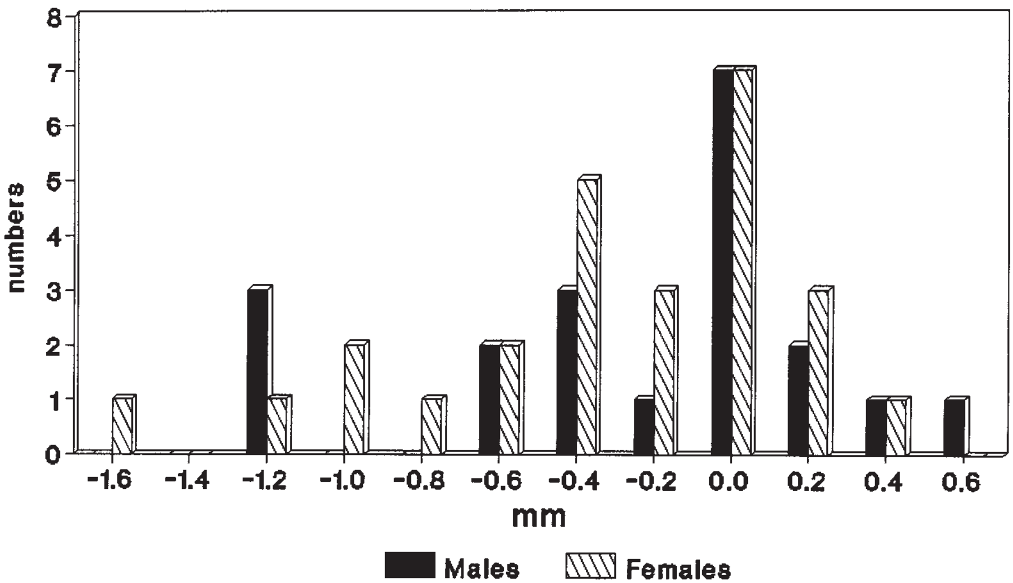

Figure 3 Histogram showing the distribution of the change in space condition between 18 and 28 years (T3 – T1).

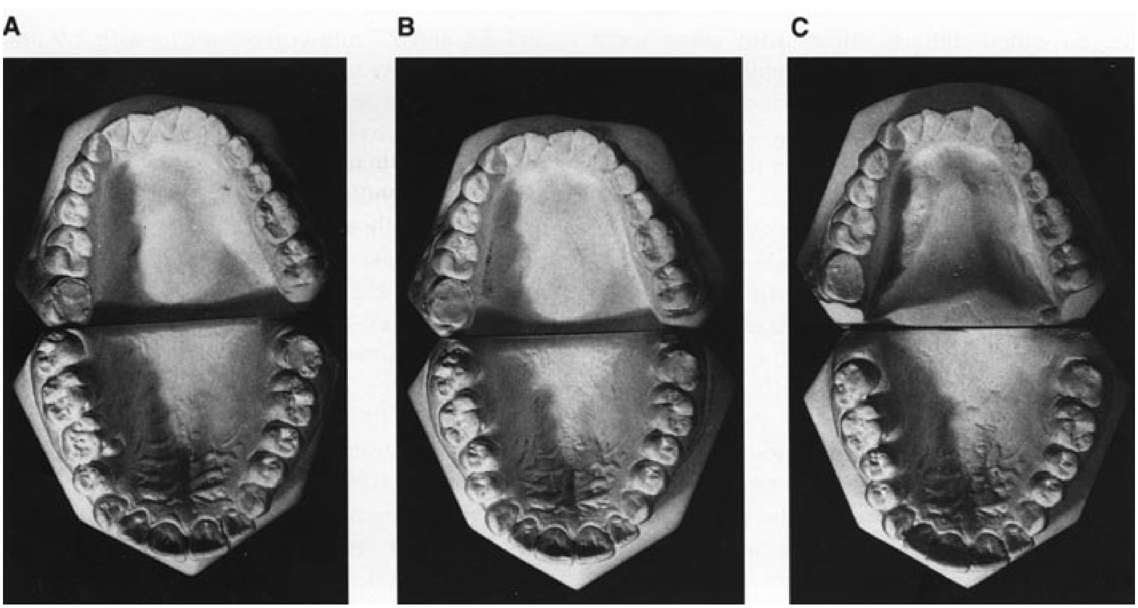

Figure 4 Models of a girl showing an increase of 0.6 mm in lower arch crowding from 18 years (A) to 21 years (B) and 0.7 mm from 21 years to 28 years (C).

Arch width changes were negligible and statistically non-significant with the exception of an increase in molar width in males (0.3 mm T1–T3) which is of little clinical significance.

On average, changes in arch width dimensions in untreated subjects after 12 years of age are small. Mean changes in inter-canine width between 12–13 and 18–26 years ranging from –0.7 to 0.2 mm have been reported (Brown and Daugaard-Jensen 1951; Richardson, 1979; Sampson *et al.*, 1983; Sinclair and Little, 1983; Bishara *et al.*, 1989), and between 26 and 45–46 years, Bishara *et al.* (1994, 1996, 1997) noted mean decreases of 0.4 mm in males and 0.6 mm in females. DeKock (1972) found a significant increase in molar width of 0.6 mm in males between 12 and 15 years.

Harris (1997) reported a surprisingly large 2.3 mm increase in molar width from 20 ± 2.8 to 54.3 ± 5.6 years, and suggested that it could be explained by the buccal component of occlusal force.

Duterloo (1991) noted both increases and decreases in canine and molar width dimensions between 17 and 29 years, which he attributed to the so called 'billard effect' with some teeth moving buccally and others lingually. Richardson (1994a) showed that increased incisor crowding could occur with either increase or decrease in inter-canine width depending on the direction in which the contacts slip.

The largest change in the present sample was in arch length with an average reduction of approximately 0.6 mm from T1 to T3. It is often claimed that arch length decreases with age in untreated subjects but different methods of measurement make comparison difficult. Sampson *et al.* (1983), using a similar method to the present study found a considerably greater decrease of approximately 2.0 mm between 13 and 18 years. The findings in the present investigation suggest that changes in lower arch alignment and dimensions in untreated subjects in the third decade of life are very small, and in most cases undetectable clinically, in contrast to the larger changes observed during the teenage years.

It is difficult to compare reported changes in lower arch alignment in untreated arches with those which have been treated orthodontically for several reasons. In the first place, the methods of measuring the changes in crowding differ. Most of the post-retention studies (Table 2) have used Little's Irregularity index (1975) to measure changes in alignment and average increases ranging from 0.8 mm (Moussa *et al.*, 1995) to 4.4 mm (Little *et al.*, 1988) have been reported. The incisor irregularity is calculated as the sum of the linear displacement of the anatomic contact points of each mandibular incisor from the anatomic contact point of the adjacent tooth. The irregularity index is not synonymous with the space condition (crowding). Puneky *et al.* (1984) found a significant correlation ($r = 0.84$, $P < 0.001$) between the irregularity index and the space condition (measured as in the present investigation), the irregularity index giving a higher reading than space condition and a mean irregularity index of 3.6 mm (SD 2.2) corresponding with an average crowding of 1.3 mm (SD 1.2). Increases in irregularity index of 2.0, 2.9, and 3.3 mm corresponded with increases in crowding of 1.0, 0.9, and 1.8 mm, respectively (Kuitert and Prahl-Andersen, 1990), and 2.4 and 2.7 mm corresponded with 1.9 and 2.0 mm (Freeman, 1994).

Of the post-retention studies measuring the change in space condition (Tables 3 and 4), Uhde *et al.* (1983) found post-retention increases in total arch crowding of 1.1 mm (SD 1.1) in non-extraction cases and 1.3 mm (SD 1.0) in extraction cases, while Kahl-Nieke *et al.* (1995) found much larger increases of 3.9 mm (SD 2.6) in non-extraction cases and 5.0 mm (SD 3.4) in extraction cases. Kuitert and Prahl-Andersen (1990) found increases in anterior crowding (3–3) of 1.0, 0.9, and 1.8 mm in three sub-groups each containing extraction and non-extraction cases, and Freeman (1994) increases of 2.0 mm in non-extraction cases and 1.9 mm in extraction cases.

Some of the studies which have measured the space condition as available space minus tooth size have measured available space diagonally from the mesial contact points of the canines to the mid-point of the central incisors (Freeman, 1994), or segmentally from the mesial contact point of the first molars to the mesial contact point of the first premolars (Bishara *et al.*, 1994)

Table 2 Changes in the lower arch irregularity index (II) after treatment and retention in various studies.

Reference	*N*	Ex/N-ex	T1 (years)		T3 (years)		T2–T3 (years)		Change II T2–T3 (mm)
			Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)
Kaplan, 1974	30								3.0 (2.2)
	20	both			27	21	9	4–	2.2 (1.2)
	25								2.0 (1.2)
Little *et al*. (1981)	65	Ex	13	8–18	30	25–43		10–	4.0
Glenn *et al.* (1987)	28	N-ex	13		27		8	3–	1.2
Little *et al*. (1988)	31	Ex		10–16		37–51		20–	4.4
Little and Riedel (1989)	30	N-ex		10–22				10–	2.3
Ades *et al*. (1990)	84	both			29	19–39	13	10–28	3.0 (3.6)
Little *et al*. (1990a)	30	Ex		8–12		24–42		10–22	2.5
Little *et al*. (1990b)	26	N-ex		8–15		20–41		6–23	4.0
Kuitert and	27	both	13	11–17	22	19–27		3–11	2.0
Prahl-Andersen	25	both	13	9–33	23	16–44		3–12	2.9
(1990)	25	both	13	10–20	21	16–27		3–9	3.4
McReynolds and	14	Ex	11	8–14		23–37	14		3.0
Little (1991)	32	Ex	13	10–15		24–49	17		2.6
Paquette *et al*. (1992)	30	N-ex	13		29		15	9–20	2.9
	33	Ex	13		29		15	9–20	2.3
Freeman (1994)	14	N-ex	11 (3.3)		23 (3.7)		8	5–	2.7
	28	Ex	12 (2.4)		24 (1.4)		8	5–	2.4
Sadowsky *et al.* (1994)	22	N-ex	11	8–42			6	5–17	1.4
Kahl-Nieke *et al*. (1995)	135	N-ex	11 (2.0)		31 (4.8)		6 (4.4)		2.3 (2.1)
	91	Ex	11 (2.0)		31 (4.8)		6 (4.4)		1.8 (2.0)
Dugoni *et al*. (1995)	25	N-ex	8	7–11	28	21–31		5–22	1.6 (1.8)
Franklin *et al*. (1995)	114	both	13	8–39	31	21–51	12	5–24	1.8
Moussa *et al*. (1995)	55	N-ex	12	8–19	30	29–51		5–20	0.8 (1.2)
Årtun *et al*. (1996)	37	Ex	11	7–17	31	23–50	14	9–33	3.1
	41	N-ex	11	7–17	31	23–50	14	9–33	2.6

T1, pre-treatment; T2, post-treatment (including retention); T3, post-retention.
Ex = extraction; N-ex = non-extraction.

Table 3 Changes in total lower arch space condition (SC) after treatment and retention in various studies.

Reference	*N*	Ex/N-ex	T1 (years)		T3 (years)		T2–T3 (years)		Change SC* T2–T3 (mm)
			Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)
Uhde *et al*. (1983)	45	N-ex	prior to				20	12–35	1.1 (1.1)
	27	Ex	adulthood				20	12–35	1.3 (1.0)
Kahl-Nieke *et al*. (1995)	135	N-ex	11 (2.0)		31 (4.8)		16 (4.4)		3.9 (2.7)
	91	Ex	11 (2.0)		31 (4.8)		17 (4.4)		5.0 (3.4)
Franklin *et al*. (1995)	114	both	13	8–39	31	21–51	12	5–24	1.5

T1, pre-treatment; T2, post-treatment (including retention); T3, post-retention.
Ex = extraction; N-ex = non-extraction.
*Positive values for change in space condition (SC) indicate an increase in crowding.

Table 4 Changes in anterior lower arch space condition (SC) after treatment and retention in various studies.

Reference	*N*	Ex/N-ex	T1 (years)		T3 (years)		T2–T3 (years)		Change SC* T2–T3 (mm)
			Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)
Kuitert and Prahl-Andersen (1990)	27	both	13	11–17	22	19–27		3–11	1.0
	25	both	13	9–33	23	16–44		3–12	0.9
	25	both	13	10–20	21	16–27		3–9	1.8
Freeman (1994)	14	N-ex	11 (3.3)		23 (3.7)		9	5–	2.0
	28	Ex	12 (2.4)		24 (1.4)		9	5–	1.9
Franklin *et al.* (1995)	114	both	13		12				1.0

T1, pre-treatment; T2, post-treatment (including retention); T3, post-retention.
Ex = extraction; N-ex = non-extraction.
*Positive values for change in space condition (SC) indicate an increase in crowding.

or canines (Uhde *et al.*, 1983), and from there to the mesial contact point of the central incisors. Such measurements may under-estimate the available space and give an inflated measurement of crowding.

Another problem is the wide range of treatment age in many of the studies, with early and late treatments included in the same sample, and the variable lengths of post-retention time (Tables 2–4).

Subjects treated early will have completed retention well before the age of 18 years, in the period when the maximum increase in crowding occurs in untreated subjects, and when the factors responsible for such crowding will be operative in addition to those associated with the orthodontic treatment. This applies particularly in cases treated without extractions. When teeth have been removed some of the force responsible for the increase in crowding will have been expended in the process of space closure, depending, of course, on the degree of pre-treatment crowding.

Orthodontically-treated subjects completing retention after the age of 18 years might be expected to show a similar degree of stability to the untreated subjects in the present investigation. This does not appear to be the case. In general post-retention crowding and dimensional changes seem to be greater than those in untreated subjects.

None of the post-retention studies have included an untreated control group with the exception of Freeman (1994), who concluded that there was no significant difference in mandibular incisor irregularity in the long term between orthodontically-treated and untreated subjects. However, the ages of his samples were not comparable. The untreated group was examined at 10, 14, and 20 years, while the treated group covered a much wider age range.

Further post-retention studies of subjects treated at the same age, reviewed at regular intervals and compared with untreated controls over the same age range might be expected to shed more light on the problem.

Conclusions

Changes in lower dental arch alignment and dimensions in untreated subjects during the third decade of life are very small and in most cases undetectable clinically.

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