



WIDTH OF NEONATAL LINE: IT'S RELATION WITH DURATION AND MODE OF DELIVERY.

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Article History:

Received: 7th July 2023

Revised: 30th July 2023

Accepted: 9th August 2023

Abstract:

Introduction: Dental enamel is the essential source of observing normal development or abnormal pathological conditions related to past living circumstances faced by human population. Ameloblasts start laying down the most rigid structure, called enamel, subdividing into secretory and maturation stages from intra-uterine life for deciduous teeth. In the literature, special attention is given to one of the incremental lines called a neonatal line which is distinctively observed on all primary teeth at the time of labor. Methodology: A review of literature having a sample size above 100 was done from the year 2000 to 2022 through electronic search engines like PubMed and Google Scholar with the following keywords neonatal line, enamel tooth, primitive teeth diseases, hypocalcification, and gestation period along with thickness and thinness of neonatal lines. Results: We found alterations in the width of the neonatal line with the mean value of 12.4, 11.52, and 12.48 μm in relation to normal, cesarean, and emergency operative deliveries, respectively. Conclusion: The review shows variation in neonatal line width is associated with multiple factors like mode of childbirth during delivery, complication at birth, birthweight of a newborn, the length or period of gestation, metabolic diseases, and infections, to name a few and this may lead to clinical malformations of teeth or making the teeth more prone to dental caries.

Keywords – Incremental lines; Mode of delivery, Gestation, Width of neonatal lines

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DOI: 10.48047/ecb/2023.12.si10.00381

Introduction:

This review on morphological and pathological variations in enamel growth and maturation concentrates on the development of incremental lines with particular emphasis on the neonatal line. This neonatal line is a distinctive line on all primary teeth observed at the time of labor as a ring appearing on dental enamel and dentin as a birthmark histologically (Figure 1) [1]. Enamel is one of the reliable sources of monitoring normal development or disease conditions related to past living circumstances faced by the human population. Permanent teeth are more rigid than primary teeth owing to their rigid mineralization process [2,3]. Usually, the dentin structure is arranged in numerous anastomosis systems called tubular patterns. Any external involvement in aligning strategy may lead to lethal changes in odontoblasts [3]. The superficial layer of the tooth crown is composed of a hard and mineralized structure present within the mouth of the vertebral body, known as enamel. It forms by ameloblasts cells only found in teeth, subdivided into secretory and maturation stages that lead to tremendous crystallization by mineralization process in mature enamel [4]. The mineralization process of all teeth is done in this specific phase. This phase coincides with the metabolic activity during the 13th or 16th week of gestation towards the baby's first year [4]. In this period, development and growth are related to physical changes and affect brain growth. Approximately 90% appearance of the neonatal lines is observed at birth time. The period of gestation matters and is correlated with the position of neonatal line [1,5-8]. To our knowledge, factors influencing amelogenesis in the formation of neonatal line and the width difference are mostly undiscovered. Among the histological structures of the enamel, the neonatal line is formed due to unspecified stress factors disturbing the growth of the enamel [5]. It is well known that the prenatal and postnatal enamel and dentin are separated by

the neonatal line. The location of the line varies in different teeth [2]. This is usually shifted due to the gradual growth of the prenatal enamel from preterm to post-term conditions [2,3]. From a topographic point of view, generally the neonatal line in incisors extends from the cervical third of the dentinoenamel junction toward the surface of the enamel. On the other hand, the neonatal line in canines and molars is situated close to the incisal and occlusal parts of the enamel, respectively. [3,9].

The neonatal line can be appeared as a thick dark line compared to the incremental lines of Retzius in the enamel and dentin while observing under the light microscope. This line is not visible to its full extent in the enamel and dentin due to the continuous mineralization process of the enamel and dentin within the neonatal lines [3,9]. At the time of birth, only partial mineralization of the enamel occurred. The mineralization process continued in order to increase in width of the enamel. The thickness of the enamel is achieved by the collocation of additional deposits secreted by the ameloblast cell layers. The daily deposition rate of the enamel is 4 to 5 μm started in a rhythmic manner at the level of the dentinoenamel junction. [9].

The distance between the dentinoenamel junction and neonatal line was significantly lower in a pre-term born children which is attributed to the premature cessation of activity of ameloblasts to form enamel [10]. The general width of neonatal line was about 12 μm . It was thinner than 12 μm in elective C-section while wider observed in emergency caesareans. The wider neonatal line usually found in diabetic mothers due to hypocalcemia occurring in these mothers [4]. There are other factors on which the published literature was able to give us a review and hence are mentioned with a separate side heading.

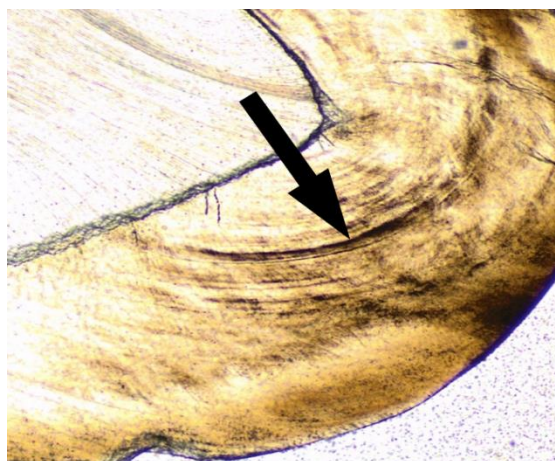


Figure 1. Neonatal line in enamel indicated by black arrow.

Metabolic disorders:

Many factors affect dental development, such as metabolic disorders, hereditary dentine disorders (for example, dentinogenesis imperfecta and dentine dysplasia), allergies, and continuous uterine changes that affect both mother and child. Metabolic diseases such as diabetes and less insulin secretion have slowly and steady lethal effects on organs, i.e., eyes, nerves, the heart, and blood vessels [11,12]. Extensive mineralization of bone also lies in metabolic disorders. Studies showed that diabetes decreases ameloblast activity in the fetus, which reduces calcium deposition in the mineralization phase during enamel development. Gutowska et al. showed a significant decrease in fluoride concentration and increased magnesium concentration in the teeth. This disturbed enamel matrix secretion causes the tooth crown's flaw known as hypoplasia [10,12,13]. It reduces the thickness of the teeth and is globally considered as quantitative damage, physically appearing in the form of a groove, hole, and sometimes a total lack of crown or cone-like pointed structure [14].

Infections and diseases:

There is an association between mother and fetus through which some infections, allergies, and diseases may transfer along with the structural characteristics. Interglobular dentine is also called a mineralization defect. Generally, this disturbance was the effect of the final and second phases of mineralization in the neonatal stage [9]. Interglobular dentine study deals with vitamin D, phosphate metabolism, and Vitamin C during the mineralized stage. The effect of prescribing antibiotics in pregnancy may cause mineralization defects, which are included in Interglobular dentine developed in the unborn baby [8]. Hershkovitz et al. reported that a disturbing situation due to the high mineralization of magnesium in enamel before birth in the fetus might lead to cerebral palsy. He observed the 5.69 μm width of the neonatal line in the deciduous teeth and the cerebral palsy in the infant stage [9,15]. Birth diseases associated with nutritional deficiencies, medicinal and non-medicinal drugs, stress, and the use of alcohol during pregnancy affect premature development later in life. These data types were recorded and analyzed by the developmental origin of health and disease [1]. Its framework is based on gathering information to reduce the maximum number of fetal deficiencies and diseases. These studies have valuable information regarding individuals' antenatal maternal and fetal development and prescribing precision medication programs to overcome adverse mental health by clinical practice and policies [16]. The data recorded in

developmental origin of health and disease in which high mineralization content was observed due to excessive use of alcohol during pregnancy on Poland by Kurek while the same results observed by Behie on Austrian mom [1,17].

Depression and stress:

The neonatal line was metabolic stress that affects the development of the primary and secondary structures of the tooth [3]. Depression and anxiety also significantly impact the neonatal line, which was wider than usual, as observed by Mountain et al [18]. In his research, he observed noticeable stress lines in teeth conjunct between prenatal and perinatal reasons [18]. Teeth Encoding Experiences and Transforming Health model was proposed to elaborate the biomarker activity of teeth to give important information regarding past life hardship and mental health problems. This model was designed by Davis et al. to examine maternal psychological and social stress to reduce paternal pressure and provide social support to decrease the adverse effects [19]. The unavailability of detailed information may have called as retrospective reports or material based on memory and recall bias.

Tooth features also provide information that helps in forensic odontology, the facial features in which mandible and mandibular structures create a unique pattern of the facial shape. The genuine fact is that the face recognition method is also used as a scanning system in many companies and industries. Furthermore, the specific enamel pattern in individuals employed in the biometric study for identification determination is known as amelogyphics. Light body dental impressions, cellulose film, and cellophane tape are used to form proper teeth information records [20-22]. The current study is based on the collection of authentic data provided world widely.

Studies database:

The recent study based on the neonatal line variation in width indicates complications faced by a fetus and their impact on its development. The reported outcomes showed short-term and long-term conditions. The current data were collected by computed and extracted by literature provided by Google scholar and PubMed. The review is mainly based on the advantages and disadvantages of neonatal line variation and the mode of delivery. The mode of delivery and the gestation length play essential roles in fetus development. The reported assessment was discussed, analyzed, and summarized by means of a comparative point of view. It also illustrated the link between diseases, such as the transfer of disease by the mother

genetically during development or malnutrition affecting the developmental process. The study demonstrates the impact of delivery mode and related complications on their development. The study also correlates the general impact rather than in situ findings. The observation was also analyzed by mode of delivery. There are three types of delivery, so we divided them into three groups: normal delivery, elective cesarean section, and emergency operative, along with the relation between the width of neonatal lines. Chances of inherited diseases were discussed superficially. The review of this database is the outcome of a detailed study on morphology, pre-birth primary tooth formation process, and the disease condition followed by the disturbance in the mineralization process.

Methodology:

The electronic database was reviewed for the last 22 years, from 2000 to 2022, through Google Scholar and PubMed, with keywords such as neonatal line, enamel, primitive teeth diseases, hypocalcification, and gestation period along with thickness and thinness of neonatal lines. We were able to collect a total of 100 articles. Among them, around 25 were related to the scope of this article, and hence only these were shortlisted. The data were analyzed by the Kruskal-Wallis rank test to obtain a mean value. This testing method was effective as the width of the neonatal line is in μm ,

and most of our sample size has used this testing method. The vitamin and mineral concentrations were also observed due to increased lead concentration in preborn or by-birth diseases.

Results:

The neonatal line width can be considered an important registered milestone between intra-uterine and post-uterine life. A change in width is categorically related to the form of delivery. This width is recorded in the form of μm and often ranges from 10 μm to 15 μm . The Kruskal-Wallis rank test holds good as it can calculate values in μm , which matches our review requirements. Furthermore, many of our review articles have followed this method; hence, translating the data holds the accuracy factor, which is an important aspect of our review.

The width of the neonatal lines in healthy individuals was between 12-15 μm in the normal mode of delivery, while cesarean delivery has a range of 11.5-9.5 μm and emergency operative mode of delivery has a range of 13-14 μm was observed. The current observed mean values are 12.4, 11.52, and 12.48 μm of normal, cesarean, and emergency operative modes of delivery, respectively. The recent observations showed that the mode of delivery may affects the width of the neonatal line, and an increase and decrease in the mineralization rate may lead to disease in the baby (Figure 2).

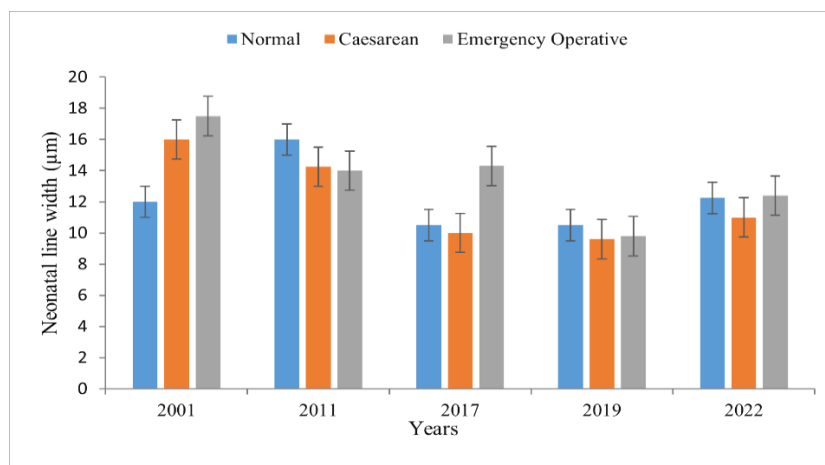


Figure 2. A survey from 2000-2022 on neonatal line width associated with mode of delivery.

On the contrary, Zanoli et al. suggested the opposite opinion by histo-morphological investigation performed on the deciduous teeth. Their study did not support the idea of a thinner neonatal line for the caesarian section compared to children associated with the normal delivery mode. They postulated that it might be due to the effect employed by the factors associated with the variation of gestational length [6]. Further, Hassett

et al. studied the relationships among the width of the neonatal line, maternal health, gestation, and the birth process. They suggested no association between the width of the neonatal line and the type or duration of delivery [23]. Hurnanen et al reported that the width of neonatal lines was inversely proportional to the delivery duration and suggested that a lengthy delivery process might restrict the development of neonatal lines [7]. To

our knowledge, factors influencing neonatal line development and the variety of its width are largely

unknown. The variation in neonatal lines due to the mode of delivery has been shown in Table 1.

Table 1. Literatures expressing neonatal line width associated with mode of delivery.

ARTICLE NO.	PUBLICATION YEAR/AUTHOR	AIM OF STUDY	NEONATAL LINE WIDTH	Method Followed	Sample size/variation	Conclusion	relation to article
Article 1	Behie Alison 2019	Investigate the maternal conditions affect the thickness of neonatal line (NNL)	Mean width 10.28 μ m	Kruskal-Wallis rank test	53 mothers	Maternal lifestyle factors influence NNL formation possibly due to physiological change	Factors associated with NNL
Article 5	Blyschak K 2011	Effects of duration of the birth process on the width of NNL	Mean width 9.12 μ m	Kruskal-Wallis rank test	Exfoliated deciduous teeth used from 45 Children	No correlation between birth duration and the width of the NNL	Factors associated with NNL
Article 6	Clement zanolli 2011	Width of NNL related to mode of delivery and gestation	6.5 to 28.4 μ m	Turkey honest significance difference	100 patients; 40 – caesarian; 5 – operation; 65 – normal; More than 24 μ m – 7 patients with normal birth;	Gestation months rather than mode of delivery	Same as ours
Article 7	Jaana Harnanen 2016	Effect of Duration and mode of delivery on NNL. (Duration of delivery is start of contraception with an interval of every 5min.)	Median width of 9.63 μ m (min 3.16 μ m, max 27.58 μ m)	Pearson correlation coefficient	129 patients; no statistical correlation to mode of delivery; vaginal unassisted delivery has wider NNL	Width is inversely proportional to the duration of delivery No relation to mode of delivery	Same as ours
Article 8	Brenna R Hasset 2020	Potential relationships between NNL width and early life history variables such as maternal health, gestation, the birth process, and perinatal health	Mean 10.21; 1.80 to 28.45 μ m		71 deciduous canines	Post term infants, infants in autumn had narrower NNL, Hypertensive mothers wider NNL, No relation to mode and duration of delivery	Factors associated with NNL
Article 10	Bhansali 2020	Chemical composition & structure of deciduous enamel in pre- and full-term babies	Pre term babies enamel width (0.265 \pm 0.272 mm) Post term born babies enamel width (1.365 \pm 0.360 mm)	Chi square test and unpaired t test	20 extracted early childhood caries teeth from preterm and full term	Preterm babies have less enamel from CEJ to NNL compared to post term babies hence more caries	Not talked about width of NNL
Article 15	F.Hershkovitz 2019	Compare NNL width and composition of pre-natal and post-natal enamel of deciduous teeth of cerebral palsy patients	NNL width mean 9.25 in control and 5.69 in cerebral palsy.(Min & Max Value not given)	P value and SD values are given	58 extracted teeth; 29 from cerebral palsy and 29 from controls	Neonatal line was narrower in cerebral palsy pt. Mg and Na are higher in prenatal enamel of cerebral palsy pt.	Mean NNL width
Article 17	Kurek M.et al 2015	Determine prenatal factors that may influence the NNL thickness in human deciduous teeth	Mean 9.38; Min 5.52; Max 15.15 μ m	Multiple regression analysis	60 deciduous incisor's from full term babies	Children born in summer and spring has thinner NNL Children's born to mothers taking antispasmodic has thinner NNL	Not talk about gestation and type of delivery
Article 18	Rebeca V Mountain 2021	To assess whether NNL, is associated with exposure to prenatal and perinatal maternal psychosocial factors.	Mean 10; Min 2 and Max 15 μ m	Pearson correlation coefficient	70 patients	NNL were narrower in children born to mothers who self-reported high social support shortly after birth	
Article 23	Hassett et al 2020	Explore potential relationships between NNL width and early life history variables such as maternal health, gestation, the birth process, and perinatal health	Mean 12.33 at cusp;10.21 at middle; Amelodontinal junction 7.m69 μ m	P value, e ω 2 value & Cohen's D are given	Deciduous canines from 71 children	No association between wider NNLs and long or difficult births	No association were found

The concentration differences of minerals and ions also affects the development of the deciduous teeth. The literature showed calcium concentrations were decreased rather than magnesium concentrations [1,5-7,23,24]. The decreased calcium may cause calcium deficiency. The summarized data of

reported diseases that may cause due to mineralization imbalance, change of mode of delivery, and ups and downs of vital ions and minerals (Table 2), where the literature showed increased magnesium as compared to calcium, Vit D, and phosphorus [1,7].

Table 2. Increase and decrease the concentration of Vitamins and minerals.

Vitamin D	Calcium	Phosphorus	Magnesium	Year	REF
↑↓	↑↓	↑↓	↑↓		
↓	↓	-	-	2001	⁵
↓	↓	-	-	2011	⁶
↓	↓	↓	↑	2017	⁷
↓	↓	↓	-	2015	²⁴
↓	↓	↓	↑	2019	¹
↓	↓	-	-	2020	²³

Discussion:

The tooth enamel is the most mineralized tissue in human body. The Striae of Retzius demarcate the deposited layers of tissue. A markedly visible Striae of Retzius is seen as a birth mark on the dental enamel in the form of a ring, an accentuated striae of retzius called as neonatal line initially described in Rushton 1933; Schour 1936. Skinner in 1992 also suggested that this line is not only seen in enamel but also in dentine. It is not only visible on all the deciduous teeth but also on the 1st permanent molar as discussed by Christensen and Kaus 1965, Deutsch and Pe'er 1982; to name a few [6]. The neonatal line are dark bands and are the result of the metabolic stress that affects tooth development at birth. The enamel inside this line is formed before birth (prenatal), while the outer enamel is deposited after birth (postnatal). Variations in thickness and composition of these two regions have been described in the literature [3]. The level or location of the neonatal line has been measured by most of the authors at more than two positions in all the literature, middle of the teeth was always done, followed by close to dentinoenamel junction and at the cervical region which was also referred to as close to the apex of the crown [6-8, 15,17,18]. The reason suggested for taking the neonatal line value at 3 different locations was largely related to avoiding inter examiner difference as well as to attain standardization. The width of the neonatal line was commonly compared apart from its location on the tooth. In this review through various search engines, we found that most of the authors have

followed the hypothesis that change in the metabolic stress between the prenatal and postnatal is directly related to the width of it. This change in the accentuation of the neonatal line has been studied in relation to mothers with alcohol consumption, pre term, full term and post term babies, type of delivery, mental health of the mothers, season of birth and nutritional status of mothers. The results have been summarized in table 1. Some of the studies have also compared variation to climate with the neonatal line and felt that children born in pleasant climatic zones have a thinner neonatal line since the stress level is reduced and metabolism of mother and fetus can follow the circadian rhythm [8,17]. These genetic linked diseases can be both X linked or XY linked but little focus is there on the type of XY linked diseases. Especially in children who are suffering from cerebral palsy, it was noticed that the neonatal line was thinner [15]. Cerebral palsy is a disability in children characterized by a non-progressive motor disturbance of the central nervous system. Hypocalcemia and metabolic diseases and psychological diseases are most common [4]. Our study has also found list of possible disease that can cause variation in neonatal line (Table 3). The related disease was detailed discussed by Blyschak [5]. The tooth development phase has accurate concentration of vitamins and minerals such as calcium, fluoride, phosphate, magnesium, and potassium. The change in their values cause hypocalcemia, decrease insulin level can cause reduced mineralization [4].

Table 3. Enlist some pathological conditions caused by the wideness of the neonatal line before Delivery [5,25].

Serial No.	Pathological conditions
1	Hypocalcemia
2	Depression
3	Jaundice
4	Minimal brain dysfunction
5	Congenital hypothyroidism
6	Vitamin D deficiency
7	Anemia
8	Autistium [25]

The current review showed that the neonatal line and related diseases are linked with the mother's physical and mental situation during pregnancy [8,18]. Depression has been considered as a major cause for variation in width of neonatal line as it affects the gestation period. It is worth to mention that the average width of the neonatal line has a huge normal range ratio from 1.8 to 28.4 μm which might make it difficult to differentiate from normal to abnormal value consideration [6-8,18,23]. One of the limitations of our study is that it was a narrative review, not a systematic review and meta-analysis. Most of the publications related to the neonatal line are too old and the medical fraternity has agreed to the huge normal range ratio. Thus, the quality assessment was not conducted in this study. Due to the limitation of this study, there should be further studies to standardize normal neonatal line width which can give a better value in understanding the abnormalities and its relation to respective diseases. Furthermore, since there are various genetic diseases in which the neonatal line gets affected hence there can be further studies to include those genetic disorders involving the XY chromosome or to put simply the genetic disorders transmitted from the father of the child.

Conclusion:

The review concludes that there was a relation between the delivery mode and perinatal complication which was registered in the enamel as an increased neonatal width. However, there are various other factors which cannot be ruled out for the variation in neonatal line width as it was also associated with the mode of childbirth procedure followed during delivery, complication at birth, birthweight of a newborn, the length or the period of gestation, metabolic diseases, and infections, to name a few. Among the above mentioned etiologic causes, variation due to infection is least probably due to general asepsis followed throughout the world due to WHO guidelines and general awareness. We have found studies who attribute the neonatal width variation to the mode of delivery and in this the longer the gestation, more chances

of variation in the neonatal line width. It is further found to be difficult to standardize the various parameters involved in this kind of research since the period of gestation cannot be predicted. An attempt was made through this review to highlight the most relevant etiology for changes seen in the neonatal lines and their role in the clinical malformations of the teeth or making the teeth more prone to dental caries.

Acknowledgments: The author was thankful to the Deanship of Graduate Studies and Scientific Research at Dar Al Uloom University for the financial support for the project.

Conflicts of Interest: Authors do not have any conflict of interest.

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