Review Article

A Systematic Review of the Consequences of Premature Birth on Palatal Morphology, Dental Occlusion, Tooth-Crown Dimensions, and Tooth Maturity and Eruption

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Abstract: This systematic review addresses the question whether prematurity results in alteration of palatal morphology, dental occlusion, tooth-crown dimensions, and tooth maturation. A literature survey from the PubMed database covering the period from January 1966 to November 2002 used the Medical Subject Headings terms ''infant, premature,'' and ''infant, low birth weight'' in combination with ''jaws,'' ''dental physiology,'' ''dentition,'' and ''tooth abnormalities.'' Controlled studies written in English and with definitions of premature birth according to the World Health Organization were selected. Two reviewers selected and extracted the data independently and also assessed the quality of the studies. The search strategy resulted in 113 articles, of which 13 met the inclusion criteria. Scientific evidence was found for altered palatal morphology in the short term among the premature children, and oral intubation was a contributing factor to the alterations. If corrected age was considered for the premature children, no delay in dental development and eruption was found compared with normally born children. Thus, the early birth of premature children must be taken in account when planning for orthodontic treatment. Because of the contradictory results and lack of longitudinal studies, the scientific evidence was too weak to answer the questions whether premature birth causes permanent alteration of palatal morphology, alteration of dental occlusion, and altered tooth-crown dimensions. To answer these questions and obtain reliable scientific evidence whether premature children are at risk for malocclusions from possible alterations of palatal morphology such as asymmetry and high arched palates, further well-designed controlled studies as well as longitudinal studies are needed. (*Angle Orthod* 2004;74:269–279.)

Key Words: Premature birth; Oral intubation; Palatal morphology; Tooth eruption; Tooth size

INTRODUCTION

Prematurity

As defined by the World Health Organization (WHO), a premature birth is one that occurs before 37 weeks of gestation or in which the birth weight is below 2500 g. The incidence of premature birth varies widely among different populations and is generally correlated with differences in living conditions between the developing and the developed countries. The incidence ranges between 5% and 10% in Europe, North America, Australia, and parts of South America, whereas it lies between 10% and 30% in many countries in Africa and in Southeast Asia.[1] The etiology of premature birth is multifactorial and may be related to disease in the fetus or in the mother, although, in about half the cases, the etiological factors are unknown.[1,2] Recent epidemiological, microbiological, and immunological studies have suggested that maternal periodontal disease may be an independent risk factor for preterm (PT) low birth weight (LBW). Postulated mechanisms include translocation of periodontal pathogens to the fetoplacental unit and action of a periodontal reservoir of lipopolysaccharides or inflammatory mediators. However, noncausal explanations for the correlation between periodontitis and PT LBW can also be offered.[3] Nevertheless, it has been shown that periodontal therapy significantly reduces the rates of PT LBW in a population of women with periodontal disease.[4]

The weight of an infant at birth is usually accepted as the best index of prematurity. Premature infants are classified into one of the following three groups: LBW, <2500 g; very low birth weight (VLBW), <1500 g; and extremely

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Accepted: May 2003. Submitted: March 2003.

low birth weight (ELBW), <1000 g.[5] However, a new classification, which is based on gestational age, has been introduced recently. It has been claimed that the ultrasonographically determined gestational age describes the maturity of infants better. Thus, infants are categorized as PT if they are born in the gestational week 33–36, very PT (VPT) if they are born in the gestational week 29–32, and extremely PT (EPT) if they are born before the 29th gestational week.[6] The great improvement in neonatal health and intensive care in the past 20 years has led to increasing survival of premature infants, especially EPT/ELBW infants.[7,8]

Complications of prematurity

Premature infants are poorly prepared for extrauterine life. Especially, VPT and EPT infants require many weeks of intensive neonatal care. Many serious complications may occur in nearly all the major organ systems. The brain, the lungs, and the eyes are the most susceptible organs. Furthermore, the infants are at increased risk of infections either at or shortly after birth or at a later age.[2,9] Because premature infants often have respiratory distress syndrome resulting from immature lung tissues and a deficiency of surfactant (the mixture of lipoproteins excreted by the alveolar epithelium that lowers surface tension), they have to be treated with oxygen ventilation through an oro- or nasotracheal tube in combination with surfactant administration. Oxygen can also be supplemented with continuous positive airway pressure.[9] Infants aged 35–36 gestational weeks are mature enough to suck and swallow milk. Less mature infants will need to be fed with breast milk supplemented with proteins, calories, and minerals through an oro- or nasogastric tube.[9]

The early and long-term effects of premature birth on the physical and psychological growth and development of a child have been subjects of considerable interest. Many studies have indicated that in early childhood, PT children show significant delay in many areas of physical and psychological growth and development.[10–12] PT children, especially EPT children, were shorter, had lower weight, and had a smaller head circumference than full-term controls.[6] Also, less muscle mass has been reported among PT children.[13] Behavioral symptoms observed in PT children included increased rate of hyperactivity, difficulties in concentration, and below-grade-level performance at school.[6,11]

Oral defects

Like other tissues and organs of the body, the facial bones and dentition can be affected by premature birth. Most studies on oral defects have shown that premature birth can cause enamel defects, classified as quantitative loss of enamel (hypoplasia), qualitative change in the translucence (opacity) of the enamel, or a combination of both. These effects are usually located on the primary teeth, which are undergoing mineralization around the time of the premature birth, although even permanent teeth can be affected.[14] The pathogenesis is considered multifactorial, the most important factor being calcium disturbances in the neonatal period. However, contributing causes of the enamel defects include local trauma from laryngoscopic and endotracheal intubation, which abuts against the maxillary anterior alveolar ridge.[15]

Other defects, such as notching of the alveolar ridge, palatal grooving, high arched palate, dental crossbite, and palatal asymmetry, have also been reported with higher frequencies when compared with full-term controls. Moreover, delayed eruption and developmental defects of both the primary and permanent dentitions have also been noted.[14] Many of the studies considering altered morphology have also highlighted that pressure from the oro- or nasotracheal tube or direct trauma from the laryngoscope when the tube is placed might account for the defects.[16] Thus, the presence of the tube on the palate can conceivably inhibit a normal growth process, and it has also been discussed whether altered morphology of the alveolar ridge and palate can be eliminated by compensating remodeling and growth.[15]

Conceivably, the altered palatal morphology can lead to an increase in malocclusions such as crossbite, resulting in an increasing need for orthodontic treatment. Moreover, changes in the path of eruption of teeth, which can influence the occlusion and tooth spacing, can also contribute to an increasing need for orthodontic treatment.

To date, several case reports and case series as well as cross-sectional and longitudinal studies have been published, providing insight into the response of palatal morphology, dental occlusion, and tooth maturity and eruption to premature birth and neonatal medical care. However, it is difficult to interpret whether the increased frequency of these defects depends only on premature birth or whether the increased frequency could be influenced by extrinsic factors such as neonatal intubation. Because of different definitions of prematurity, ie, with respect to birth weight and gestational age, and confounding factors such as intubation, the results and conclusions in many studies are sometimes conflicting and may be difficult to compare and interpret. Because it is time consuming for practitioners to read and analyze every article, they may rely on literature reviews. Even if many reviews are well designed,[14–16] they most often are biased because of the lack of formal methodology and inclusion criteria.[17] In view of this and because evidence-based medicine has grown in importance,[18] a systematic review of the present knowledge seems motivated. Systematic reviews locate, appraise, and synthesize evidence from scientific studies to provide informative answers to scientific questions by including a comprehensive summary of the available evidence.[19] This systematic review was undertaken to answer the following important questions:

- Does prematurity result in alterations of palatal morphology, dental occlusion, tooth-crown dimensions, and tooth maturation and eruption?
- What role does oral intubation play in the appearance of the alterations?
- Are the alterations in morphology permanent or transient?

Furthermore, a quality analysis of the methodological soundness of the studies in the review was performed.

MATERIALS AND METHODS

Search strategy

The method for undertaking this systematic review was influenced mainly by the National Health Service Centre for Reviews and Dissemination[19] and The Cochrane Collaboration Handbook.[20] To identify all studies that examined the relationship between premature birth and alterations of palatal morphology, dental occlusion, tooth-crown dimensions, and tooth maturity and eruption, a literature survey was performed using the Medline database (EntrezPubMed, www.ncbi.nim.nih.gov). The survey covered the period from January 1966 to November 2002 and used the Medical Subject Headings terms ''infant, premature and jaw,'' ''infant, low birth weight and jaw,'' ''infant, premature and dentition,'' ''infant, low birth weight and dentition,'' ''infant, premature and dental physiology,'' ''infant, low birth weight and dental physiology,'' ''infant, premature and tooth abnormalities,'' and ''infant, low birth weight and tooth abnormalities.''

Selection criteria

Controlled studies published as full-length articles reporting quantitative data on the effects of premature birth on jaws, dentition, dental physiology, and tooth abnormalities were selected. A premature birth was defined either as one that occurs before the 37th gestational week or as one in which the birth weight is below 2500 g. No restrictions were placed on sample size, but case series without controls, case reports, abstracts, letters, and review articles were not considered. Only papers written in English were included. All the exclusion criteria and the number of excluded articles are listed in detail in Table 1. The reference lists of the retrieved articles were also checked for additional studies. Two independent reviewers (Drs Paulsson and Bondemark) assessed all the articles with respect to the inclusion and exclusion criteria. Interexaminer conflicts were resolved by discussion of each article to reach a consensus.

Data collection and analysis

Data were extracted on the following items: year of publication, definition of prematurity (birth weight, gestational age, or both), sample size, material and age, methods and measurements, and outcomes and authors' conclusions. Also, correlation between prematurity and deformity or alteration, intubation and deformity, and sucking habit and deformity were considered (for details, see Tables 2–4). Additionally, to document the methodological soundness of each article, a quality evaluation modified by the methods described by Jadad et al[21] and Antczak et al[22] was performed with respect to preestablished characteristics. The following nine characteristics were used: sample size, selection description, description of prematurity/control, withdrawals declared, valid methods, confounding factors considered, method error analysis, blinding in measurements, and adequate statistics. The quality of each article was categorized as low (three or less characteristics fulfilled), medium (four to seven characteristics fulfilled), or high (eight or nine characteristics fulfilled).

The data were extracted from each article by two independent evaluators (Drs Paulsson and Bondemark) and without blinding. Interexaminer conflicts were resolved by discussion of each article to reach a consensus. One author (Dr Söderfeldt) performed the statistical evaluation.

TABLE 1. Exclusion Criteria and Number of Excluded Articles in This Systematic Review

Exclusion Criteria	Number of Excluded Articles
Case reports and case series	13
Review articles, abstracts, and letters	7
Studies concerning medical and intensive neonatal care	25
Studies concerning equipment in neonatal care	8
Craniofacial syndrome diagnosis	18
Studies concerning enamel defects	20
Papers written in a language other than English	
Polish	4
Russian	2
Bulgarian	1
French	1
Serbo-Croatian	1
Total number	100

RESULTS

The search strategy resulted in 113 articles. After selection according to the inclusion/exclusion criteria, 13 articles[23–35] remained to be qualified for the final analysis. The reasons for exclusion and the number of excluded articles are listed in Table 1.

Of the remaining 13 articles, five[23–27] concerned altered palatal morphology including altered dental occlusion, ie, crossbite, five[28–32] concerned altered dental maturation/development and eruption, and three[33–35] were regarding altered tooth-crown dimensions. Twelve studies were cross-sectional, and one was longitudinal.[32]

Of the 13 studies, five were performed in the United

TABLE 2. Summarized Data of the Five Studies Concerning Palatal Morphology and Crossbite[a]

Article	Birth Weight, g/Gestational Age, wk	Material and Age	Methods/ Measurements	Correlation: Intubation/ Deformity	Correlation: Prematurity/ Deformity	Correlation: Sucking Habit/ Deformity	Outcomes and Authors' Conclusions
Seow et al[23]	P: mean, 1213 g; range, 605–1500 g	49 (23 boys, 26 girls) of whom 18 were intubated and 31 were not Age: 2–5 y	Medical records Study models Olivetti inspector machine	No	Not analyzed	Sucking habits excluded	No asymmetry of the palate in the intubated group compared with the nonintubated group Growth and remodeling of the palate probably repair any deformity of the palate resulting from intubation
Kopra and Davis[24]	P: two groups PI: mean, 993 g; range, 595–1247 g; mean, 29 wk; range, 25–36 wk PII: mean, 1044 g; range, 537–1616 g; mean, 29 wk; range, 22–33 wk C: two groups CI: NBW/full term CII: mean, 3486 g; range, 1814–4173 g; full term	PI: 43 (gender not declared) CI: 40 (gender not declared) Age: 3–5 y PII: 47 (gender not declared) CII: 44 (gender not declared) Age: 7–10 y All prematures had been intubated	Medical records Study models Optical gauging Questionnaire to the parents	Yes, but not by the duration of intubation	Not analyzed	Sucking habits excluded	3–5-y-old children High-vaulted palate: PI 63% and CI 10% (PI/CI: $P < .01$) Palatal groove: PI 15% and CI 0% (PI/CI: $P < .05$) Crossbite: PI 22% and CI 2% (PI/CI: $P < .05$) 7–10-y-old children High-vaulted palate: PII 62% and CII 9% (PII/CII: $P < .01$) Palatal groove: PII 23% and CII 0% (PII/CII: $P < .01$) Crossbite: PII 21% and CII 2% (PII/CII: $P < .05$) Strong support for intubation as a cause of oral defects
Fadavi et al[25]	P: mean, 1151 g; range, 520–2268 g; mean, 29 wk; range, 28–38 wk C: full term	P: 52 (gender not declared) C: 45 (gender not declared) Age: 2–5 y All prematures had been intubated	Study models Plastic ruler and an adjustable template	Moderate, to duration of intubation	Strong	Not analyzed	In P, 70% high palatal vault and 25% palatal grooving In P, 17% crossbite and in C, 15% (NS) Prolonged intubation leads to significant palatal defects
Procter et al[26]	P: two groups PI < 32 wk PII 32–35 wk C: >36 wk	P: 56 (gender not declared) PI: 27, PII: 29 C: 20 (gender not declared) Age: 0–1 y 48/56 had been intubated	Study models Reflex microscope	Yes, prolonged intubation	No	Not analyzed	Wide variation in palatal shape Prolonged intubation leads to small and temporary increase in palatal depth Gestation and postmenstrual age have no effect
Macey-Dare et al[27]	P: range, 957–2040 g; range, 20–37 wk C: NBW/full term	P: 43 (gender not declared) Age: 8.4–11.4 y C: 50 (gender not declared) Age: 8.9–10.8 y All prematures had been intubated	Medical records Study models Reflex microscope	Yes, but not by the duration of intubation	Not analyzed	Unclear	In P, significantly narrower palatal widths posteriorly ($P < .001$), steeper palatal vaults anteriorly ($P < .01$), and more asymmetry ($P < .05$) Intubation can be a contributing factor to the long-term form of the palate

[a] P indicates premature group; C, control group, ie, NBW (>2500 g) or full-term birth (>37 gestational weeks); NBW, normal birth weight; and NS, not significant.

TABLE 3. Summarized Data of the Five Studies Concerning Tooth Development and Eruption[a]

Article	Birth Weight, g/Gestational Age, wk	Material and Age	Methods/ Measurements	Correlation Prematurity/Tooth Development and Eruption	Outcomes and Authors' Conclusions
Golden et al[28]	P: four groups I: 26–28 wk II: 29–31 wk III: 32–34 wk IV: 35–37 wk C: full term	P: 129 (gender not declared) I: 8 II: 24 III: 50 IV: 47 C: 38 (gender not declared) Age: 2–3 y	Primary dentition Clinical examination Questionnaire Chronological/corrected age considered	No	On the basis of chronological age, P got their first tooth later than C On the basis of corrected age, P got their first tooth at the same time as C
Seow et al[29]	P: two groups PI (VLBW): mean, 1179 g; range, 783–1499 g; mean, 29 wk; range, 24–33 wk PII (LBW): mean, 2176 g; range, 1577–2486 g; mean, 37 wk; range, 32–41 wk C: NBW/full term	PI: 73 (30 boys, 43 girls); mean age, 2.0 y PII: 33 (14 boys, 19 girls); mean age, 2.1 y C: 47 (22 boys, 25 girls); mean age, 2.5 y	Primary dentition Clinical examination Medical records Chronological/corrected age considered	Yes, the lower the birth weight, the more delayed the eruption	On the basis of chronological age, PI (VLBW) has retardation of eruption compared with PII (LBW) and C ($P <$ .01) On the basis of corrected age, there is no difference between the groups, indicating that the delay in eruption in PI (VLBW) may be attributable to the early birth
Harris et al[30]	P: <2000 g; mean, 32 wk; range, 24–40 wk C: full term	P: 66 (gender not declared); mean age, 5.5 y C: 76 (matched for age and gender)	Permanent dentition Dental maturity/dental age Panoramic radiographs Difference between dental age and chronological age	Not analyzed	In P, there is delayed dental development of permanent incisors and first molars ($P < .05$) All other teeth are unaffected
Seow[31]	P: mean, 1203 g; range, 652–1499 g; mean, 30 wk; range, 24–35 wk C: NBW/full term	P: 55 (25 boys, 30 girls); mean age, 7.7 y C: 55 (25 boys, 30 girls); mean age, 7.7 y	Permanent dentition Dental maturity/dental age Panoramic radiographs Difference between dental age and chronological age	Yes, the lower the birth weight, the more delayed the dental development	In P, there is delayed dental development ($P < .02$) Greatest delay in those younger than 6 y of age In children aged 9 y or older, no delay, showing that catch-up had occurred
Backström et al[32]	P: mean, 1505 g; range, 690–1930 g; mean, 31.5 wk; range, 23.5–35 wk C: full term	P: 30 (14 boys, 16 girls) I: age 1–2 y II: age 9–11 y C: two different groups I: 60 (28 boys, 32 girls); mean age, 2 y II: 60 (28 boys, 32 girls); age 9–11 y	Longitudinal study Clinical examination Chronological/corrected age considered Dental maturity/dental age of permanent dentition Panoramic radiographs	No	First longitudinal study to follow primary and permanent tooth maturation in the same preterm children Premature birth had no appreciable late sequelae in tooth maturation or primary/permanent dentition In P, first tooth later for girls ($P < .01$) and also later than girls in C ($P < .02$)

[a] P indicates premature group; C, control group, ie, NBW (>2500 g) or full-term birth (>37 gestational weeks); NBW, normal birth weight; VLBW, very low birth weight; and LBW, low birth weight.

States,[24,25,28,30,35] four in Australia,[23,29,31,34] three in the UK,[26,27,33] and one in Finland.[32]

Palatal morphology and crossbite

Summarized data of the five studies concerning palatal morphology and crossbite are listed in Table 2. All studies were cross-sectional, and all had a full-term control group except one study[23] in which two groups of premature children were compared, one intubated and one nonintubated.

Four studies[24–27] found a positive correlation between altered palatal morphology (grooves, asymmetries, and high-vaulted palate) and oral intubation, whereas Seow et al[23] did not. Fadavi et al[25] found a moderate correlation between the duration of oral intubation and the prevalence of altered morphology, whereas Kopra and Davis[24] and Macey-Dare

TABLE 4. Summarized Data of the Three Studies Concerning Tooth-Crown Dimensions[a]

Article	Birth Weight, g/Gestational Age, wk	Material and Age	Methods/ Measurements	Correlation Prematurity/ Tooth Dimensions	Outcomes and Authors' Conclusions
Fearne and Brook[33]	P: range, 840–1990 g; range, 27–37 wk C: NBW	P: 72 (35 boys, 37 girls); mean age, 7 y C: 58 (31 boys, 27 girls); mean age, 7 y	Primary molars and canines Medical records Study models Dial calipers	Yes, the lower the birth weight, the smaller tooth-crown dimensions	In P, smaller mesiodistal tooth-crown and smaller buccolingual dimensions ($P < .001$) in all but the first primary molars No association of neonatal illness and tooth size
Seow and Wan[34]	P: two groups PI (VLBW): mean, 1265 g; range, 695–1498 g; mean, 31 wk; range, 24–35 wk PII (LBW): mean, 2202 g; range, 1820–2470 g; mean, 36 wk; range, 34–37 wk C: NBW/full term	P: 111 (53 boys, 58 girls); PI (VLBW), 86; PII (LBW), 25; age not declared C: 169 (84 boys, 85 girls); age not declared	Primary incisors Medical records Donated natural exfoliated and extracted teeth Digital micrometer	Yes, the lower the birth weight, the smaller the tooth-crown dimensions	In PI (VLBW), 6–12% smaller tooth-crown dimensions compared with C ($P < .001$) In PII (LBW), intermediate dimensions Maxillary and mandibular left lateral incisors of VLBW children significantly smaller compared with the right side
Harila-Kaera et al[35]	P: two groups PI: <36 wk (white children) PII: <35 wk (black children) C: full term	PI: 60 (40 boys, 20 girls) PII: 268 (140 boys, 128 girls) C: 803 white (408 boys, 395 girls); 1001 black (477 boys, 524 girls); age: 5–14 y	Permanent incisors and first molars Medical records Clinical examination Study models Electronic calipers	Not analyzed	In P, both decreased and increased tooth-crown dimensions compared with C The increased dimensions differ from earlier reports Environmental factors including neonatal factors are important in determining tooth-crown size

[a] P indicates premature group; C, control group, ie, NBW (>2500 g) or full-term birth (>37 gestational weeks); NBW, normal birth weight; VLBW, very low birth weight; and LBW, low birth weight.

et al[27] found no such correlation. In studies of the correlation between birth weight per se and palatal deformities, Fadavi et al[25] found that the lower the birth weight, the more the deformities, whereas Procter et al[26] found no such correlation.

Two studies[24,27] showed that altered palatal morphology persisted up to 10 years of age and claimed that oral intubation was a contributing factor for the long-term form of the palate. On the other hand, Seow et al[23] claimed that growth and remodeling of the palate probably had repaired the deformities resulting from the intubation process because no difference in palatal morphology could be detected between intubated and nonintubated two- to five-year-old children.

Fadavi et al[25] found no significant difference between the premature and control groups regarding the prevalence of crossbite in the primary dentition. However, Kopra and Davis[24] found a significantly higher prevalence of crossbite among both three- to five-year-old PT children and 7- to 10-year-old PT children (Table 2).

Tooth maturation/development and eruption

Summarized data of the five studies concerning tooth maturation/development and eruption are listed in Table 3. Every study had full-term children as controls, and four studies were cross-sectional, whereas one was longitudinal.[32]

All studies demonstrated a delay in tooth maturation/development and eruption among the premature children, but when corrected age was considered, no delay was found in tooth maturation/development and eruption. Seow et al[29] and Seow[31] could also show that the lower the birth weight, the more the delay in dental eruption. However, Seow et al[29] declared that when corrected age was considered, there were no differences between the groups, implying that the delay in dental eruption among the children with lowest birth weight was simply attributable to their early birth. Moreover, Seow[31] reported that the greatest delay was found in children younger than 6 years of age, whereas for those aged 9 years or older, there was no difference, indicating that a ‘‘catch-up’’ had occurred.

Backström et al[32] also investigated the effects of intake of different minerals (calcium, phosphorous) and vitamin D supplementation on dental maturation in the neonatal period. They found that mineral or vitamin D intake did not affect the tooth maturation of the primary dentition. However, higher vitamin D dose resulted in a more mature permanent dentition, but mineral intake did not affect maturation of the permanent teeth. Backström et al[32] also investigated whether tooth development was associated with bone mineral status in premature children but found no such association.

Tooth-crown dimensions

Summarized data of the three studies concerning tooth-crown dimensions are listed in Table 4. All studies were cross-sectional and had full-term children as controls. Fearne and Brook[33] found significantly smaller tooth-crown dimensions for all teeth except the first primary molars in the premature group. Seow and Wan[34] reported that premature children had the smallest tooth-crown dimensions, whereas Harila-Kaera et al[35] registered both increased and decreased tooth-crown dimensions in the premature group (Table 4). Fearne and Brook[33] and Seow and Wan[34] also showed that the lower the birth weight, the smaller the tooth-crown dimensions.

Quality analysis

A quality analysis of the 13 studies involved is summarized and presented in Table 5. The judged quality standard was high for three studies,[31,34,35] medium for nine studies,[23–25,27–30,32,33] and low for one study.[26] Most of the studies had used sufficient sample size, but no study declared a prior estimate of sample size. The selection description and the description of prematurity/control were adequate in most of the studies (Table 5). In two studies,[29,30] there was an obvious risk that children of gestational age of 37 weeks or more, ie, children of normal gestational age, had been incorporated in the premature groups because in these groups, the gestational age range was 32 to 41 weeks and 24 to 40 weeks, respectively. Moreover, in three[25–27] of the five studies regarding palatal morphology, sucking habit was not considered or was unclear.

Withdrawals (dropouts) were not declared in five[24,25,27,28,30] of the studies. In all studies, the methods used to detect and analyze defects were reliable and well known. However, method error analysis was done only in six[23,27,31,33–35] of them, and blind measurements were made only in three studies[25,30,35] (Table 5). In eight[23,24,27–29,31,34,35] of the 13 articles, the used statistical methods were judged as adequate (Table 5). The errors in the other articles differed. In several articles, only bivariate methods were used when multivariate methods were indicated. In some cases, more serious errors, such as using the wrong methods for analysis with disregard for variable scale levels, were found.[25,26] There was one instance of the ecological fallacy, using aggregated data for individual conclusions.[30] In eight[24–27,29,30,32,34] of the 13 studies, ethical approval, informed consent, or both were declared.

DISCUSSION

This systematic review was undertaken to answer the following questions: Does prematurity result in alterations of palatal morphology, dental occlusion, tooth-crown dimensions, and tooth maturation? What role does oral intubation play in the appearance of the alterations? Are the alterations in morphology permanent or transient? To answer these questions, an exhaustive literature search was performed in an attempt to find all controlled clinical trials involving premature births as defined by the WHO. Although it was not possible to statistically combine the data because of heterogeneity, some consistent results among the 13 studies were found.

The great improvement in neonatal health and intensive care in the last 20 years has led to increasing survival of premature infants, especially EPT/ELBW infants.[7,8] EPT/ELBW children were represented in some of the 13 studies. However, it is important to note that no comparison was performed, in any of these studies, between ELBW/EPT children and less premature children or full-term children. Thus, this issue needs further study.

The relationship between premature birth and enamel defects was not considered in this review. It was regarded that altered palatal morphology and occlusion as well as changes in path of eruption of teeth and tooth size were of primary interest because these alterations and changes can contribute to an increasing need for orthodontic treatment. The relationship between premature birth and enamel defects will be reviewed separately in a forthcoming article.

Palatal morphology and crossbite

Scientific evidence was found for altered palatal morphology in the short term among premature children, and oral intubation was a contributing factor to the alterations. However, because of contradictory results and lack of longitudinal studies, the scientific evidence was too weak to answer the questions whether premature birth causes permanent alteration of palatal morphology and alterations of dental occlusion.

Various types of equipment have been devised by researchers over the years to measure palates. Most of the studies in this review have used fairly reliable methods and appliances for measurements of palatal alterations such as Olivetti inspector machine,[23] optical gauging,[24] and reflex microscope.[26,27] However, there are hardly any normal standards to determine accurately whether a palate is deformed, and this can conceivably be a reason for the divergent results observed in the studies regarding palatal morphology. Furthermore, an important confounding factor, sucking habit, was not always considered. It is generally known that sucking habit may cause a crossbite and alterations of palatal morphology.[36] Therefore, it was remarkable that only

TABLE 5. Quality Evaluation of the 13 Involved Studies

Article	Sample Size	Selection Description	Description, Prematurity/ Control	Withdrawals Declared	Valid Methods	Confounding Factors Considered	Method Error Analysis	Blinding in Measurements	Adequate Statistics Provided	Judged Quality Standard
Palatal morphology and crossbite										
Seow et al[23]	Partly sufficient (18 + 31)	Adequate	Adequate	Yes	Yes	Yes	Yes	No	Yes	Medium
Kopra and Davis[24]	Sufficient (43 + 47 + 40 + 44)	Adequate	Adequate	No	Yes	Yes	No	No	Yes	Medium
Fadavi et al[25]	Sufficient (52 + 45)	Adequate	Adequate	No	Yes	Partly, sucking habit not considered	No	Yes	No	Medium
Procter et al[26]	Partly sufficient (27 + 29 + 20)	Unclear	Adequate	Yes	Yes	Partly, sucking habit not considered	No	No	No	Low
Macey-Dare et al[27]	Sufficient (43 + 50)	Adequate	Adequate	No	Yes	Partly, unclear about sucking habits	Yes	No	Yes	Medium
Tooth development and eruption										
Golden et al[28]	Sufficient (129 + 38)	Adequate	Adequate	No	Partly	Yes	No	No	Yes	Medium
Seow et al[29]	Sufficient (106 + 47)	Adequate	Partly adequate, prematurity incorrectly defined: 32–41 wk	Yes	Yes	Yes	No	No	Yes	Medium
Harris et al[30]	Sufficient (66 + 76)	Adequate	Partly adequate, prematurity incorrectly defined: 24–40 wk	No	Yes	Yes	No	Yes	No	Medium
Seow[31]	Sufficient (55 + 55)	Adequate	Adequate	Yes	Yes	Yes	Yes	No	Yes	High
Backström et al[32]	Sufficient (30 + 60 + 60)	Adequate	Adequate	Yes	Yes	Yes	No	No	Partly	Medium
Tooth-crown dimensions										
Fearne and Brook[33]	Sufficient (75 + 58)	Adequate	Adequate	Yes	Yes	Yes	Yes	No	Partly	Medium
Seow and Wan[34]	Sufficient (111 + 169)	Adequate	Adequate	Yes	Yes	Yes	Yes	No	Yes	High
Harila-Kaera et al[35]	Sufficient (328 + 1804)	Adequate	Adequate	Yes	Yes	Yes	Yes	Yes	Yes	High

two studies[23,24] declared that children with sucking habit were excluded. Additionally, it was difficult to compare and interpret the results because the age of children included in the cross-sectional studies ranged from newborn to 11 years of age, implying that both the primary and the mixed dentition were represented.

Thus, from a clinical point of view and because orthodontic problems are often multifactorial, it is still not possible to predict whether premature children are at risk for malocclusions from putative alterations of palatal morphology such as asymmetry and high arched palates. To evaluate whether alterations of palatal morphology or alterations of dental occlusion are permanent or transient, it would have been more appropriate to longitudinally follow premature and normally born children. Thus, further well-controlled longitudinal studies are needed.

Tooth maturation/development and eruption

All studies demonstrated a delay in dental development and eruption among premature children. However, four studies[28,29,31,32] reported that when both chronological age and corrected age, ie, chronological age in weeks minus (40 weeks minus gestational age in weeks), were considered, there was no delay in tooth maturation or eruption. This means that the early births of prematurely born children must be taken in account when estimating times for eruption of their dentition or when planning for orthodontic treatment.

Tooth-crown dimensions

The findings from the studies were contradictory. Fearne and Brook[33] and Seow and Wan[34] found a positive correlation between birth weight and tooth-crown dimensions, whereas Harila-Kaera et al[35] registered both increased and decreased tooth-crown dimensions in the premature group. The alterations of tooth-crown dimensions reported may be the result of several influences and therefore difficult to interpret. The assessment of tooth-crown dimensions was performed on deciduous teeth in two studies[33,34] and on permanent teeth in one study.[35] Moreover, among normally born individuals, the variation in tooth-crown size has often been claimed to be multifactorial, with strong genetic and environmental contributions, and may reflect general disturbances of individual development in both the prenatal and postnatal period.[37] Some studies have indicated that genetic factors contribute about 60% of the observed variation in tooth size in both the deciduous and permanent dentition.[38,39]

Furthermore, the influence of environmental factors is thought to be greater on the permanent dentition than on the deciduous dentition.[40] Also, race and sex must be taken into consideration when investigating processes affecting the dentition.[41–43] Because the determination of tooth-crown size is multifactorial and it is unclear which factors are likely to be the most important and involved in the etiology of altered tooth size, and because this systematic review presented contradictory results regarding tooth-crown dimensions among prematurely born children, this issue needs further study.

Quality of the studies

Several methods and scales to incorporate quality into systematic reviews have been proposed[21,22] and have been extensively applied to miscellaneous randomized controlled trials (RCTs) in medicine. However, because RCTs never can be used as a research design when facial morphology and oral defects are studied among prematurely born children, many items and scales suggested for quality analysis were clearly not applicable to this systematic review. Instead, the quality of the articles was judged as low, medium, or high according to the characteristics given in Table 5.

According to the criteria used, the quality of most of the studies was medium or high. Only one study[26] showed low quality (Table 5). It was encouraging that almost all studies used sufficient sample sizes, adequate selection descriptions, and well-defined premature and control groups. Furthermore, in most of the studies, the methods used to detect and analyze defects were valid, reliable, and well known (Table 5). However, no study declared a prior estimate of sample size. Other shortcomings in the studies were lack of method error analysis and blinding in measurements, no declaration of withdrawals, and deficient statistical methods (Table 5). From a methodological point of view, it was notable that only three[25,30,35] of the 13 studies declared use of blinding in measurements or analysis. For example, it has been shown that nonrandomized trials or RCTs without double-blind design are more likely to show advantage of an innovation over a standard treatment method.[44] Also, RCTs in which treatment allocation was inadequately concealed showed significantly larger treatment effects than trials using adequate concealment.[45] This implies that the measurements can be affected by the researcher.

In five[25,26,30,32,33] of the 13 articles, the used statistical methods were judged as not adequate or partly adequate. These statistical errors might have influenced the outcome reliability of the studies.

It was also remarkable that three[25–27] of the five studies regarding alteration of palatal morphology had not considered the confounding variable sucking habit. It is generally known that the presence of a sucking habit may cause alteration of palatal morphology and a crossbite and also counteract or inhibit a normal palatal growth process. Thus, information regarding the presence or absence of a sucking habit is useful when evaluating the results.

CONCLUSIONS

To our knowledge, this is the first systematic review reporting on the consequences of premature birth on palatal morphology, dental occlusion, tooth-crown dimensions, and tooth maturation and eruption. After assessing the quality of the retrieved studies, several conclusions can be drawn:

- Scientific evidence was found for altered palatal morphology in the short term among premature children, and oral intubation was a contributing factor to the alterations.
- If corrected age was considered for the premature children, no delay in dental development and eruption was found compared with normally born children; thus, the early births of prematurely born children must be taken in account when estimating times for eruption of their dentition or when planning for orthodontic treatment.
- Because of contradictory results and lack of longitudinal studies, the scientific evidence was too weak to answer the questions whether premature birth causes permanent alteration of palatal morphology, alterations of dental oc-

clusion, and altered tooth-crown dimensions. This also means that the literature gives no answers to the clinician regarding whether prematurely born children are at risk for malocclusion.

- Further well-designed controlled studies as well as longitudinal studies are needed, and researchers have to focus on and make efforts to strictly divide the premature children into groups according to their birth weight and gestational age and use well-defined matched control groups.
- Researchers should also to take the opportunity to consider confounding variables, use correct statistical methods and valid, reliable methods, and perform method error analysis and blinding in measurements.

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