

Late lower arch crowding in relation to the direction of eruption

Margaret E. Richardson

Department of Orthodontics, The Royal Hospitals, School of Dentistry, Belfast

SUMMARY The change in lower arch crowding 3–4 years after second permanent molar eruption was examined in 85 subjects, in relation to the angulation and change in angulation of molars and incisors relative to the mandibular plane using correlation and multiple regression analyses. Crowding increased significantly during the observation periods. Changes in molar and incisor angulation in both mesial and distal directions were observed. The increase in crowding was not related to molar or incisor angulation at 12 years. Some association between increase in crowding, reduction in arch depth and retroclination of incisors was found.

Introduction

The concept of continuous eruption of teeth to maintain occlusal equilibrium is fundamental to orthodontic theory and practice. The amount and direction of eruption may vary in relation to mandibular growth.

Björk (1963) demonstrated that vertical condylar growth was accompanied by forward eruption of all teeth and that condylar growth in a sagittal direction was associated with backward eruption of anterior teeth.

Sanin and Savara (1973), assuming that the axial inclinations of the lower incisors and first molars are indicative of the direction of their eruption, postulated that there may be favourable and unfavourable relationships between the axial inclinations of these teeth contributing to decrease or increase in lower arch crowding during the change-over from the mixed to the permanent dentition.

The purpose of the present investigation was to examine the axial inclinations of lower molars and incisors and the changes in these inclinations in relation to the increase in lower arch crowding which commonly occurs in the years following eruption of second permanent molars as described by Siatowski (1974), Sakuda *et al.* (1976), Moorrees *et al.* (1979), Richardson (1979) and Sampson *et al.* (1983).

Subjects and methods

Subjects

In all, 85 subjects (38 male 47 female) recorded soon after eruption of second permanent molars were followed longitudinally for 3 years (18 male, 26 female) or 4 years (20 male, 21 female). Their average age at the beginning of the study was 12 or 13 years for the 4 and 3 year groups respectively. The sample included normal and near normal occlusions and some mild or moderate malocclusions. None were treated orthodontically. Records included plaster models and 90 degree left lateral cephalograms.

Measurements

Models. Lower arch space condition was measured on models at the beginning and end of the observation periods as arch length (perimeter, between the mesial contact points of left and right first molars) minus the sum of the mesio-distal tooth dimensions using a Baker vernier microscope (London, UK). In a well-aligned arch with all the teeth in contact, arch length was equal to total tooth size. Where spaces occurred these were added to the total tooth size to find the arch length. Where teeth were crowded the space between adjacent teeth was measured and substituted for the tooth size to calculate arch length (Richardson, 1970).

Negative values for space condition indicated crowding. 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.

The change in lower arch space condition (CSC) during the observation periods was calculated. Positive values indicated an increase in crowding.

90 degree left lateral cephalograms. The following points were marked on a tracing of the first radiograph (Fig. 1): (i) mid-point of the occlusal surface of the lower first molar; (ii) bifurcation of the roots of the lower first molar; (iii) incisal edge; and (iv) apex of the most procumbent lower incisor. The tracing was superimposed on the second radiograph registering on internal mandibular structures (the inner outline of the mandibular symphysis and inferior dental canal) and the same points added to the tracing. If left and right sides were not exactly superimposed the mid-points were used. The accuracy of landmark identification was checked by replacing the tracings on each radiograph after an interval of at least 1 month. If the marked points did not coincide, a new tracing was made and the process repeated.

The horizontal and vertical vectors of each point were recorded using a GTCO 2436LM PC controlled digitizer with the mandibular

plane, Gonion to Menton, orientated along the x-axis and the following dimensions calculated (Fig. 1): (i) the change in linear distance from molar to incisor (mid-occlusal point to incisal edge, CMI) during the observation period; (ii) the anterior angle between the long axis (mid-occlusal point to bifurcation) of the lower first molar and the mandibular plane (MMP) on the first radiograph; (iii) the posterior angle between the long axis (incisal edge to apex) of the most procumbent lower incisor and the mandibular plane (IMP) on the first radiograph; (iv) the change in angle ii (CMMP); and (v) The change in angle iii (CIMP) during the observation periods.

Positive changes indicate decrease in molar to incisor distance, mesial tipping of molars and retroclination of incisors.

Statistical analysis

Means and SD were calculated for (i) the change in space condition (CSC); (ii) the change in molar to incisor distance (CMI); (iii) the initial molar angulation to the mandibular plane (MMP); (iv) the initial incisor angulation to the mandibular plane (IMP); (v) the change in molar angulation (CMMP); (vi) the change in incisor angulation (CIMP). The significance of the changes was tested with the paired sample *t*-test and differences between males and females with the independent sample *t*-test.

Correlation and multiple regression analyses were used to examine the relationships between the change in space condition and the other variables. Separate analyses were performed for the 3 and 4 year observation periods with male and female groups combined. In regression analysis, the forward stepwise approach to variable selection was used with significance set at the 5 per cent level.

Results

On average there was a significant positive change in space condition (CSC), indicating an increase in crowding, in males and females in both the 3 and 4 year observation groups. The mean change in molar to incisor distance (CMI) was not significant in the 3 year observation group but decreased significantly in both males and females in the 4 year group. Average changes in the molar and incisor angles to the mandibular plane (CMMP, CIMP) were non-

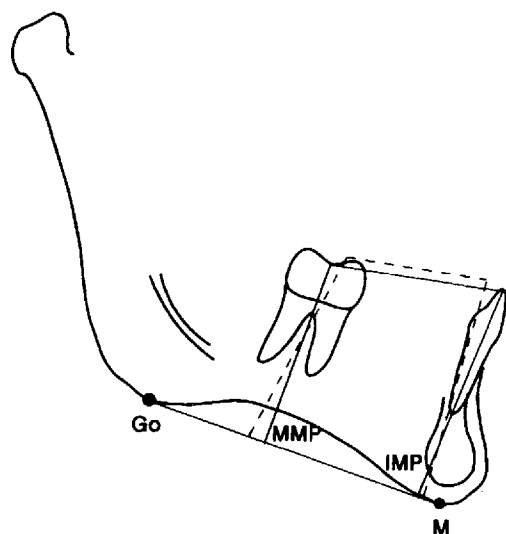


Figure 1 Angular and linear measurements on 90 degree left lateral cephalograms with a tracing of the first radiograph superimposed on the second registering on internal mandibular structures. Solid line = first film; broken line = second film.

The significant increase in lower arch crowding found in this material (Table 1) is consistent with the findings of others (Brown and Daugaard-Jensen, 1951; Lundström, 1969; Humerfelt and Slagsvold, 1972; Siatowski, 1974; Sakuda *et al.*, 1976; Moorrees *et al.*, 1979; Richardson, 1979; Sampson *et al.*, 1983; Sinclair and Little, 1983; Meng *et al.*, 1985; Bishara *et al.*, 1989) although the changes were of smaller magnitude probably due to shorter observation periods.

Table 1 Means, standard deviations and differences between males and females for the variables and changes in 3 and 4 year observation periods

Variable	3 years				4 years				Difference	
	Males (<i>n</i> = 18)		Females (<i>n</i> = 26)		Males (<i>n</i> = 20)		Females (<i>n</i> = 21)		M	F
	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD		
CSC	0.9*	1.7	0.7*	1.4	1.1***	1.0	1.5***	1.2	0.4	
CM1	0.0	1.7	0.4	1.2	0.6*	1.0	1.1***	1.1	0.4	
MMMP	100.2	5.0	99.5	7.2	102.1	5.0	101.5	5.4	0.6	degrees
CMMP	-2.1	6.1	-1.5	4.1	-0.2	4.4	1.0	4.0	1.2	
IMP	92.4	8.1	89.7	8.7	91.7	5.0	93.0	6.5	1.3	
CIMP	-1.2	2.7	0.7	2.9	-0.4	3.2	0.4	3.4	0.8	

CMC=change in lower arch space condition; CM1=change in distance from mid-occlusal point of the lower first molar to incisor edge; MMP=anterior angle between the long axis of the lower first molar and the mandibular plane; CMMP=change in MMP; IMP=posterior angle between the long axis of the most procumbent lower incisor and the mandibular plane; CIMP=change in IMP.

Table 2 Pearson correlation coefficients for the 3 year observation group ($n=44$)

	CSC	CMI	MMP	CMMP	IMP
CMI	0.49*				
MMP	0.05	0.17			
CMMP	0.19	0.09	0.38**		
IMP	0.25	0.11	-0.46**	0.14	
CIMP	0.10	0.43**	-0.28	-0.38**	0.26

Abbreviations as in Table 1.

* $P < 0.001$; ** $P < 0.01$.**Table 3** Pearson correlation coefficients for the 4 year observation group ($n=41$)

	CSC	CMI	MMP	CMMP	IMP
CMI	0.43**				
MMP	-0.28	0.30			
CMMP	0.08	0.07	0.34*		
IMP	0.19	0.09	-0.07	0.14	
CIMP	0.43**	0.33	-0.16	-0.18	0.14

Abbreviations as in Table 1.

* $P < 0.05$; ** $P < 0.01$.

The significant decrease in molar to incisor distance in the 4 year observation group indicates a reduction in arch depth corresponding to that commonly observed in the years following eruption of second molars measured on models perpendicular from central incisors to a line joining left and right first molars, sometimes referred to as arch length (Brown and Dugaard-Jensen, 1951; Lundström, 1969; DeKock, 1972; Humerfelt and Slagvold, 1972).

Average non-significant changes in molar and incisor angulations relative to the mandibular plane (Table 1) would appear to support Sanin and Savara's (1973) assumption, based on Björk's (1963) work, that the axial inclinations of molars and incisors are indicative of the direction of their subsequent changes. In fact all subjects showed some change in molar and incisor angulation in both positive and negative directions. Histograms showing the distribution of angular changes for the 3 and 4 year observation groups combined show that in over 50 per cent of cases these changes exceeded ± 2.0 degrees (Figs 2 and 3). Significant correlation coefficients between the change in space condition (CSC) and the change in molar to incisor distance (CMI, $r=0.49$, $P < 0.001$; $r=0.43$, $P < 0.01$) (Tables 2 and 3) indicate that an

increase in crowding is associated with a decrease in arch depth which is not altogether surprising but unhelpful in establishing causes of increased crowding.

The significant positive correlation between the change in space condition (CSC) and the change in incisor to mandibular plane angle (CIMP, $r=0.43$, $P < 0.01$) in the 4 year observation group (Table 3) indicates an association between increased crowding and retroclination of lower incisors.

The significant correlation coefficients between the changes in molar to incisor distance and incisor to mandibular plane angulation (CMI, CIMP) in both the 3 and 4 year groups ($r=0.43$, $P < 0.01$; $r=0.33$, $P < 0.05$) indicates that retroclination of incisors is associated with a reduction in arch depth.

Uprighting or retroclination of lower incisors has been described by Humerfelt and Slagvold (1972), Björk and Palling (1954) and Siatowski (1974), who claimed that it was sufficient to account for an increase in incisor crowding. However attempts to demonstrate a direct relationship between increase in crowding and change in incisor inclination or position have been unsuccessful (Lundström, 1975; Richardson, 1979). The present findings suggest that there is a relationship between increased crowding and retroclination of incisors although the correlations would explain only about 20 per cent of the variation in the change in space condition.

There was a suggestion that distally inclined molars tended to become more distally inclined as shown by the correlations between molar angulation and change in molar angulation to the mandibular plane (MMP, CMMP) which lends some support to the view that angulation is indicative of direction of eruption. However the correlation coefficients were low ($r=0.38$, $P < 0.01$; $r=0.34$, $P < 0.05$) and since these two variables are not completely independent they are of little consequence. No such correlations were found for incisor angulation and change in angulation.

There was a slight tendency for distally inclined molars to be associated with retroclined incisors and vice versa as shown by the negative correlation between molar and incisor angulation) significant in the 3 year observation group ($r=-0.46$, $P < 0.01$). This may be explained by variations in size of the mandibular plane angle.

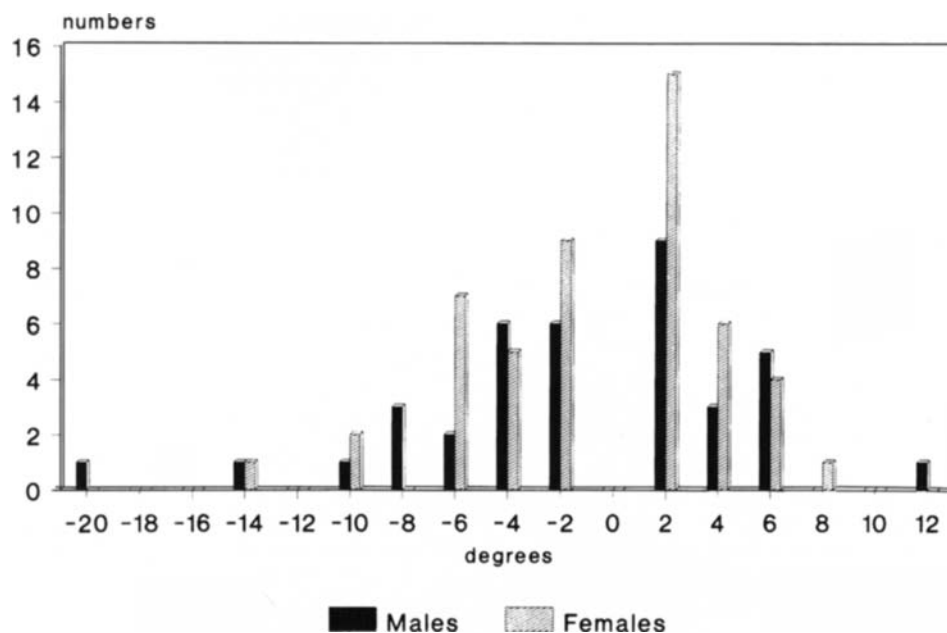


Figure 2 Distribution of the change in molar to mandibular plane angle (CMMP) for 3 and 4 year groups combined ($n = 85$).

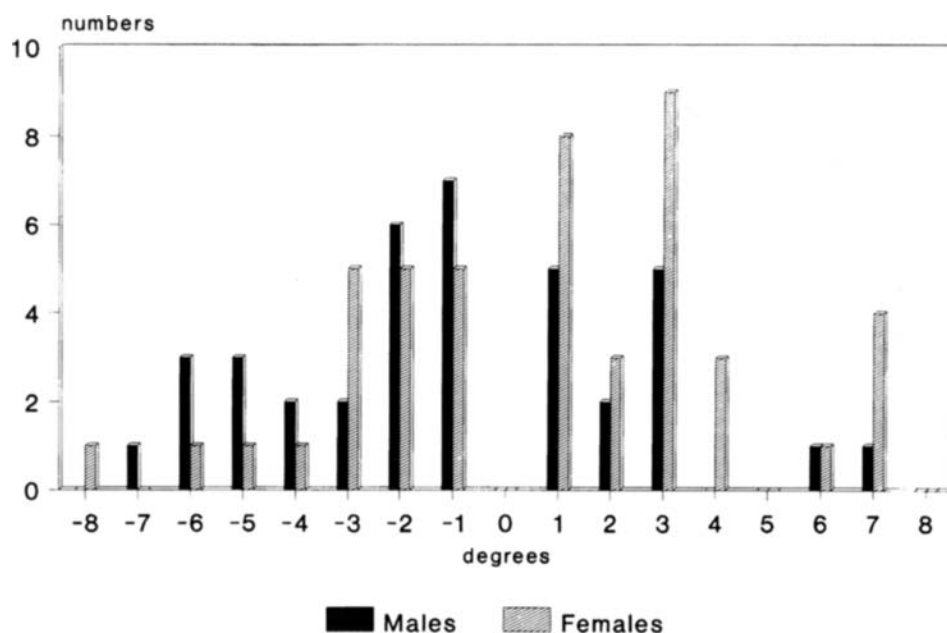


Figure 3 Distribution of the change in incisor to mandibular plane angle (CIMP) for 3 and 4 year groups combined ($n = 85$).

Molars which became more mesially inclined tended to be associated with lingually inclining incisors ($r = -0.38$, $P < 0.01$), which would lead to a reduction in arch depth. However this

correlation was significant only in the 3 year group.

Mesially-inclined molars and retroclined incisors which continue to erupt in the same

direction would result in maximum reduction in arch depth and an increase in crowding. Regression analyses of all the variables with the change in space condition as the dependent variable were unable to demonstrate any such relationship. In both 3 and 4 year observation groups only the change in molar to incisor distance contributed to the regression equations. The forward stepwise approach selects the variable with the strongest correlation to the exclusion of others which may also have some association with the dependent variable. In particular the change in incisor angulation, which was correlated with changes in space condition and molar to incisor distance, may be worthy of note.

It would appear that the direction of eruption of teeth in the lower arch can change after the age of 12 years and that these changes, particularly of incisors, may contribute to an increase in crowding. While that in itself is of interest it is more important to identify factors which may influence the change of angulation. The amount and direction of late mandibular growth (Lande, 1952; Björk and Palling, 1954; Humerfelt and Slagvold, 1972; Siatowski, 1974), complex growth patterns (Björk, 1969), soft tissue maturation (Subtelny and Sakuda, 1966; Bench, 1963; Cohen and Vig, 1976; Vig and Cohen, 1979; Mamandras, 1984; Fränkel and Löffler, 1990; Nanda *et al.* Woodside *et al.*, 1991; Linder-Aronson *et al.*, 1993) and occlusal factors (Brodie, 1939; Owman *et al.*, 1989) are among those which may alter incisor angulation.

Conclusions

1. On average lower arch crowding increases in the 3 and 4 years following second molar eruption.
2. The angulation of molars and incisors relative to the mandibular plane at 12 years does not always indicate the direction of eruption in the next 3 or 4 years.
3. No relationship was found between the angulation of molars and incisors at 12 years and the increase in lower arch crowding.
4. There was a tendency towards reduction in arch depth.
5. Reduction in arch depth was associated with retroclination of incisors.
6. Increase in lower arch crowding was associated with reduction in arch depth and retroclination of incisors.

Acknowledgments

I am very grateful to Emeritus Professor Philip Adams for access to the Belfast Growth study from which the material was drawn, to Professor Andrew Richardson for assistance with the digitization program and to Dr Chris Patterson for advice on statistical procedures.

Address for correspondence

Margaret E Richardson
Department of Orthodontics
The Royal Hospitals
School of Dentistry
Belfast BT12 6 BA
N. Ireland

References

- Bench R W 1963 Growth of the cervical vertebrae as related to tongue, face, and denture behavior. *American Journal of Orthodontics* 49: 183–214
- Bishara S E, Jakobsen J R, Treder J E, Stasi M J 1989 Changes in the maxillary and mandibular tooth size arch length relationship from early adolescence to early adulthood. *American Journal of Orthodontics and Dentofacial Orthopedics* 95: 46–59
- Björk A 1963 Variations in the growth patterns of the human mandible: longitudinal radiographic study by the implant method. *Journal of Dental Research* 42: 400–411
- Björk A 1969 Prediction of mandibular growth rotation. *American Journal of Orthodontics* 55: 585–599
- Björk A, Palling M 1954 Adolescent age changes in sagittal jaw relation, alveolar prognathia and incisal inclination. *Acta Odontologica Scandinavica* 12: 201–232
- Brodie A G 1939 Retention. *Angle Orthodontist* 9: 3–16
- Brown V P, Dagaard-Jensen I 1951 Changes in the dentition from the early teens to the early twenties. *Acta Odontologica Scandinavica* 9: 177–192
- Cohen A M, Vig P S 1976 A serial growth study of the tongue and intermaxillary space. *Angle Orthodontist* 46: 332–337
- DeKock W H 1972 Dental arch depth and width studied longitudinally from 12 years of age to adulthood. *American Journal of Orthodontics* 62: 56–66
- Fränkel R, Löffler U 1990 Functional aspects of mandibular crowding. *European Journal of Orthodontics* 12: 224–229
- Humerfelt A, Slagvold O 1972 Changes in occlusion and craniofacial pattern between 11 and 25 years of age. *Transactions of the European Orthodontic Society*, pp. 113–122

- Lande M J 1952 Growth behaviour of the human bony facial profile as revealed by serial cephalometric roentgenology. *Angle Orthodontist* 22: 78–90
- Linder-Aronson S, Woodside D G, Hellsing E, Emerson W 1993 Normalisation of incisor position after adenoidectomy. *American Journal of Orthodontics and Dentofacial Orthopedics* 103: 412–427
- Lundström A 1969 Changes in crowding and spacing of the teeth with age. *Dental Practitioner* 19: 218–224
- Lundström A 1975 A study of the correlation between mandibular growth direction and changes in incisor inclination, overjet, overbite and crowding. *Transactions of the European Orthodontic Society*, pp. 131–140
- Mamandras A H 1984 Growth of the lips in two dimensions: a serial cephalometric study. *American Journal of Orthodontics* 86: 61–66
- Meng H P, Gebauer U, Ingervall B 1985 Die entwicklung des engstandes der unteren inzisiven im zusammenhang mit veränderungen der zahnbogen und des gesichtsschadels bei individuen mit guter okklusion von der puberat bis zum erwachsenenalter. *Schwiezer Monatsschrift für Zahnmedizin* 95: 762–777
- Moorrees C F A, Lebet L M L, Kent R L 1979 Changes in the natural dentition after second molar emergence (13–18 years). *International Association for Dental Research* 737: 276 (Abstract)
- Nanda R S, Meng H, Kapila S, Goorhuis J 1990 Growth changes in the soft tissue profile. *Angle Orthodontist* 60: 177–190
- Owman G, Bjerklin K, Kurol J 1989 Mandibular incisor stability after orthodontic treatment in the upper arch. *European Journal of Orthodontics* 11: 341–350
- Richardson M E 1970 The early developmental position of the lower third molar relative to certain jaw dimensions. *Angle Orthodontist* 40: 226–230
- Richardson M E 1979 Late lower arch crowding: facial growth or forward drift? *European Journal of Orthodontics* 1: 219–225
- Sakuda M, Kuroda Y, Wada K, Matsumoto M 1976 Changes in crowding of the teeth during adolescence and their relation to growth of the facial skeleton. *Transactions of the European Orthodontic Society*, pp. 93–104
- Sampson W J, Richards L C, Leighton B C 1983 Third molar eruption patterns and mandibular dental arch crowding. *Australian Orthodontic Journal* 8: 10–20
- Sanin C, Savara B S 1973 Factors that affect the alignment of the mandibular incisors: a longitudinal study. *American Journal of Orthodontics* 64: 248–257
- Siatowski R E 1974 Incisor uprighting: mechanism for late secondary crowding in the anterior segments of the dental arches. *American Journal of Orthodontics* 66: 398–410
- Sinclair P M, Little R M 1983 Maturation of untreated malocclusions. *American Journal of Orthodontics* 83: 114–123
- Subtelny J D, Sakuda M 1966 Muscle function, oral malformation, and growth changes. *American Journal of Orthodontics* 52: 495–517
- Vig P S, Cohen A M 1979 Vertical growth of the lips: a serial cephalometric study. *American Journal of Orthodontics* 75: 405–415
- Woodside D G, Linder-Aronson S, Stubbs O 1991 Relationship between mandibular incisor crowding and nasal mucosal swelling. *Proceedings of the Finnish Dental Society* 87: 127–138