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Long-term effect of neonatal endotracheal intubation on palatal form and symmetry in 8–11-year-old children

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SUMMARY Premature and low birth weight infants often require neonatal oral intubation for resuscitation and to relieve respiratory distress. The endotracheal tube exerts pressure on the developing palate, which can result in palatal groove formation, a high-arched palate, and palatal asymmetry. The purpose of this investigation was to determine whether such intubation can have a long-term effect on palatal form and symmetry.

Arch widths, palatal widths, and palatal depths were measured from the study casts of 43, 8–11-year-old previously intubated premature and low birth weight children using a reflex microscope, with a fixed rectangular Cartesian co-ordinate system, and compared with a group of non-intubated gender- and age-matched controls.

Significant differences were found between the intubated and non-intubated children. The intubated children had significantly narrower palatal widths posteriorly ($P \leq 0.001$), steeper palatal vaults anteriorly ($P \leq 0.01$), and exhibited a directional palatal width asymmetry with the left side of the palate measuring consistently wider than the right. These differences did not, however, appear to be affected by the length of intubation.

Therefore, it is concluded that an oral endotracheal tube might exert excess force on the developing alveolus anteriorly with the tube being displaced to the right of the palate posteriorly leading to a steep anterior palatal vault and a left-sided palatal asymmetry, which can persist until the age of 11 years of age.

Introduction

Genetic and environmental disturbances can affect intra-uterine growth and development, resulting in the birth of premature and low birth weight children. Not only are affected infants born with immature organs, but many experience life-threatening conditions in the early neonatal period, requiring interventive support procedures to sustain life. Such disturbances can result in delayed growth, with affected children failing to catch up with their peers (Hoskins *et al*., 1983), and also a delay in their general development (Portnoy *et al*., 1988; Teplin *et al*., 1991).

Many premature and low birth weight children undergo neonatal laryngoscopy and endotracheal intubation for post-partum resuscitation and thereafter to relieve respiratory distress. Previous studies have highlighted the harmful effects of prolonged intubation on the upper airway, which include: vocal cord oedema and perforation, granuloma formation, subglottic stenosis, and tracheitis (Roshi and Kuhns, 1972). A few have also reported on specific oral defects including: notching of the alveolar ridge (Boice *et al*., 1976), localized enamel hypoplasia (Krous, 1980), palatal grooving (Erenberg and Nowak, 1984), a high-arched palate (Seow *et al*., 1985), palatal asymmetry (Kopra and Davis, 1991), and acquired cleft palate (Duke *et al*., 1976). Such defects have been implicated in impaired hearing and speech, and also in the aetiology of certain dental malocclusions.

The severity and frequency of palatal grooving in previously intubated neonates has been reported both for infants (Erenberg and Nowak, 1984) and pre-school children (Fadavi *et al*.,

Figure 1 Photograph showing the palatal grooving in a neonate following endotracheal intubation.

1992), with both sets of authors concluding that use of an oral endotracheal tube results in palatal groove formation that becomes more marked with increased length of time of intubation (Figure 1). Kopra and Davis (1991) have also shown that following neonatal intubation children between the ages of 3–5 and 7–10 have an increased prevalence of high-vaulted palates, palatal grooves, and posterior crossbites, with the 3–5-year-old group also exhibiting significant palatal asymmetry.

The aim of the present study was to determine whether neonatal oral endotracheal intubation can have a long-term effect on palatal form and symmetry.

Subjects and methods

The experimental group consisted of 43 premature and low birth weight children (gestational age: 20–37 weeks; birth weights: 957–2040 g) selected from the neonatal records of the Special Care Baby Unit, John Radcliffe Hospital, Oxford. Their mean age was 10 years (range 8.4–11.1) and they had been orally intubated for an average of 15.2 days (range 1–58). All the children had also been fed orogastrically. The control group consisted of 50 normal birth weight, term children (gestational age: 39–41 weeks; birth weights: 2650–3970 g), who were between 8.9–10.8 years of age at the time of the study. They were selected from over 100 children from a local Middle School in the Oxfordshire region, and were individually matched with the study group according to age and gender. All the children were Caucasian in origin, none had a cranio-facial anomaly or history of a habit activity, and all had an intact dentition with deciduous canines, and first and second primary molars present. None of the controls had a history of oral intubation or orogastric feeding.

Skeletal pattern was assessed for each subject by palpating points A and B intra-orally, and applying the British Standards Institutions (BSI) definitions (1983). Upper and lower impressions were then taken using alginate impression material (Henry Schein Alginate Plus, Henry Schein Rexodent, Southall, Middlesex, UK) in non-perforated plastic trays (‘O’ Trays, Hawley Russell and Baker Ltd., Hertfordshire, UK) and a simple wax bite registration taken (Henry Schein Modelling Wax) with the teeth in centric occlusion using softened pink wax in the buccal segments only. The impressions were then cast within 24 hours using a 50–50 mix of plaster and white stone (Dental/Kaffir Mix, South Western Industrial Plasters, Wiltshire, UK).

Palatal measurements

On each study model, width, length, and height measurements were recorded as values of the X, Y, and Z co-ordinates of the Cartesian scale (Figure 2). Sagittal and horizontal reference planes were marked on the dental casts and from these the measurements were taken.

Reference planes

Sagittal plane. The sagittal plane was defined by the median palatal raphe, as described by Lebret (1962). This line passed from the centre of the incisive papilla (point 1) anteriorly to the posterior aspect of the cast (point 2).

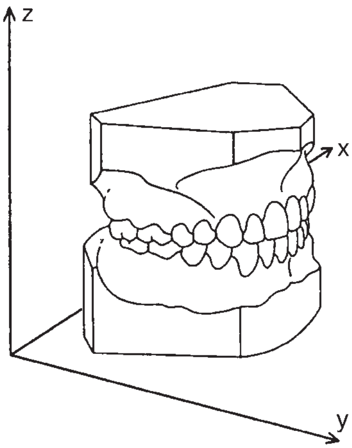

Figure 2 Diagram showing the Cartesian co-ordinates.

Horizontal plane. The horizontal plane was the peripheral outline of the palate as defined by the gingival alveolar margins of the deciduous and permanent teeth (Kopra and Davis, 1991).

Reference points

1. Canine—the cusp tips or estimated cusp tips of the deciduous canines.
2. Molar—the mesiobuccal cusp tips of the first permanent molars.
3. Gingival margins. Located by drawing tangents to the mesiopalatal and distopalatal tooth surfaces, and then projecting a line bisecting their angle of intersection to the gingival margin (Seow *et al*., 1985).
4. Median palatal raphe.

Each cast was mounted onto a dental surveyor and then overlaid with a clear plastic template with an incorporated grid (Figure 3). The grid markings were lined up with the gingival reference points and the median palatal raphe, and at the perpendicular intersection of the two a mark was made on the median palatal raphe using a 0.2-mm lead pencil in the surveyor arm (Morris *et al*., 1993).

Width measurements were taken where a perpendicular line from a specific reference point crossed the median palatal raphe. Total width was measured as the sum of right and left sides,

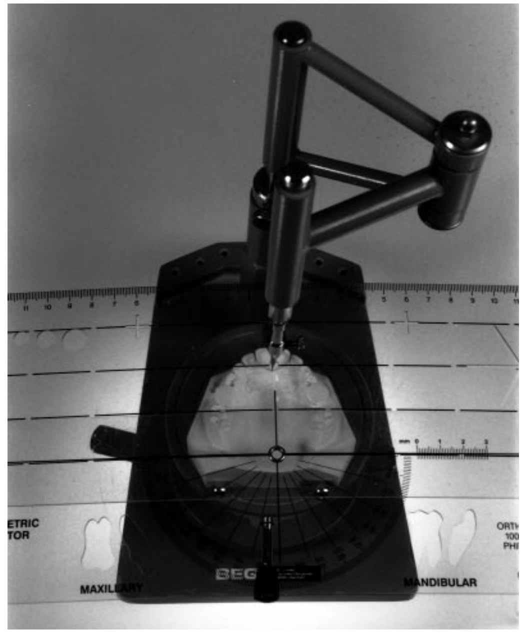

Figure 3 Photograph showing the palatal height measurements.

whilst width asymmetry was taken to be the difference between homologous measurements. Where a tooth was missing no measurement was taken.

Depth measurements were taken from the horizontal reference plane to the points marked on the median palatal raphe.

In addition, incisor classification was recorded according to British Standards Institutions definitions (1983), and the presence and severity of dental crossbites according to the numerical system of Huddart and Bodenham (1972).

Measuring instrument

A reflex microscope (Reflex Measurement Ltd, London, UK), a three-dimensional digitizer which employs stereoscopic vision, was used at ×20 magnification with a light dot of 10 µm for landmark identification. For this study, measurements were taken to the nearest 0.001-mm. The COMP3D software programme was used to analyse the co-ordinate data (Scott, 1981).

The study was approved by the Central Oxford Research and Ethics Committee.

Error of the method

The error of the method included double determination of measurements taken from the study casts. This error was calculated using Dahlberg's formula (Dahlberg, 1940):

$$S_e = \sqrt{\frac{\Sigma d^2}{2n}}$$

where d = difference between the two measurements and n = number of double determinations. The error of the method ranged from 0.111–0.211 mm, which is similar to that recorded for other studies (Speculand *et al.,* 1988).

Analysis

Statistical analysis of the data was performed using the SPSS for Windows (SPSS Incorporated, Chicago, USA) computer package. As no significant differences were found between genders, males and females were pooled for all analyses.

Independent t-tests were performed to test for differences in the effects of length of intubation (Table 1), and palatal widths and heights (Table 2), chi-squared tests for group differences in skeletal pattern and incisor relationship (Table 3), a one-way analysis of variance for arch widths (Table 4), and a one sample t-test for palatal width asymmetry (Table 5). In view of the small numbers recorded for dental crossbites, this data was not subjected to comparative statistical analysis.

Results

To determine the effects of the length of time of intubation on palatal width asymmetry and/or palatal height dimensions, the intubated children were divided into two groups: those who had been intubated for less than or equal to 15 days (n = 23), and those who had been intubated for more than 15 days (n = 20). Independent t-tests revealed no differences at any level between groups (Table 1). No statistically significant differences were found between groups in skeletal pattern and incisor relationship (Table 3), or arch widths (Table 2), although it was noted that there were slightly more subjects with Class III malocclusions in the intubated group and, with the exception of lower inter-canine width, all

Table 1 Intubated children by length of intubation (independent t-test).

Variable	Intubated ≤15 Days			Intubated >15 Days							
	Number of cases	Mean difference (mm)	SD	Number of cases	Mean difference (mm)	SD	Mean difference (mm)	95% CI for mean differences	t-value	df	P-value
Palatal widths											
1-1	23	–0.25	0.47	20	–0.18	0.53	–0.07	–0.59–0.49	–0.280	41	0.789 NS
2-2	23	–0.16	0.77	20	–0.03	1.55	–0.14	–1.28–1.00	–0.250	41	0.802 NS
C-C	21	–0.31	1.11	18	0.14	1.35	–0.45	–1.81–0.92	–0.700	37	0.496 NS
D-D	20	–0.16	1.21	17	–1.89	0.84	1.72	0.45–3.00	2.890	35	0.090 NS
E-E	21	–0.84	1.40	20	–1.73	1.46	0.89	–0.68–2.47	1.220	39	0.243 NS
6-6	23	–0.81	1.32	20	–0.74	2.15	–0.08	–1.79–1.64	–0.090	41	0.928 NS
Palatal heights											
1	23	0.75	0.63	20	0.44	0.37	0.31	–0.29–0.90	1.100	41	0.288 NS
2	23	1.64	0.86	20	1.71	0.77	–0.07	–0.96–0.81	–0.170	41	0.866 NS
C	21	5.86	1.12	18	5.21	1.36	0.65	–0.73–2.03	1.010	37	0.328 NS
D	20	10.02	1.27	17	9.42	1.79	0.59	–1.03–2.21	0.780	35	0.450 NS
E	21	11.85	1.34	20	11.88	1.60	0.02	–1.58–1.53	–0.030	39	0.974 NS
6	23	11.33	1.55	20	11.10	2.02	0.23	–1.58–2.05	0.270	41	0.788 NS

NS, not significant at $P \geq 0.05$.

Table 2 Study groups by arch widths (one-way analysis of variance).

	Mean arch widths (mm)							
	Intubated children	Non-intubated children	Comparison groups	Sum of squares	df	Mean of squares	F test	Significance (P-value)
			Between groups	28.94	3	9.65		
UC-C	29.96	30.83	Within groups	518.41	84	6.17	1.563	0.204 NS
			Total	547.35	87			
			Between groups	8.54	3	2.85		
LC-C	24.63	5.32	Within groups	210.80	85	2.48	1.148	0.334 NS
			Total	219.35	88			
			Between groups	33.91	3	11.30		
U6-6	48.30	49.00	Within groups	717.28	89	8.06	1.403	0.247 NS
			Total	751.19	92			
			Between groups	27.45	3	9.15		
L6-6	42.75	43.283	Within groups	463.15	89	5.20	1.758	0.161 NS
			Total	490.60	92			

NS, not significant at $P \geq 0.05$.

Table 3 (a) Study groups by skeletal pattern.

Skeletal pattern	Groups	
	Intubated (%)	Non-intubated (%)
Skeletal I	26 (60)	33 (66)
Skeletal II	9 (21)	11 (22)
Skeletal III	8 (19)	6 (12)
Total	43 (100)	50 (100)
Chi-squared test	$\chi^2 = 0.79$; df (2); $P = 0.67$; NS	

Table 3 (b) Study groups by incisor relationship.

Incisor relationship	Groups	
	Intubated (%)	Non-intubated (%)
Class I	23 (53)	28 (56)
Class II division 1	8 (19)	9 (18)
Class II division 2	3 (7)	6 (12)
Class III	9 (21)	7 (14)
Total	43 (100)	50 (100)
Chi-squared test	$\chi^2 = 1.30$; df (3); $P = 0.73$; NS	

Figures in parentheses represent percentage of children.
NS, not significant at $P \geq 0.05$.

arch widths were slightly higher in the control group.

Palatal widths were shown to be statistically narrower at the level of the second deciduous molars ($P \leq 0.001$) and first permanent molars ($P \leq 0.001$), when compared with the control group children (Table 4). When the differences between contralateral reference points were measured a directional palatal width asymmetry was revealed with the left side of the palate being consistently wider than the right (Table 5). These differences were again shown to be statistically significant at the level of the second deciduous molars ($P \leq 0.05$) and first permanent molars ($P \leq 0.05$) in those children who had been intubated. Palatal heights were also significantly steeper in the intubated children at the level of the central ($P \leq 0.01$) and lateral ($P \leq 0.01$) incisors (Table 4).

The prevalence of posterior crossbites in the intubated group was low (11 per cent, including those with a crossbite tendency).

Discussion

There are several factors that might account for the abnormal palatal form seen in premature and low birth weight infants. The narrow high-vaulted palate may be an oral manifestation of

Table 4 Study groups by palatal width and height (independent *t*-test).

Variable	Intubated children			Non-intubated children			Mean difference (mm)	95% CI for mean differences	*t*-value	df	*P*-value
	Number of cases	Mean (mm)	SD	Number of cases	Mean (mm)	SD					
Palatal widths											
1-1	43	6.18	0.70	50	6.88	1.00	0.71	0.32–1.00	0.775	91	0.473 NS
2-2	43	16.67	1.61	50	17.56	1.61	0.89	0.42–1.23	0.981	91	0.586 NS
C-C	41	22.54	1.42	48	24.00	1.96	1.46	0.76–3.65	2.784	87	0.210 NS
D-D	40	24.14	2.42	47	26.30	2.05	2.15	1.25–4.06	3.522	85	0.067 NS
E-E	41	27.03	2.17	50	29.83	2.32	2.80	1.27–4.34	3.654	89	0.001***
6-6	43	29.37	1.91	50	32.04	2.25	2.68	1.27–4.09	3.811	91	0.001***
Palatal heights											
1	43	0.65	0.57	50	0.29	0.23	–0.36	–0.61–0.10	–2.847	91	0.007**
2	43	1.66	0.81	50	0.98	0.71	–0.68	–1.15–0.21	–2.907	91	0.006**
C	41	5.66	1.20	48	5.33	1.11	–0.32	–1.08–0.43	–0.863	87	0.394 NS
D	40	9.84	1.41	47	9.64	1.48	–0.19	–1.13–0.74	–0.421	85	0.676 NS
E	41	11.86	1.39	50	12.22	1.44	0.36	–0.55–1.27	0.797	89	0.430 NS
6	43	11.25	1.66	50	11.28	1.74	0.03	–1.03–1.10	0.061	91	0.952 NS

NS, not significant at $P \geq 0.05$; *$P \leq 0.05$, significant; **$P \leq 0.01$, highly significant; ***$P \leq 0.001$, very highly significant.

Table 5 Palatal width asymmetry in the intubated children (one sample *t*-test).

Variable	Number of cases	Mean difference between right and left sides (mm)	95% CI	*t*-value	df	*P*-value
UR1–UL1	43	–0.23	–0.463–0.008	–2.038	42	0.057 NS
UR2–UL2	43	–0.12	–0.637–0.401	–0.479	42	0.638 NS
URC–ULC	41	–0.17	–0.784–0.453	–0.569	40	0.577 NS
URD–ULD	40	–0.68	–1.370–0.026	–2.040	39	0.058 NS
URE–ULE	41	–1.18	–1.943–0.405	–3.253	39	0.050*
UR6–UL6	43	–0.79	–1.568–0.003	–2.119	41	0.049*

NS, not significant at $P \geq 0.05$; *significant at $P \leq 0.05$.

the typical narrow elongated head of the preterm infant or the head posture in the incubator may contribute to palatal collapse. Orotracheal and orogastric tubes may press on the alveolar ridge and mid-line of the palate, disturbing palatal growth, and the descent of the maxilla. This pressure may be increased by the tape securing the tubes in position.

In the present study differences in palatal width were seen at the level of the second deciduous molars and first permanent molars. This might be explained by the effects of oral intubation, which has been reported to cause narrowing of the palatal vault posteriorly (Ash and Moss, 1987; Kopra and Davis, 1991; Fadavi *et al.*, 1992). Palatal widths were consistently wider on the left-hand side in both the intubated and the non-intubated children, with differences being statistically significant at the level of the second deciduous molars ($P \leq 0.05$) and first permanent molars ($P \leq 0.05$) in the intubated group (Table 5). Previous studies have recorded asymmetry as mean differences between right and left sides (Seow *et al*., 1985; Kopra and Davis, 1991). However, by recording all differences as positive values it is impossible to determine which side is asymmetric.

Although it was hospital procedure to position the oral endotracheal tube against the mid-line of the palate, Gregory (1972) has shown that true stabilization is only achieved extra-orally. This leaves open the possibility for intra-oral tube displacement posteriorly towards the side of the prone nursing position, which is on the right in premature and low birth weight children to aid gastric emptying (Klaus and Fanaroff, 1993). This displacement could, feasibly, affect posterior palatal width dimensions as a result of palatal moulding around the tube (Ash and Moss, 1987). Although there are no well-documented studies to elucidate a relationship between sleep position, intra-oral tube position and palatal asymmetry, prone sleep position has been shown to promote dolichocephaly (a long, narrow head) and cranial moulding on the side on which the infant is nursed (Updike *et al*., 1986).

In the current study, palatal heights were significantly steeper at the level of the central incisors (mean difference 0.357 mm) and at the level of the lateral incisors (mean difference 0.678 mm) in the intubated children, which is in agreement with Kopra *et al*. (1988), who observed high-vaulted palates in a group of previously intubated 3–5-year-old children, and Kopra and Davis (1991) who reported similar findings in a group of 7–10-year-old children.

Several theories have been put forward to account for the steep anterior palatal vaults in young children. These include: leverage forces from the laryngoscope (Seow *et al*., 1984), pressure from the endotracheal tube on the anterior alveolus (Boice *et al*., 1976; Duke *et al*., 1976; Saunders and Easa, 1977; Wetzel, 1980), inhibition of the moulding effect of the tongue on the lateral palatine ridges (Hanson *et al*., 1976; Behrstock *et al*., 1977; Saunders and Easa, 1977), and constriction of the palate adjacent to the tube (Biskinis and Hertz, 1978). However, Larsson (1972) has commented on the remodelling capability of the palate, reporting spontaneous correction of palatal deformities following cessation of a prolonged habit activity in older children, whilst Seow *et al*. (1985) have reported smoothing out of palatal grooves within 5 years of oral extubation. Interestingly, no palatal grooves were detected amongst the intubated children despite their palates being steeper anteriorly.

In this study, the prevalence of posterior crossbites in the intubated group is comparable to that recorded for the general population (7–10 per cent; Björk *et al*., 1964). This is in contrast to the 25 per cent found in a similar study (Kopra and Davis, 1991) and is surprising considering that mean palatal widths were found to be significantly narrower ($P \leq 0.05$) at the level of the first permanent molars on the right-hand side in these children.

Duration of intubation is an important factor in determining the severity of its iatrogenic effects (Fadavi *et al*., 1992). However, in this study, length of intubation was found to have no effect on the prevalence or site of high-vaulted palates or palatal asymmetry (Table 1), posterior crossbites not being compared, due to the very small numbers involved.

Conclusions

It may be concluded that neonatal endotracheal intubation may be a contributing factor on the long-term form of the palate. By exerting excess force on the developing alveolus anteriorly and by becoming displaced to the right of the palate posteriorly, the tube may help produce a steep anterior palatal vault and a left-sided palatal asymmetry, which persists at least until the age of 11. It is therefore suggested that neonates be closely monitored during the intubation period and be followed up longitudinally.

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