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Mandibular incisor alignment and dental arch changes 1 year after extraction of deciduous canines

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SUMMARY This study investigated the early effects on mandibular incisor irregularity and rotation together with dental arch dimensions of the extraction of four deciduous canines.

Children, during early mixed dentition, were randomized into one extraction (n = 32) and one control (n = 41) group. Dental casts from baseline (T0) and 1 year follow-up (T1) were used to evaluate changes in the irregularity index and in mandibular incisor rotation, dental arch dimensions, overjet, and overbite. Median mandibular incisor irregularity decreased over time, significantly more in the extraction than the control group (1.2 versus 0.7 mm; $P < 0.01$), with wide ranges in both groups. Rotational changes greater than 10 degrees for lateral incisors were twice as common in the extraction group (42 versus 20 per cent; $P < 0.01$). Central incisors displayed only minor changes in both groups. The correlation between changes in irregularity index and changes in incisor rotation was weak in both groups ($r_s < 0.3$ not significant). According to professional assessment of overall alignment, 84 per cent in the extraction group versus 34 per cent in the control group ($P < 0.001$) improved from T0 to T1. A significant decrease in maxillary and mandibular arch length and circumference from T0 to T1 was recorded in the extraction group (1.3, 1.1 mm and 2.4, 2.0 mm, respectively; $P < 0.001$), while arch dimensions were preserved in the control group. To conclude, 1 year after extraction of the deciduous canines, small improvements in mandibular incisor alignment were seen, together with reduced arch dimensions. Little's index underestimated malalignment related to tooth rotation.

Introduction

Clinicians' desire to reduce or eliminate future need for orthodontic treatment by means of early correction of incisor crowding has promoted several interceptive treatment modalities, such as serial extraction (Hotz, 1947; Kjellgren, 1948), discing of deciduous teeth (Dewel, 1954), and orthodontic appliances for space maintenance (Gianelly, 2002). Serial extraction is a well-established interceptive treatment procedure (Dale and Brandt, 1976; Little, 1987; Kau *et al.*, 2004) to facilitate spontaneous correction of crowded permanent incisors and eruption of permanent canines and premolars. The initial step in this procedure is the removal of deciduous canines in the early mixed dentition to reduce rotation and contact point displacement (CPD) of the permanent incisors. Later on, extractions of primary molars and permanent premolars are frequently needed (Hotz, 1947; Kjellgren, 1948).

Kau *et al.* (2004) estimated that a significant proportion of primary tooth extractions in England are probably conducted based on orthodontic indications and at substantial costs. Removing mandibular deciduous canines to reduce incisor crowding has become controversial and is now questioned due to suspected and reported decrease in dental arch length along with the wide range of incisor alignment following these extractions (Yoshihara *et al.*, 2000; Kau *et al.*, 2004).

Significant improvement of mandibular incisor alignment, measured as CPD, has been observed by Yoshihara *et al.* (2000) and Kau *et al.* (2004) after extraction of the deciduous canines. However, relief of mandibular incisor crowding considered great enough to be of clinical significance (i.e. a 50 per cent reduction in initial incisor crowding or less than 2.5 mm of total irregularity score at endpoint) was reported in only one quarter of treated children (Kau *et al.*, 2004).

In studies of incisor crowding, the method most frequently used for evaluating the amount of tooth misalignment is Little's irregularity index (Little, 1975). This index quantifies CPD, which is a combined effect of tooth rotation, position, and inclination (Little, 1975). Incisors with contact points in close proximity and with a minimum of CPD can, despite this, display substantial rotation. Because rotated incisors are assumed to be key indicators of reduced postretention stability (Surbeck and Årtun, 1998; Naraghi *et al.*, 2006), registration of rotation should be important both for evaluating spontaneous alignment and for treatment planning.

To our knowledge, no published studies have examined changes in tooth rotation following extraction of deciduous canines, nor has agreement between measurements of irregularity and subjective clinical evaluations of incisor alignment been assessed. Such comparisons would facilitate interpretation of treatment outcome, provided cut-off scores could be established for clinically detectable changes. Furthermore, contradictive results regarding the importance of tooth size and arch dimensions for incisor crowding (Fastlicht, 1970; McKeown, 1981; Sampson and Richards, 1985; Radnzic, 1988; Türkkahraman and Sayin, 2004; Puri *et al.*, 2007) complicate predictions of favourable treatment outcome for this kind of intervention during early mixed dentition.

Drawbacks connected to extracting deciduous canines have been reported. The best described is decreased arch length due to mesial migration of the first molars (Yoshihara *et al.*, 2000; Kau *et al.*, 2004), resulting in less available space for the permanent canines and premolars (Kau *et al.*, 2004). Increased mandibular incisor retrusion (Yoshihara *et al.*, 2000; Sayin and Türkkahraman, 2006) and incisor retroclination (Yoshihara *et al.*, 2000) have also been reported. However, no significant differences in overjet or overbite were found between an extraction and a control group of children during early mixed dentition followed over 1.5–2 years (Kau *et al.*, 2004). Conclusions regarding the benefits of these early extractions for the dental arch as a whole have little or no support in the literature (Yoshihara *et al.*, 2000; Kau *et al.*, 2004). Clinical evaluation of treatment outcome from these extractions is highly dependent on development stage of the dentition and endpoints in studies of spontaneous incisor alignment differ substantially. That is why we initiated a study of the early effects of such extractions of deciduous canines on mandibular incisor irregularity and rotation together with changes in dental arch dimensions. This study will be followed by a long-term follow-up to investigate longitudinal changes in incisor alignment and dental arch dimensions. Furthermore, general alignment was professionally evaluated and cut-off scores for detecting changes in rotation and irregularity were established.

Subjects and methods

The study subjects were recruited from among children during early mixed dentition (dental stage 1, according to Björk *et al.*, 1964) attending routine check-ups at public dental clinics in the county of Örebro, Sweden, from November 2005 to June 2007. As a first step, children with lower intercanine distance less than 26 mm (measured between the cusp tips of tooth 73 and 83) were offered an orthodontic consultation.

Inclusion criteria were evaluated by the consulting orthodontists as lack of space for the lower incisors of at least two-thirds of the mandibular central incisor mesiodistal width and, for the upper incisors, of at least one-half of the maxillary central incisor mesiodistal width. Children diagnosed with one or more of the following were excluded: diseases affecting somatic growth, neuropsychiatric disabilities and/or learning disabilities, tooth agenesis and/or anterior crossbite, primary or permanent tooth extracted, and prior or ongoing orthodontic treatment.

The sample size was based on an assumption of a clinically relevant difference between the study and control group of one-third to two-third of the difference between baseline and endpoint irregularity. Calculations based on mean values and standard deviations (SDs) for displacement of contact points from the only study with a control group (Kau *et al.*, 2004) indicated that a sample of 70 subjects were needed using a one per cent significance level with a power of 90 per cent.

Dropout rate was estimated to 17 per cent due to the long follow-up period (2.5 years) and an initial total number of 82 subjects would be sufficient.

One hundred and ten children and their accompanying parents were invited to participate in the study. Sixteen child/parent pairs declined participation without giving a specific explanation, while 11 pairs preferred one of the treatment alternatives and were also excluded; this left 83 children for randomization (gender stratification) into the extraction (n = 40) and control (n = 43) groups. After randomization, 10 children (eight from the extraction and two from the control group) were lost due to increased mobility or loss of deciduous canines (n = 3), withdrawal of consent to participate or lack of cooperation (n = 6), or referral to specialist paediatric dental clinic for first molar extraction (n = 1). Thus, the extraction group consisted of 14 boys and 18 girls with mean ages of 8.8 and 8.5 years, respectively, and the control group of 16 boys and 25 girls had mean ages of 8.8 and 8.4 years, respectively, at baseline (T0). At baseline, there were no significant group differences in background data pertaining to factors such as age, intercanine distance, and mesiodistal width of incisors or in the outcome variables described below (Table 2). All participants received oral and written information, and an adult with parental responsibilities and rights returned a signed informed consent. The research ethics committee, Regionala Etikprövningsnämnden, Stockholm, Sweden, approved the study.

Procedures

All interventions took place at public dental clinics, and the child's regular dentist performed the extractions following routine clinical procedures. The four deciduous canines were extracted in a specific order over three occasions, starting with the left lower canine (73), followed by the two canines on the right side (53 and 83), and, finally, the upper left canine (63). Extractions were completed within 2.5 months of baseline for all but two children (3.6 and 4.8 months). Alginate impressions for plaster models were taken before extractions (baseline: mandibular incisors not fully erupted, T0) and after 1 year (follow-up: T1) for evaluation of early changes. All plaster models were made by the same orthodontic dental laboratory using white BESV gypsum plaster (Bo Ehrlander AB, Gothenburg, Sweden) to make the models.

Instrumentation

Irregularity (i.e. CPD), arch width, arch length, intercanine distance, and tooth width were measured directly on the plaster models using a digital calliper (Digital 6; Mauser, Winterhur, Switzerland) and recorded to the nearest 0.01 mm. A multithreaded wire coaxial, with a diameter of 0.0175 inches, was used to measure the arch circumference. The wire was placed at the gingival margin and the distances from the left and right first molar to the midline were measured.

Rotation of the mandibular incisors was measured to the nearest 0.1 degrees from digital photographs using Facad 2.2 software (Ilexis AB, Linköping, Sweden). One examiner made all the measurements of linear and angular variables on plaster casts and digital photographs from T0 and T1.

Outcome measures

The measurement methods for the following variables are described in greater detail in a methodological article by Sjögren *et al.* (2010).

Irregularity was measured according to Little's irregularity index (Little, 1975). Results are presented according to a modified index based on measurements made at three contact point sites (between lateral and/or central mandibular incisors). From baseline measurements based on five sites between the mesial contact points of the deciduous canines and the three-site index used in this study, the irregularity index correlated well between the two measurements for both the control and the extraction groups (r_s = 0.72 and 0.84, respectively). Rotation was measured as the angle between a line indicating the longitudinal extension of the incisal edge of the incisor and a perpendicular to a line between the mesiolingual/palatal cusp tips of the first permanent molars. No significant difference in irregularity or rotational change was seen between the right and the left side for the lateral or central incisors.

Assessments of alignment

To identify clinically detectable cut-off scores for irregularity and rotational changes, a qualified orthodontist subjectively assessed the change in general alignment of the incisor segment and in rotation of each mandibular incisor from T0 to T1 (professional assessment). The outcome was registered in three categories: negative change, no change, and positive change (dichotomized in the analyses as change/no change). For that purpose, plaster models from the extraction (n = 32) and control (n = 41) groups were used and observations were made from an occlusal view.

Parental assessments of alignment were recorded approximately 1 year after baseline (parental assessment). Parents were interviewed by telephone according to a structured questionnaire containing the following questions and response alternatives:

> Compared with how your child's front teeth were at the appointment when the first impressions for plaster models were taken one year ago, what is your opinion of the position of the lower front teeth today? You have four response alternatives. Which one is the most accurate?
> – fully aligned
> – improved
> – no change
> – worse

In the analysis, these ratings were dichotomized as improvement (fully aligned or improved) or no improvement (no change or worse).

Arch dimensions

Arch width was measured as the intermolar width, i.e. the distances between the mesiolingual/palatal cusp tips of the first permanent molars in the mandible and maxilla, respectively. Arch length was measured as the perpendicular average distance from a line used for arch width measurements to the estimated mesial contact point of the left and right central incisors. Arch circumference was measured as the distance from half the mesiodistal width of the first permanent molars at the gingival margin on each side to a point representing the estimated contact point of the central incisors at a level corresponding to the buccal gingival margin. Correlation coefficient between the two measurement techniques was r = 0.58. Overjet, i.e. average value of the horizontal distance between incisors 11/41 and 21/31, respectively, was measured directly on the plaster casts from the mid-incisal edge of the upper incisor to the centre of the buccal surfaces of the lower incisor. Overbite was the average value of the vertical distance between mid-incisal edges of incisors 11/41 and 21/31, respectively.

Statistical methods

Descriptive statistics (i.e. mean, SD, 95 per cent confidence intervals, median, interquartile range, minimum, and maximum) were used to report the data. The distributions for background and outcome variables were tested using the detrended normal *Q–Q* plot and the Shapiro–Wilks test, which did not indicate a symmetric normal distribution for all measurements. Differences between groups were analysed using the independent samples *T*-test and Mann–Whitney *U*-test, while categorical data were analysed using the χ^2 test. Changes over time were analysed using the paired samples *T*-test and Wilcoxon signed-rank test. The results from the parametric tests are presented in the tables with differences in *P*-values compared to the non-parametric tests marked with numbers and presented below the tables. Analysis of correlation between records at T0 and changes from T0 to T1 for irregularity and rotation used Spearman's rank correlation (r_s). Receiver operating characteristic (ROC) analysis was used to establish cut-off values for 'clinically detectable changes' in rotation angle and reduction of irregularity. The combined highest values for sensitivity and specificity were selected and professional assessment of change/no change was used as the state variable. The cut-off for reduction of irregularity was established at a 25 per cent reduction (sensitivity 0.66, specificity 0.91). The cut-off for clinically detectable changes in rotation was determined to be 7 degrees (sensitivity 0.83, specificity 0.80). Two lateral incisors in the extraction group displayed inadequate eruption for evaluation of alignment at T0, and CPD was therefore calculated as an average value for these individuals and assessment of rotation was omitted. *P*-values less than 0.05 were considered statistically significant. Statistical analyses were performed using version 15.0 of the SPSS and version 17.0 of the PASW software packages (SPSS Inc., Chicago, Illinois, USA).

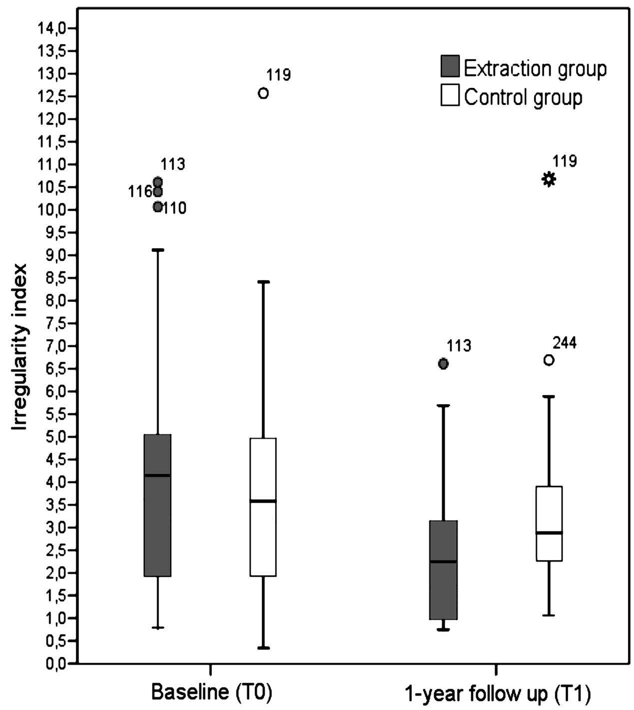

Figure 1 Distribution of irregularity in the control and extraction groups at baseline and at the 1 year follow-up. Box plots showing median, interquartile range, and minimum and maximum values. If whiskers are less than 1.5 box lengths from either end of the box, the extensions indicate minimum and maximum values. Outliers (o) are defined as cases with values 1.5–3 box lengths from either end of the box, and extreme values (*) are defined as cases with values more than three box lengths from either end of the box.

Results

Alignment

The irregularity index indicated a significant decrease in median and mean values from T0 to T1 in both the extraction and the control groups (Figure 1, Table 1), with considerable variation in both groups (Table 1). The median irregularity index at T1 was significantly lower in the extraction than in the control group (2.3 versus 2.9, $P = 0.01$; Figure 1). A significant larger reduction in irregularity from T0 to T1 was seen in the extraction group (Table 2). A greater than 25 per cent reduction in the initial irregularity index was recorded for 21/32 of the subjects in the extraction group and 8/41 of the subjects in the control group; the corresponding numbers for a greater than 50 per cent reduction were 10/32 and 1/41. Changes in irregularity index from T0 to T1 displayed a strong correlation with initial ratings in both the control and the extraction groups ($r_s = 0.77$ and 0.83, respectively).

Rotation of mandibular incisors displayed a wide range at baseline in the extraction group (lateral incisors 28.3–119.5 degrees, central incisors 52.6–121.1 degrees) and in the control group (lateral incisors 34.1–117.4 degrees, central incisors 54.5–104.4 degrees; Figure 2). Lateral incisors in the extraction and control groups displayed significant changes in rotation from T0 to T1 (Table 1). No significant difference was recorded for central incisor rotation during the same time period (Table 1). Fifty-six per cent of the lateral incisors in the extraction group displayed a change in rotation of greater than 7 degrees (cut-off for clinically detectable changes) versus 39 per cent in the control group ($P < 0.05$). A change of greater than 10 degrees was twice as common for laterals in the extraction group (42 versus 20 per cent, $P < 0.01$; Table 3). Correlation between initial rotation angle and absolute difference in rotation angle from T0 to T1 were significant for lateral incisors 32 and 42 in the extraction ($r_s = 0.82$ and 0.61, $P < 0.01$) and control ($r_s = 0.53$ and 0.49, $P < 0.01$) groups, while no such correlation was present for the central incisors in either group (Figure 2).

Change in irregularity index (T0–T1) displayed a weak correlation with change in rotation angle for the four incisors (sum of absolute difference from T0 to T1) in both the control and the extraction groups ($r_s < 0.3$ not significant).

The professional assessments of alignment for the mandibular incisor segment revealed significantly more

Table 1 Changes in alignment (millimetres and degrees) and arch dimensions (millimetres) from baseline to the 1 year follow-up in the extraction and control groups.

		Extraction group							Control group						
		Baseline		Follow-up		Difference Follow-up - Baseline			Baseline		Follow-up		Difference Follow-up - Baseline		
		Mean	SD	Mean	SD	Mean	SD	P-value*	Mean	SD	Mean	SD	Mean	SD	P-value*
Irregularity		4.24	2.72	2.36	1.49	−1.88	2.23	$P < 0.001$	3.76	2.37	3.26	1.79	−0.50	1.09	$P < 0.01$
Rotation	Lateral incisors	79.13	17.00	71.62	10.97	−7.52	8.70	$P < 0.001$	81.13	20.71	75.39	17.75	−5.74	7.69	$P < 0.001$
	Central incisors	81.63	13.38	81.96	11.60	0.33	4.84	NS	78.80	10.60	79.08	10.37	0.28	3.00	NS
Arch width	Maxillary	39.44	2.11	39.26	2.05	−0.18	0.51	NS	38.97	2.67	39.10	2.61	0.13	0.57	NS
	Mandibular	33.52	1.85	33.34	1.87	−0.18	0.47	$P < 0.05$**	32.99	2.32	33.22	2.30	0.23	0.45	$P < 0.01$
Arch length	Maxillary	33.73	2.16	32.42	1.94	−1.31	0.88	$P < 0.001$	33.09	1.84	33.38	1.84	0.29	0.99	NS
	Mandibular	27.07	1.63	26.02	1.62	−1.05	0.78	$P < 0.001$	27.25	1.65	27.28	1.70	0.03	0.67	NS
Arch circumference	Maxillary	92.60	4.07	90.17	3.88	−2.43	1.21	$P < 0.001$	92.45	3.93	92.90	3.75	0.45	1.28	$P < 0.05$
	Mandibular	87.57	3.85	85.55	3.86	−2.02	1.72	$P < 0.001$	86.83	3.43	87.19	3.51	0.36	1.12	$P < 0.05$***
Overjet		3.34	1.39	3.00	1.36	−0.35	0.87	$P < 0.05$	2.99	1.28	3.15	1.26	0.16	0.77	NS
Overbite		2.42	1.71	3.00	1.23	0.58	1.09	$P < 0.01$	2.96	1.42	3.07	1.27	0.10	1.09	NS

SD, standard deviation.
*NS, not significant, $P < 0.05$; $P < 0.01$; $P < 0.001$.
**Mandibular arch width showed NS with Wilcoxon signed-rank test.
***Mandibular arch circumference showed NS with Wilcoxon signed-rank test.

Table 2 Differences between the extraction and control groups in alignment (millimetres and degrees) and arch dimensions (millimetres) at baseline at the 1 year follow-up and for changes over time (baseline to follow-up).

		Baseline			Follow-up			Difference between groups for changes over time		
		Mean	95% Confidence interval	P-value*	Mean	95% Confidence interval	P-value*	Mean	95% Confidence interval	P-value*
Irregularity		0.48	−0.70 to 1.67	NS	−0.89	−1.68 to −0.11	$P < 0.05$	1.37	0.51 to 2.24	$P < 0.01$
Rotation	Lateral incisors	−2.00	−8.22 to 4.22	NS	−3.77	−8.50 to 0.96	NS	1.77	−0.93 to 4.48	NS
	Central incisors	2.83	−1.09 to 6.75	NS	2.89	−0.71 to 6.49	NS	0.06	−1.43 to 1.31	NS
Arch width	Maxillary	0.47	−0.68 to 1.62	NS	0.16	−0.96 to 1.28	NS	0.31	0.06 to 0.57	$P < 0.05$
	Mandibular	0.53	−0.47 to 1.53	NS	0.11	−0.89 to 1.11	NS	0.42	0.20 to 0.63	$P < 0.001$
Arch length	Maxillary	0.64	−0.29 to 1.57	NS	−0.96	−1.84 to −0.07	$P < 0.05$	1.60	1.16 to 2.04	$P < 0.001$
	Mandibular	−0.18	−0.95 to 0.59	NS	−1.27	−2.05 to −0.48	$P < 0.01$	1.09	0.74 to 1.42	$P < 0.001$
Arch circumference	Maxillary	0.15	−1.73 to 2.03	NS	−2.72	−4.52 to −0.93	$P < 0.01$**	2.87	2.29 to 3.46	$P < 0.001$
	Mandibular	0.74	−0.96 to 2.44	NS	−1.64	−3.36 to 0.08	NS***	2.38	1.71 to 3.05	$P < 0.001$
Overjet		0.35	−0.27 to 0.98	NS	−0.15	−0.77 to 0.46	NS	0.50	0.12 to 0.89	$P < 0.05$
Overbite		−0.54	−1.27 to 0.19	NS	−0.07	−0.66 to 0.52	NS	−0.47	−0.99 to 0.04	NS****

*NS, not significant, $P < 0.05$; $P < 0.01$; $P < 0.001$.
**Maxillary arch circumference showed $P < 0.001$ with the Mann–Witney U-test.
***Mandibular arch circumference showed $P = 0.046$ with the Mann–Witney U-test.
****Overbite showed $P = 0.031$with the Mann–Witney U-test.

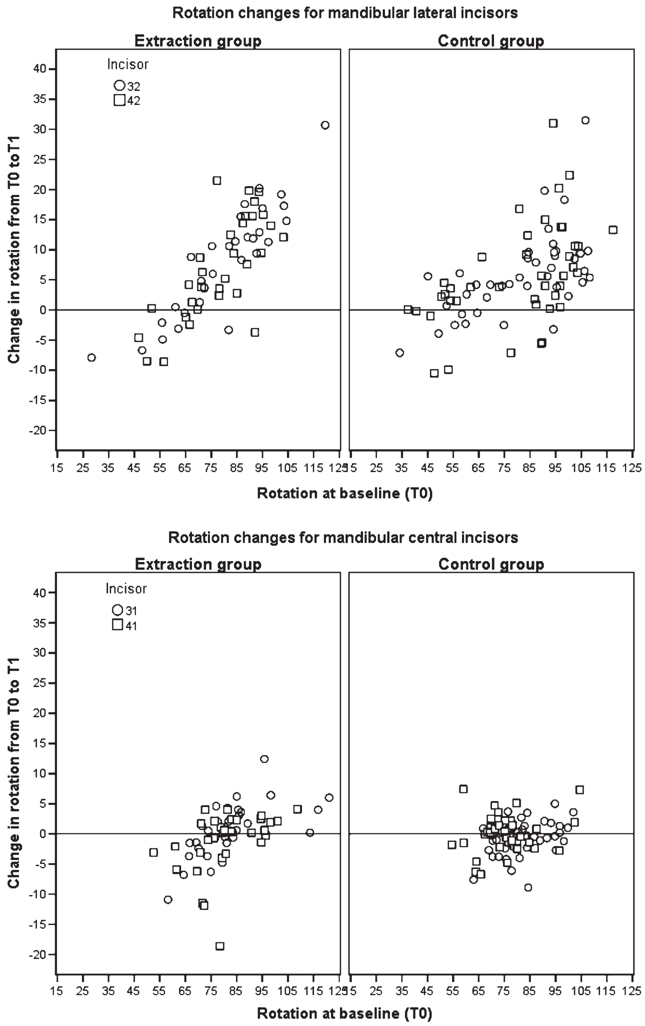

Figure 2 Distribution of initial rotation and change between baseline (T0) and the 1 year follow-up (T1) for mandibular incisors in the extraction and control groups. Lateral and central incisors are separated and marked as left and right incisors (32 and 42).

individuals rated as having a positive change in the extraction than the control group (84 versus 34 per cent, $P < 0.001$; Table 4). More parents of children in the extraction group rated changes of mandibular incisor alignment as improved after 1 year (13/32 versus 7/41, $P = 0.03$). Forty-one per cent of the parents in both groups expressed uncertainty about accurately remembering the initial status and/or correctly reporting changes in alignment.

Arch dimensions

A significant decrease in maxillary and mandibular arch length and circumference and mandibular arch width was recorded from T0 to T1 in the extraction group. In contrast, the control group displayed a significant increase in maxillary and mandibular arch circumference and mandibular arch width (Table 1). Changes over time

Table 3 Absolute change in rotation for mandibular lateral and central incisors from baseline to the 1 year follow-up in the extraction and control groups.

	Extraction group (n = 32)				Control group (n = 41)			
	Lateral incisors		Central incisors		Lateral incisors		Central incisors	
	n	%	N	%	n	%	n	%
0–5°	23	37	52	81	39	48	75	92
6–10°	13	21	7	11	26	32	7	8
11–15°	12	19	4	6	10	12	0	0
>15°	14	23	1	2	7	8	0	0

Table 4 Professional assessment regarding change in general alignment of the mandibular incisor segment from baseline to the 1 year follow-up.

	Extraction group (n = 32)		Control group (n = 41)	
	n	%	n	%
Positive change	27	84	14	34
No change	5	16	26	63
Negative change	0	0	1	3

indicated significant differences between the extraction and the control groups in maxillary and mandibular arch width, length, and circumference (Table 2). Overjet decreased and overbite increased over time in the extraction group, while no significant change was detected in the control group (Table 1).

Discussion

This study evaluated the spontaneous alignment of crowded mandibular incisors and dental arch changes 1 year after extraction of deciduous canines. Improvements in CPD and changes in rotation were greater in the extraction than the control group. Minor changes in irregularity and rotation were detectable by professional assessment. A reduction in available arch length and circumference was recorded after extraction of the deciduous canines.

The significantly greater reduction in contact point discrepancies in the extraction group should be evaluated in light of the substantial number of subjects in the control group displaying minor reductions in irregularity versus the limited number of individuals in the extraction group displaying major reductions. This indicates a heterogeneous clinical treatment effect on CPD at this point and that the control group might manifest improved alignment later during exfoliation of the primary canines and first deciduous molars. Professional assessment of alignment made it possible to detect even small changes, with a cut-off representing only half the value Kau *et al.* (2004) deemed to indicate an improvement of incisor crowding. The number of subjects assessed as having a positive change in general alignment was significantly greater in the extraction group. However, 34 per cent of control group subjects were considered improved as well, in line with the outcome of irregularity measurements.

We found it valuable to explore post-extraction changes in incisor rotation because Little's irregularity index does not include irregularities caused by rotation alone and no data on this subject were available in previous studies of spontaneous alignment. No gold standard was available for measuring the ideal rotation angle of the mandibular incisors due to variation in arch form and changes in arch form over time. The magnitude of altered incisor rotation was therefore evaluated from measurements of absolute change in rotation angle. The modest changes in rotation for incisors in general and central incisors in particular, despite an initial wide range, are not encouraging signs of spontaneous correction but could be explained by the short follow-up period. The difference in magnitude of rotational change between the lateral and central incisors was probably due to a more advanced eruption stage and somewhat smaller initial rotation range for the central than the lateral incisors.

Our efforts to establish cut-off scores for rotational changes and reduced irregularity were based on ROC analysis, indicating that orthodontists can detect very small changes in rotation. To our knowledge, no such analysis has previously been conducted, although Naraghi *et al.* (2006) did report that mean relapse of maxillary incisors was 7.3 degrees and thus should be possible, though difficult, to detect in clinic. However, the levels of sensitivity and specificity scores in the ROC analysis indicate uncertainty, probably due to lack of fixed reference points as the surrounding teeth change positions and the arch form adapts. The clinical significance of these changes remains to be evaluated from functional and aesthetic points of view.

The weak association we found between changes in scores for CPD and rotation of mandibular incisors indicates that Little's irregularity index is a blunt instrument for assessing alignment. Incisors with large CPDs due to a labio/lingual inclination and/or position probably preserved the same rotation angle during alignment, and incisors having initially small discrepancies between contact points might have rotated with no or minor changes in contact point position. The significant positive correlation between the amounts of correction and relapse for maxillary incisor rotation, but not for contact point discrepancies, found by Naraghi *et al.* (2006) further emphasizes the importance of reliable tools for evaluating rotation.

To evaluate the overall clinical outcome of the deciduous canine extractions, benefits of reduced incisor crowding must be weighed against changes in available space for permanent dentition. The decrease in arch length and circumference in the extraction group and the, at least, preserved arch dimensions in the control group hamper the positive effects of improved incisor alignment in the extraction group. If this reduction in arch dimensions increases with time, it might lead to a need for extractions in borderline cases, where an alternative treatment would be expansion of the dental arches.

A small but significant increase in mandibular arch width was seen in the control group as opposed to the extraction group and might be a sign of buccal uprighting and mesial migration of the first permanent molars. The increased mandibular arch circumference in the control group is probably related to 'secondary spacing' during the eruption of lateral incisors (Moorrees and Reed, 1965). Arch length and circumference were measured at two vertical levels. The relatively strong correlation between these two measurements implies that the shortening of arch length is not only due solely to incisor tipping but also to retrusion of the incisors and/or mesial migration of the molars, as suggested by Yoshihara *et al.* (2000) and Kau *et al.* (2004). Both the increased overbite and decreased overjet in the extraction group probably signify incisor retrusion and/or retroclination, as demonstrated by Yoshihara *et al.* (2000) and Sayin and Türkkahraman (2006).

The risk of gingival recession on blocked-out incisors in a buccal position should also be taken into consideration during evaluation of the developing early mixed dentition (Andlin-Sobocki and Bodin, 1993).

The strength of this study is its randomized clinical control design together with the early intervention, which allowed the lateral incisors in the extraction group to complete eruption with adequate space. Furthermore, cut-off scores based on ROC analysis and the professional assessment of alignment are improvements for further analysis of rotated and displaced incisors.

Measurements of deciduous canines at baseline and of permanent canines at follow-up include errors connected with canine position and with irregularity of the incisors of interest. Therefore, our method should offer a more accurate evaluation of incisor alignment on its own, even though the distal contact points of the lateral incisors are omitted. A strong correlation between baseline measurements of the three- and five-site irregularity indices in the two investigated groups, together with the fact that no significant differences could be detected between the left and the right sides in terms of irregularity or rotation, strengthens this assumption. The reduced number of measured teeth is also preferable because it can facilitate further follow-up and is more robust in relation to variations in eruption time of the permanent canines.

The professional assessment was made on plaster models from an occlusal view and therefore reflects a professional functional opinion of alignment. The parental opinion of incisor alignment was based on a more overall judgement from a frontal view and produced more positive ratings in the extraction than the control group. Since many respondents reported uncertainty (41 per cent in both the extraction and the control groups), the validity of this questionnaire is questionable. In addition, a certain amount of treatment bias could be expected. The well-known problem of rotated incisors being prone to relapse after orthodontic treatment and the different views used in observing alignment, described above, call for more sophisticated instruments to establish clinically and scientifically reliable cut-off scores for evaluating spontaneous correction of incisor crowding. The identification of cut-off scores for clinically detectable changes would probably have been more precise if a larger sample had been used. A more detailed professional evaluation scale might also have brought additional information on the magnitude of change. How alignment and arch dimensions will develop later on, when the permanent canines and premolars are erupting, has yet to be investigated. Will there be further improvement of incisor alignment in both groups, or has the potential for spontaneous correction of incisor crowding already been consumed in the extraction group, further improvement being seen only in the control group? If changes in irregularity and rotation remain at the present modest level, with wide ranges in both groups, a serious problem arises in predicting who will benefit from a treatment procedure including extraction of deciduous canines. Further research using a more extended follow-up period is necessary to evaluate the consequences for spontaneous alignment and dental arch changes.

Conclusions

One year after extraction of the deciduous canines, minor changes in overall alignment and incisor rotation were clinically detectable. Objective and subjective improvements of mandibular incisor alignment were registered in most subjects, together with a significant loss of available space. Little's index was demonstrated to underestimate malalignment related to tooth rotation.

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References

Andlin-Sobocki A, Bodin L 1993 Dimensional alterations of the gingiva related to changes of facial/lingual tooth position in permanent anterior teeth of children. A 2-year longitudinal study. Journal of Clinical Periodontology 20: 219–224

Björk A, Krebs A, Solow B 1964 A method for epidemiological registration of malocclusion. Acta Odontologica Scandinavica 22: 27–41

Dale J G, Brandt S 1976 Dr. Jack G. Dale on serial extraction. Journal of Clinical Orthodontics 10: 44–60

Dewel B 1954 Serial extractions in orthodontics: indications, objectives and treatment procedures. American Journal of Orthodontics 40: 906–926

Fastlicht J 1970 Crowding of mandibular incisors. American Journal of Orthodontics 58: 156–163

Gianelly A A 2002 Treatment of crowding in the mixed dentition. American Journal of Orthodontics and Dentofacial Orthopedics 121: 569–571

Hotz R P 1947 Active supervision of the eruption of teeth by extraction. Transactions of the European Orthodontic Society 34–47

Kau C H, Durning P, Richmond S, Miotti F A, Harzer W 2004 Extractions as a form of interception in the developing dentition: a randomized controlled trial. Journal of Orthodontics 31: 107–114

Kjellgren B 1948 Serial extraction as a corrective procedure in dental orthopedic therapy. Acta Odontologica Scandinavica 8: 17–43

Little R M 1975 The irregularity index: a quantitative score of mandibular anterior alignment. American Journal of Orthodontics 68: 554–563

Little R M 1987 The effects of eruption guidance and serial extraction on the developing dentition. Pediatric Dental Journal 9: 65–70

McKeown M 1981 The diagnosis of incipient arch crowding in children. New Zealand Dental Journal 77: 93–96

Moorrees C F, Reed R B 1965 Changes in dental arch dimensions expressed on the basis of tooth eruption as a measure of biologic age. Journal of Dental Research 44: 129–141

Naraghi S, Andren A, Kjellberg H, Mohlin B O 2006 Relapse tendency after orthodontic correction of upper front teeth retained with a bonded retainer. Angle Orthodontist 76: 570–576

Puri N, Pradhan K L, Chandna A, Sehgal V, Gupta R 2007 Biometric study of tooth size in normal, crowded, and spaced permanent dentitions. American Journal of Orthodontics and Dentofacial Orthopedics 132: 279.e7–14

Radnzic D 1988 Dental crowding and its relationship to mesiodistal crown diameters and arch dimensions. American Journal of Orthodontics and Dentofacial Orthopedics 94: 50–56

Sampson W J, Richards L C 1985 Prediction of mandibular incisor and canine crowding changes in the mixed dentition. American Journal of Orthodontics 88: 47–63

Sayin M O, Türkkahraman H 2006 Effects of lower primary canine extraction on the mandibular dentition. Angle Orthodontist 76: 31–35

Sjögren A P, Lindgren J E, Huggare J A 2010 Orthodontic study cast analysis-reproducibility of recordings and agreement between conventional and 3D virtual measurements. Journal of Digital Imaging 23: 482–492

Surbeck B, Årtun J 1998 Associations between initial, posttreatment and postretention alignment of maxillary anterior teeth. American Journal of Orthodontics 113: 186–195

Türkkahraman H, Sayin M O 2004 Relationship between mandibular anterior crowding and lateral dentofacial morphology in the early mixed dentition. Angle Orthodontist 74: 759–764

Yoshihara T, Matsumoto Y, Suzuki J, Sato N, Oguchi H 2000 Effect of serial extraction alone on crowding: spontaneous changes in dentition after serial extraction. American Journal of Orthodontics and Dentofacial Orthopedics 118: 611–616