Original Article

Anterior Space Relations and Lower Incisor Alignment in 9-Year-Old Children Born in the 1960s and 1980s

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Abstract: The anterior arch spaces and the effect of early loss of deciduous canines have been studied in 2 different cohorts of 9-year-old children. One group of 119 children was from Norway and consisted of 56 girls and 63 boys, and 1 group of 133 children was from Sweden and consisted of 72 girls and 61 boys. Within these cohorts, half of the children were born in the 1960s and half in the 1980s. The 1960s group has been compared with the 1980s group to look for anterior arch changes occurring during this period of time. The children who had lost a lost deciduous canine at the age of 9 years were also compared with the children with all deciduous canines remaining. Groups were compared with analysis of variance. It was found that children with a lost deciduous canine at the age of 9 years belong to a group with less available arch space and are a crowded group when compared with an earlier study. For the girls, this was also associated with larger teeth. Anterior arch space did not differ between the 1960s and the 1980s groups except for the Swedish boys, where there was less available mandibular arch space in the 1980s group. The irregularity index for the 4 mandibular incisors was increased in the 1980s group compared with the 1960s group. This could indicate a secular trend toward an increased prevalence of malocclusion in the present population. (*Angle Orthod* 2001;71:36–43.)

Key Words: Child, Dental arch/growth and development; Maxillofacial development; Health transition; Deciduous tooth; Malocclusion/etiology; Dentition/anatomy and histology

INTRODUCTION

Analysis of anterior space in the dental arch is of great importance in orthodontic treatment and treatment planning.[1–3] Identification of patients who may develop crowding is important for the decision regarding extraction or nonextraction therapy. Conventional space analysis is generally the method of choice to clarify this issue in the permanent dentition.

During development of the dentition, the loss of deciduous teeth is one part of this process affecting dental arch space. The second deciduous molar and the deciduous canine are important teeth in this respect. For the anterior space, the exfoliation of the deciduous canine is important. The timing of this process also affects the alignment of the dentition.[4] The prediction of tooth size arch length discrepancies in the permanent dentition from measurements in the deciduous dentition has given low correlations.[5] Further information on this subject would be beneficial.

The space in the anterior dental arch space changes after eruption of the incisors. Moorrees and Chadha[6] have studied the available space in the incisor segment during tooth eruption, and Hagberg[7] and Lundy and Richardson[8] have analyzed the available space for the mandibular permanent incisors during the eruption of these teeth. These authors found a relative increase in available space after incisor eruption. Moorrees and Chadha found a decrease in available space during incisor eruption, giving a maximum mean space deficiency in the mandible of 1.7 mm for boys and 1.8 mm for girls. These values were reduced after incisor eruption was completed. The maxillary development was similar, but the available space showed more positive values.[6]

Longitudinal changes in dental arch space between 23 and 34 years of age have been studied by Bondevik,[9] between 25 and 45 years of age by Bishara et al,[10] and, for the mandible only, between 18 and 28 years of age by Richardson and Gormley.[11] These authors found a decrease in the mandibular dental arch space but little if any change in the maxillary dental arch space for these ages. Secular

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TABLE 1. Age and Sex Distribution

Group	Year	n	Age			
			Mean	SD	Minimum	Maximum
Norwegian boys	1983	32	9 y, 4 mo	3.1	8 y, 10 mo	9 y, 9 mo
Norwegian girls	1983	26	9 y, 4 mo	3.5	9 y, 0 mo	9 y, 10 mo
Norwegian boys	1963	31	9 y, 4 mo	4.0	8 y, 9 mo	9 y, 11 mo
Norwegian girls	1963	30	9 y, 3 mo	3.6	8 y, 9 mo	9 y, 9 mo
Swedish boys	1984–1985	30	9 y, 2 mo	4.0	8 y, 7 mo	9 y, 9 mo
Swedish girls	1984–1985	37	9 y, 4 mo	3.8	8 y, 8 mo	9 y, 9 mo
Swedish boys	1961	31	9 y, 0 mo	3.0	8 y, 6 mo	9 y, 5 mo
Swedish girls	1961	35	9 y, 0 mo	3.1	8 y, 6 mo	9 y, 6 mo

changes in available dental arch space are less well investigated.

Secular changes in the dentition toward an increased prevalence of crowding[12,13] and a more deteriorated occlusion have been suggested.[14] A more deteriorated occlusion was found in a study comparing parents and offspring in an immigrant population of Chinese heritage. The results included higher scores for anterior and posterior tooth displacements among the offspring.[14] The prevalence of maxillary crowding increased from 31% to 38%, and the mandibular crowding increased from 39% to 43% in the 2-generation Israeli study.[13] If there is such a development in the present populations, the available space in the anterior area of the dentition would most likely be affected.

The aim of the present investigation was to evaluate the anterior space conditions and mandibular incisor alignment of 9-year-old children born within a time span of 20–25 years and to test the null hypothesis that there has been no change during these years. The aim was also to evaluate the effect of early loss of the deciduous canine on the arch perimeter in these age-groups.

MATERIALS AND METHODS

The plaster casts of 119 nine-year-old children, all from the same area in Nittedal, Oslo, Norway, were studied. The 119 children included 31 boys and 30 girls born in 1963 from the University of Oslo growth material, and 32 boys and 26 girls born in 1983. A corresponding group of 133 records of 9-year-old children from the county of Skaraborg, Sweden was also evaluated. In the Swedish group, there were 31 boys and 35 girls born in 1961 and 30 boys and 37 girls born in 1984 and 1985 (Table 1). Children with a history of orthodontic treatment, prolonged sucking habits extending beyond 4 years of age, and a recent history of immigration (the last 2 generations) were excluded.

The distance between the distal surfaces of the lateral incisors was registered (distance A, Figure 1). Measurements were also recorded from the distal surface of the left lateral incisor to the mesial surface of the left central incisor along with the corresponding measurements on the right side (distance B, Figure 1). Any midline diastema was added to this measurement. Available space was calculated with this measurement minus the sum of the mesiodistal sizes of the teeth. The sum of the mesiodistal tooth sizes of the incisors was calculated by the anatomical contact points.

Overjet was registered, and comparisons between groups were made in relation to the loss of the deciduous canine. Arch perimeter was registered from first molar to first molar. This was recorded as the distance from the mesial surface of the right first molar to the distal surface of the right lateral incisor plus the distance from the distal surface of the lateral incisor to the mesial surface of the right central incisor, plus the corresponding measurements on the left side. Any midline diastema present was added to this total.

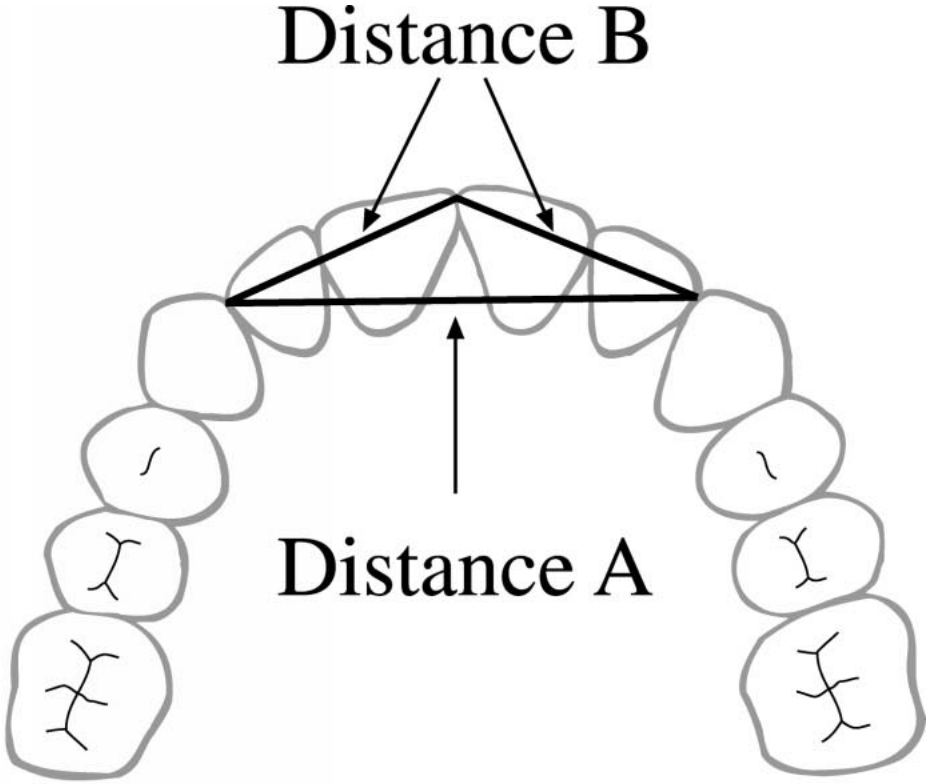
Measurements and calculations were performed only when all relevant teeth were erupted and available, and the number of observations varies accordingly. Cases with missing maxillary or mandibular incisors were thus not included in these registrations. The children with at least 1 lost deciduous canine were classified as having loss of deciduous canine. Children classified as having no loss of deciduous canines had both left and right deciduous canines remaining. This was done for the maxilla and mandible separately. There were cases in which the loss had occurred in the maxilla, but not in the mandible, and vice versa, and some cases in which the loss had occurred in both jaws. This has not been further studied because of the group sizes.

The irregularity of the mandibular incisors was registered according to the irregularity index of Little,[15] with the important exception of the permanent canines, which were not registered because of dental development stages in the material. All permanent incisors had to be present when registrations were made.

The measurements were repeated in 15 models with at least a 1-month delay. Systematic errors were tested using a paired *t*-test. The errors of the measurement were calculated with the formula

$$SE = \sqrt{\frac{sd^2}{2}}$$

The level of significance was set at 5%.



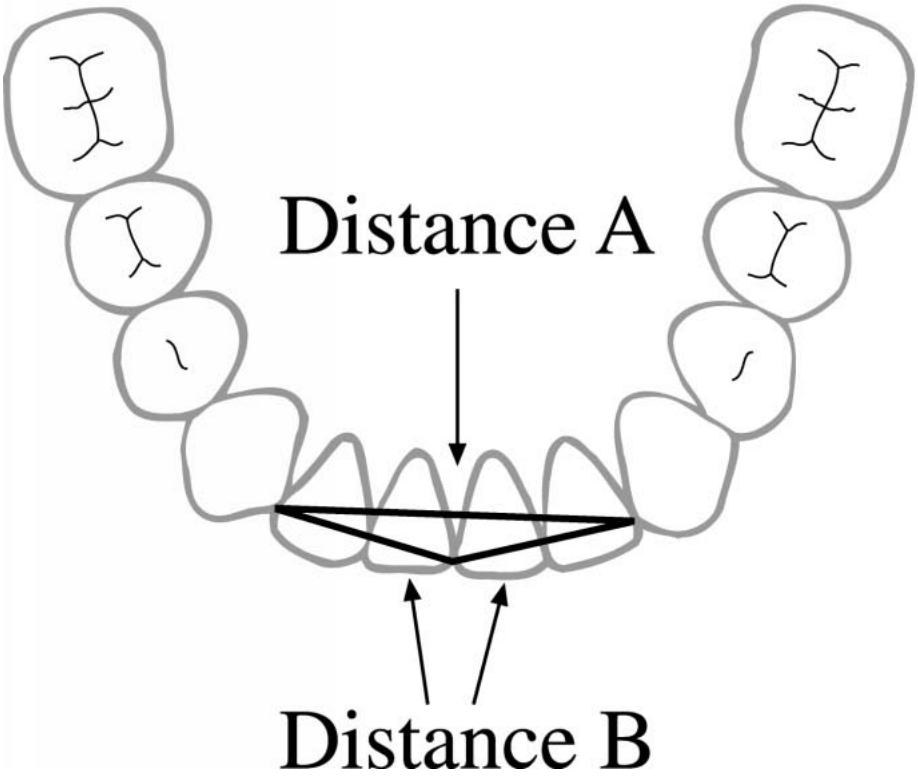


TABLE 2. Maxillary Anterior Arch Distances, Sum of the Maxillary Permanent Incisor Tooth Sizes Measured Mesiodistally, and the Available Space Calculated as Distance B Minus the Sum of Anterior Tooth Sizes (mm)

Group	n	Distance A[a]	SD	n	Distance B[b]	SD	n	Sum of Anterior Tooth Sizes	SD	n	Available Space	SD
Norwegian girls 1963	27	28.5	2.0	27	31.6	2.1	26	30.9	2.4	26	0.72	1.6
Norwegian girls 1983	24	28.7	1.6	24	31.5	2.1	23	31.2	2.1	23	0.28	1.6
Swedish girls 1961	29	29.3	1.9	29	32.1	2.4	28	30.7	1.9	28	1.52	1.7
Swedish girls 1984	36	28.5	2.3	36	32.1	2.3	35	31.3	2.1	35	0.83	1.8
Norwegian boys 1963	29	29.9	1.7	29	32.8	1.6	29	31.8	1.3	29	1.02	1.4
Norwegian boys 1983	26	28.8	2.3	26	32.4	1.5	26	31.5	1.8	26	0.97	1.8
Swedish boys 1961	23	30.4	1.7	23	33.4	2.0	22	32.8	2.1	22	0.49	1.8
Swedish boys 1984	22	29.7	1.7	22	33.4	1.8	20	32.4	2.1	20	1.14	1.3

[a] Distal surface of lateral incisor to distal surface of lateral incisor.
[b] Distal surface of lateral incisor to mesial surface of central incisor plus the corresponding distance on the other side, corrected for midline diastemata.

TABLE 3. Mandibular Anterior Arch Distances, Sum of the Mandibular Permanent Incisor Tooth Sizes Measured Mesiodistally, and the Available Space Calculated as Distance B Minus the Sum of Anterior Tooth Sizes (mm)

Group	n	Distance A[a]	SD	n	Distance B[b]	SD	n	Sum of Anterior Tooth Sizes	SD	n	Available Space	SD
Norwegian girls 1963	30	22.0	1.3	30	23.0	1.5	29	23.0	1.7	29	0.06*	0.8
Norwegian girls 1983	25	21.7	1.5	25	22.8	1.1	25	22.9	1.1	25	−0.04*	0.9
Swedish girls 1961	34	21.8	1.2	34	23.0	1.3	34	23.0	1.3	34	0.00*	0.9
Swedish girls 1984	37	21.6	1.3	37	22.9	1.4	37	23.0	1.3	37	−0.14*	0.7
Norwegian boys 1963	30	22.6	1.2	30	23.8	1.3	30	23.4	1.1	30	0.23*	0.8
Norwegian boys 1983	31	22.2	1.4	31	23.3	1.4	30	23.1	1.4	30	0.24*	1.0
Swedish boys 1961	30	22.7	1.4	30	24.2	1.3	30	23.9	1.2	30	0.25*	1.0
Swedish boys 1984	30	22.4	1.6	30	23.6	1.6	29	24.0	1.3	29	−0.34*	1.1

[a] Distal surface of lateral incisor to distal surface of lateral incisor.
[b] Distal surface of lateral incisor to mesial surface of central incisor plus the corresponding distance on the other side, corrected for midline diastemata.
* $P < 0.05$

Group means were compared by analysis of variance, with the boys and girls tested separately. Pooled standard deviations were used in the analysis of variance. The irregularity index was tested both with boys and girls separated and with boys and girls combined.

RESULTS

The maxillary arch sizes, sum of the anterior tooth sizes, and available space are shown in Table 2. There were no significant differences between 1960s groups and 1980s groups. The mandibular arch sizes, sum of the anterior tooth sizes, and available space are shown in Table 3. There were no significant differences in distances or sum of the anterior tooth sizes. The available space differed in the Swedish boys' groups so that there was less available space in the 1980s group compared with the 1960s group ($P < 0.05$). The other groups did not show any trend in the same direction.

The maxillary values for children with and without the loss of a deciduous canine are shown in Table 4. The girls who had lost a deciduous canine had a larger anterior arch distance when it was measured along the arch perimeter (distance B) compared with the girls with deciduous canines remaining ($P < 0.001$). The arch perimeters measured

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FIGURE 1. Anterior arch measurements used in the study.

TABLE 4. Maxillary Anterior Arch Sizes, Sum of Maxillary Permanent Incisor Tooth Sizes Measured Mesiodistally, Arch Perimeter Measured From Mesial Surface of Right First Permanent Molar to Mesial Surface of Left First Permanent Molar, and Overjet for Girls and Boys With and Without a Lost Deciduous Canine (mm)

Group	n	Distance A[a]	SD	n	Distance B[b]	SD	n	Sum of Anterior Tooth Sizes	SD	n	Arch Perimeter M1-M1	SD	n	Overjet	SD
Girls															
Lost deciduous canine	23	29.4	2.1	23	33.5***	2.2	23	32.3***	2.3	23	72.7***	4.9	25	3.5	2.1
No loss	93	28.6	2.0	93	31.5***	2.1	89	30.7***	1.9	92	75.7**	4.0	103	3.4	1.5
Boys															
Lost deciduous canine	10	29.5	1.8	10	33.4	2.5	10	32.6	2.2	10	74.7**	2.9	10	4.4	1.3
No loss	90	29.7	1.9	90	32.9	1.6	87	32.0	1.8	88	78.3**	3.5	111	4.2	1.8

[a] Distal surface of lateral incisor to distal surface of lateral incisor.

[b] Distal surface of lateral incisor to mesial surface of central incisor plus the corresponding distance on the other side, corrected for midline diastemata.

*** $P < 0.001$

** $P < 0.01$

TABLE 5. Mandibular Anterior Arch Sizes, Sum of Mandibular Permanent Incisor Tooth Sizes Measured Mesiodistally, Arch Perimeter Measured From Mesial Surface of Right First Permanent Molar to Mesial Surface of Left First Permanent Molar, and Overjet for Girls and Boys With and Without a Lost Deciduous Canine (mm)

Group	n	Distance A[a]	SD	n	Distance B[b]	SD	n	Sum of Anterior Tooth Sizes	SD	n	Arch Perimeter M1-M1	SD	n	Overjet	SD
Girls															
Lost deciduous canine	38	21.7	1.4	38	23.1	1.6	37	23.4*	1.6	37	66.2*	4.5	39	3.7	1.9
No loss	88	21.8	1.3	88	22.9	1.2	88	22.8*	1.2	88	68.0*	3.7	88	3.3	1.5
Boys															
Lost deciduous canine	20	22.4	1.4	20	23.8	1.5	20	23.7	1.1	20	66.5***	4.4	20	4.7	1.6
No loss	101	22.5	1.4	101	23.7	1.4	99	23.6	1.4	98	69.6***	3.8	101	4.1	1.8

[a] Distal surface of lateral incisor to distal surface of lateral incisor.

[b] Distal surface of lateral incisor to mesial surface central of incisor plus the corresponding distance on the other side, corrected for midline diastemata.

* $P < 0.05$

*** $P < 0.001$

from first molar to first molar were significantly smaller for children who had lost deciduous canines. This was true for both boys and girls ($P < 0.01$). There were no differences in overjet between the groups. The sum of the sizes of the incisors was larger for the girls with a lost deciduous canine compared with the girls with remaining deciduous canines ($P < 0.001$). The width of the incisors did not differ significantly among the boys.

The mandibular values for children with and without the loss of a deciduous canine are shown in Table 5. There were no differences in anterior space between these groups. The arch perimeters from first molar to first molar were significantly smaller for the children who had lost a deciduous canine. The level of significance for girls was $P < 0.05$, and for boys it was $P < 0.001$. The sum of sizes of the mandibular incisors was larger for the girls with a lost deciduous canine compared with the girls with remaining deciduous canines ($P < 0.05$). The mandibular incisor sizes did not differ among boys.

The irregularity index for the lower permanent incisors did not differ between groups or between boys and girls (Table 6). The groups were tested with the sexes pooled, and the 1980s group had a larger irregularity index compared with the 1960s group ($P < 0.05$). The children with loss of a mandibular deciduous canine did not differ from the children with remaining mandibular deciduous canines in the irregularity index. The error of the measurements was 0.1 mm for the distances measured. For the maxillary lateral segments, the mandibular right incisal segment, the mandibular left lateral segment, the irregularity index of the mandibular incisors, and the overjet, the error of the measurements reached 0.2 mm. There were no systematic errors.

DISCUSSION

The anterior arch perimeters were studied in 9-year-olds born in the 1960s and in the 1980s and belonging to 2

TABLE 6. The Irregularity Index for the 4 Mandibular Permanent Incisors[a] (mm)

Group	n	Irregularity Index, Incisors	SD
Norwegian girls 1963	29	1.6	1.6
Norwegian girls 1983	25	1.8	1.7
Swedish girls 1961	34	1.3	1.0
Swedish girls 1984	37	1.7	1.3
Norwegian boys 1963	30	1.3	1.0
Norwegian boys 1983	30	1.9	1.8
Swedish boys 1961	30	1.3	1.1
Swedish boys 1984	29	1.9	1.7
1960s group, boys and girls	123	1.4	1.2
1980s group, boys and girls	121	1.8*	1.5
No loss of deciduous canine, boys and girls	187	1.6	1.4
Loss of deciduous canine, boys and girls	57	1.7	1.1

[a] Boys did not differ significantly from girls. The children in the 1980s group had a significantly larger irregularity index compared with the 1960s group. The children with a lost deciduous canine did not differ from children without loss of a deciduous canine.

* $P < 0.05$

different cohorts. The major finding was a smaller arch perimeter in children with the early loss of a deciduous canine. A change in mandibular incisor alignment toward an increase in irregularity was found between the 1960s group and the 1980s group. The anterior linear dimensions were similar for the 1960s and 1980s group except for the Swedish boys, in whom an increase in mandibular space deficiency had occurred during this period.

In the present sample, the children who had lost a deciduous canine had shorter total arch lengths compared with the children with remaining deciduous canines. There were no differences in anterior arch widths between these 2 groups. There were no differences in the available space or overjet between these groups. This means that during loss of the deciduous canine, the permanent incisors drift distally and, if at all, to a lesser extent laterally.

The distance between the permanent lateral incisors has been registered longitudinally from the mean age of 9.4 years to the mean age of 25.9 years. This distance decreases both in the maxilla and in the mandible from the age of 9 years.[16] It is a common practice in some cases of anterior crowding to extract deciduous canines.[17,18] Loss of deciduous canines before 9 years of age is mainly due to space problems and seldom due to caries.[17–21] In cases of impacted maxillary canines, extraction of the deciduous canine is recommended, but this is at the age of 10 years or older.[22]

This study showed that the group with the early loss of a deciduous canine had shorter arches. This could perhaps diminish the arches to a greater extent than if early loss of a deciduous canine had not occurred. The normal difference between 8 and 13 years of age is an increase in arch length in the maxilla of 1 mm in boys and 0.7 mm in girls. In the mandible, the arch length decreases by 2.4 mm in boys and by 3.2 mm in girls between 8 and 13 years of age. These values were calculated by using arch length from the mesial surface of the first permanent molar to the first permanent molar with the distal surface of canines and the mesial surface of incisors.[23] This means that during this period, when these teeth are normally lost, there is no decrease in maxillary arch perimeter. The present investigation found a shorter total arch perimeter in the maxilla for the children who had loss of a deciduous canine. This is indirect evidence that children who lose their deciduous maxillary canines early have shorter arches. Early loss of deciduous canines was also significantly associated with wider teeth mesiodistally for the girls. In the mandible, the arches in children with loss of a deciduous canine were also shorter, but these values were in the range of normal changes for these age-groups. The same conclusion can, therefore, not be drawn for the mandible concerning the loss of a deciduous canine on the basis of these assumptions.

In a study on the effect of early loss of deciduous molars, the group with crowding at 15 years of age was compared with the group without crowding at 15 years of age. In the groups who had not lost their deciduous molars prematurely, the maxillary arch perimeter was 77.2 mm in the uncrowded group and 73.1 mm in the crowded group. The sexes were not separated in that investigation.[4] These figures are in close agreement with the arch perimeter values for 9-year-olds in this investigation. The boys with remaining deciduous canines in the maxilla had an arch perimeter of 78.3 mm, and the boys with loss of a deciduous canine had an arch perimeter of 74.7 mm, with a corresponding value for the girls of 75.7 mm and 72.6 mm. With the sexes pooled, these values support the conclusion that children with the loss of a deciduous canine are a group with less dental arch space and at risk of developing anterior crowding compared with the children with remaining deciduous canines at 9 years of age.

In the mandible, the boys with remaining deciduous canines had an arch perimeter of 69.6 mm, and the boys with loss of a deciduous canine had an arch perimeter of 66.5 mm. The corresponding values for the girls were 68.0 mm and 66.2 mm. These figures are in the range of normal growth change for the ages 8–13 years.[23] Compared with the study of 15-year-olds with and without crowding, the picture changes. The figures for mandibular arch perimeter were 67.7 mm for the uncrowded and 64.0 mm for the crowded group.[4] Considering that these groups were sex pooled, and considering the normal growth changes in these age groups, this supports the conclusion that the children with loss of a deciduous canine in the present study belonged to a group with less available dental arch space. This holds true for both the maxilla and the mandible.

In a study of 255 children examined at 11 years of age or older, no increase of malalignment in the group with

early loss of deciduous canines was found. The mean crowding score was registered as space deficiency for anterior teeth, including incisors, canines, and premolars. The normal crowding value for cases with no deciduous canine loss was 1.7 mm. For 1 or 2 deciduous canines lost, the mean crowding scores were 2.1 mm to 2.8 mm, except for 5 cases with very early loss, before the age of 7 years, in which the crowding score was 5.0 mm. This figure probably includes the individual with 4 lost deciduous canines, with a crowding score[24] of 14.0 mm. When this is taken into consideration, the children with loss of deciduous canines at a very early age in this investigation did not have larger space deficiencies compared with those who lost deciduous canines at a later age. This indicates that anterior crowding is associated with early loss of deciduous canines. The probable explanation is that crowding is the cause of the loss of the deciduous canines.

The difference in overjet showed no differences between the groups with and without deciduous canines. However, there is a certain risk of a statistical type II error in overjet changes during early loss of deciduous mandibular canines when the groups' means are considered. This means that there could be some posterior tipping of the lower incisors, although this has not been shown in the present investigation. There is no lingual movement of the mandibular incisors in a normal group during these ages.[25] One further shortcoming is that there is an overlap between individuals with lost maxillary and mandibular canines; this affects the intermaxillary relations, such as overjet. The overjet in untreated normal occlusion increases from 9–10 years of age by 0.4 mm and then decreases to the age of 19–20 years.[26] The intramaxillary registrations are not affected in this way.

The sizes of the incisors differed in the girls' groups, but not in the boys', between those with and without loss of a deciduous canine. The girls with loss of a deciduous canine had larger teeth. Larger teeth have been associated with crowded cases in comparison with uncrowded cases.[27,28] In contrast to this, Howe et al [29] found no differences in tooth sizes between crowded and uncrowded cases, but they found a difference in dental arch dimensions, in which the crowded cases had smaller arch perimeters. Mandibular anterior crowding has been associated with larger mandibular incisors[30] and perfect mandibular incisor alignment with smaller mesiodistal tooth dimensions.[31] No association between mandibular incisor alignment and tooth dimensions has been found after orthodontic therapy.[32] The present investigation showed differences for girls only concerning tooth size. There were differences in arch perimeter for both boys and girls. Interestingly, a similar difference in tooth size for girls only has been found when spacing and crowding were studied in relation to impaction of third molars.[33] In a study of serial extraction in girls only, larger teeth were also found in a crowded group compared with the control group. However, the control group values were taken from another study.[34]

Conventional methods using arch perimeter minus tooth sizes as well as the Little index of irregularity[15] have been used to describe anterior space relationships. Different methods for lower incisors' space analysis have been evaluated by Harris et al[35] and by Johal and Battagel.[36] Harris et al concluded that the irregularity index had a low correlation to a more conventional space analysis, meaning that these 2 values express different entities, whereas Puneky et al[32] found a higher degree of correlation between these analyses. These methods have also been used to describe developmental changes and treatment changes. The irregularity index decreases from 9–10 years of age to 12–13 years of age and increases again up to the age of 19–20 years.[26] The irregularity index did not differ between boys and girls in this investigation, and the boys and girls were tested together. The irregularity index did not differ between children with loss of a deciduous canine and children without loss of a deciduous canine. This could be due to the realignment that occurs in crowded cases after loss of a deciduous canine.[34]

The irregularity index was larger for the 1980s group compared with the 1960s group. A significant negative correlation has been found between the irregularity index and arch length discrepancy in the mixed dentition when registered on crowded cases.[34] The increase in the irregularity found for the permanent incisors in the present study can possibly indicate a secular trend toward an increased prevalence of malocclusion.[13,37] This is in accordance with the lower heredity found for mandibular anterior arch dimensions and anterior tooth alignment.[38,39] There was no difference in the anterior linear distances between the 1960s group and the 1980s group in this study except for the Swedish boys, in whom the available space was less in the 1960s group.

CONCLUSION

The present study showed that children with loss of a deciduous canine at an early age belonged to a group with less available arch space. The space deficiency was most likely present before the loss of the canine. It was found for the girls that this was also associated with larger teeth.

The mandibular incisors were less well aligned in 9-year-olds born in the 1980s compared with 9-year-olds born in the 1960s. This could indicate a secular trend toward an increased prevalence of malocclusion in the present population.

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