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Comprehensive Review of Dental Anomalies in Children with Cleft Lip and Palate: Prevalence, Etiology, and Management Strategies

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Abstract

Cleft lip and palate (CLP) is a common congenital malformation affecting the maxillofacial region, with prevalence varying globally. The etiology involves genetic and environmental factors leading to unsuccessful fusion during embryonic development. Dental anomalies are prevalent among CLP patients, including hypodontia, supernumerary teeth, tooth shape and size abnormalities, impaction, and malposition. These anomalies significantly impact oral function, aesthetics, and overall well-being. Early detection and multidisciplinary intervention are crucial for optimal management. Further research is needed to understand the complex etiology and improve treatment outcomes for CLP patients

Keywords: Cleft Lip and Palate; Dental Anomalies; Prevalence; Aetiology; Hypodontia; Teeth Malformation

Introduction

Cleft lip and/or palate (CL and/or P) is one of the most common congenital malformations in the maxillofacial region [1]. The prevalence throughout the world varies from 1/500 to 1/2500 live births. This variation largely depends on racial origin, ethnic background, and geographic location [2]. The aetiology of oral clefts is multifactorial in nature, with genetic and environmental factors contributing to its presence [3].

Clefts in the lip and palate result from the unsuccessful fusion of the embryonic medial nasal processes and maxillary processes and the medial nasal processes and palatine processes, respectively [4]. These fusions normally take place during the seventh to eleventh week of gestational age [5]. It can occur in isolation (non-syndromic) or be part of a wider series of birth anomalies or syndromes (syndromic) [1].

Cleft lip and/or palate malformations are divided into four main categories: palatal cleft lip and palate clefts, lip clefts, and lip and alveolar clefts [6]. According to the definition, palatal clefts do not extend to the maxillary alveolus [6]. Submucosal clefts are covered by mucosa and are also classified as a type of palatal cleft. Palatal clefts may involve both the soft and hard palates or only the soft palate [4]. Lip and palate clefts may extend bilaterally or unilaterally through the alveolar ridge and the lip to the hard and soft palates [4].

Clefts of the palate are more common in girls, while clefts of the lip, with or without palatal involvement, are more common in boys. It is interesting to note that the left side is affected more often than the right [7]. The affinity of the unilateral cleft to the left side is not well understood [8].

Clinical Challenges

Children with cleft lip and palate face several problems, which include: infant feeding problems due to an improper oral seal, swallowing and nasal regurgitation, multiple surgeries, visible facial scarring, nasolabial deformities, speech and hearing problems, and problems with appearance [9]. This may subject affected children to cruel teasing by their peers in school [9].

Dental Anomalies Associated with CLP

Subjects affected with clefts commonly show various dental anomalies involving tooth number shape, size, structure, and position [10,11]. The degree of these dental anomalies varies according to gender, ethnicity, and type of the cleft [12]. These anomalies adversely impact the dentition, resulting in aesthetic problems, impairment of mastication, and improper phonation. Moreover, they can also make dental procedures more complicated [13]. Children with cleft and their parents prioritize the surgical correction of the clefts and neglect their dental health, resulting in a higher prevalence of tooth decay, missing teeth, and overall poorer oral health [14].

Understanding dental anomalies in children with cleft lip and palate is essential for providing multidisciplinary care that addresses both the cleft and associated dental issues. It facilitates early intervention, improves oral function and psychosocial well-being, prevents secondary complications, and promotes long-term oral health and quality of life.

The objective of this paper is to provide a comprehensive review on the prevalence, types, etiology, and management strategies of dental anomalies observed in children with cleft lip and palate

The occurrence of dental anomalies in children with CLP is higher compared to the general population [15,16]. The association between these anomalies and the presence of clefts remains inadequately understood, with both genetic and environmental factors have been suggested to clarify this correlation [17,18]. This association may also arise from the close proximity of their anatomical structures as well as the concurrent timing of dental development and cleft formation. Notably, the occurrence of clefting coincides with odontogenesis, suggesting a potential interplay between these processes [19].

Some studies have confirmed that certain genes may contribute to both orofacial clefts and congenital dental anomalies [18,20,21]. Among the identified gene candidates implicated in the occurrence of clefts and congenital

defects are MSX1, PAX9, and IRF6 [22]. Furthermore, the effect of genetic risk factors may cause structural deficiencies in the embryonic oral tissues, leading to abnormalities in dental structure, shape, and number, followed by crowding, ectopic eruption, and malposition, thereby complicating access to oral hygiene [21].

Etiology of Dental Anomalies in CLP

The occurrence of dental anomalies in children with CLP is strongly associated with genetic and epigenetic mechanisms. The common genes such as *MSX1*, *PAX9*, *IRF6*, and *AXIN2* have been implicated in both orofacial clefting and congenital dental defects (Table 1).

Table 1: Key Genes Associated with Dental Anomalies in CLP Patients

Gene	Function	Associated anomalies	Clinical implication
MSX1	Regulates craniofacial and tooth development	Hypodontia, agenesis of the teeth, Cleft lip/palate	Disrupted tooth bud formation
PAX9	Controls tooth morphogenesis	Oligodontia, Molar agenesis	Impaired odontogenic patterning
IRF6	Involved in orofacial development	Cleft lip and palate (Van der Woude syndrome)	Defects in epithelial-mesenchymal signaling
AXIN2	Wnt signaling pathway component	Hypodontia/oligodontia (molars, premolars), taurodontism, linked with colorectal cancer risk	Dysregulated Wnt signaling affecting tooth development

In addition to genetic mutations, epigenetic factors play a substantial role in craniofacial development. Maternal nutrition, especially folate and vitamin A levels, can affect gene expression through the process of embryogenic development. Environmental exposures—such as tobacco smoke, alcohol, or certain toxins—can lead to epigenetic modifications (e.g., DNA methylation) that modify the function of key developmental genes without altering their underlying DNA sequence. These interactions may contribute to anomalies like cleft lip/palate or dental agenesis [23].

Environmental factors significantly contribute to the etiology of cleft lip and palate (CLP) alongside related dental anomalies. These include prenatal exposures, surgical interventions, and postnatal influences, all of which interact with genetic predispositions to disrupt dental development [2,3].

Prenatal Factors

1. Maternal Smoking

Maternal Smoking is a well-documented risk factor for CLP, elevating the likelihood by 30–50% [2,3]. The presence of nicotine and carbon monoxide leads to fetal hypoxia, which adversely affects the migration and proliferation of neural crest cells that are essential for the processes of lip/palate fusion and odontogenesis. This disruption has been associated with hypodontia (most notably affecting maxillary lateral incisors), enamel defects, and delays in tooth eruption [2,17].

2. Folic Acid Deficiency

Insufficient maternal intake of folic acid is associated with a 25–40% higher risk of CLP and concurrent dental anomalies [3,20]. Folate is critical for DNA synthesis and methylation processes during the course of embryonic development. A deficiency in folic acid disrupts epithelial-mesenchymal interactions, which can lead to hypodontia, enamel hypoplasia, and the presence of supernumerary teeth adjacent to clefts. Intake of sufficient folic acid during the Periconceptional period (≥400 μg/day) reduces CLP and dental anomaly incidence [3,20].

3. Alcohol Consumption

Prenatal exposure to alcohol disrupts the processes of cellular differentiation within the dental lamina, which

consequently results in microdontia, taurodontism, and ectopic eruptions. Substantial alcohol consumption has been associated with a twofold increase in the risk of cleft lip and palate (CLP) as well as an augmented severity of dental anomalies [2].

4. Toxins and Drugs

Exposure to pesticides, heavy metals (e.g., lead), and air pollutants during pregnancy alters mineralization and root formation. For example, lead exposure correlates with enamel hypoplasia and hypodontia in CLP patients [2,24].Certain medications (e.g., anticonvulsants), may also exert teratogenic effects during critical windows of development. Expanding the understanding of these prenatal influences is essential for effective prevention strategies and public health policies targeting maternal health.

Early Surgical Repair

Primary cleft repair procedures (e.g., periosteoplasty, bone grafting) conducted during the infancy stage may cause damage to the developing tooth germs, particularly those associated with the maxillary lateral incisors and second premolars. This iatrogenic injury explains localized hypodontia and root malformations in surgically treated patients [24,25].

Postnatal Factors

Inadequate oral hygiene, nutritional deficiencies, and persistent oral infections may exacerbate enamel defects and caries in CLP patients, thereby intensifying pre-existing dental anomalies [14].

Prevalence and Distribution of Dental Anomalies

Patients with various types of clefts show varying occurrences of dental anomalies. The prevalence is higher in individuals with cleft lip and cleft palate compared to other cleft types. Among these, bilateral clefts of the lip and palate have the highest frequency of anomalies, followed by left unilateral clefts of the lip and palate [26,27]. These anomalies are more common in permanent teeth, although it can also occur in primary dentition and it is more seen in the ipsilateral side of the cleft [28,29]. Moreover, the severity of these anomalies appears to be related to the severity of the cleft, i.e. the primary width of the cleft is positively correlated to the degree of central incisor rotation and enamel hypoplasia [30,31].

These anomalies may include anomalies of the number of teeth (hypodontia, supernumerary teeth), abnormalities of shape, dental eruption disorders, and disorders related to enamel mineralization [32]. The most prevalent dental anomalies observed in individuals with clefts are the absence of maxillary lateral incisors, the presence of supernumerary teeth, and the absence of lower incisors [33].

In Northern Finland, cleft children were found to have a higher occurrence of dental anomalies (47%) compared to the general population, where the prevalence was 11.7%. Agenesis emerged as the most frequently observed dental anomaly in this group [34].

Akcam and colleagues examined the occurrence of various dental anomalies in the maxillary dental arch in different cleft groups and found that a significant proportion (96.7%) of individuals with a cleft had at least 1 dental anomaly. The most common anomaly observed was agenesis in the anterior region on the cleft side [35].

In a case-control study, a higher prevalence of enamel defect was found in children with cleft when compared with a control group. Furthermore, these defects were more commonly observed on the cleft side of the maxilla, with the central incisor being the tooth most frequently affected in this area [36].

A case-control investigation was carried out among Colombian children aged 5 to 12 years, comprising 210 subjects with non-syndromic cleft lip and palate and an equal number of healthy controls. The findings revealed that dental anomalies were most prevalent in cleft-affected children, particularly in those with bilateral cleft lip and palate, followed by left unilateral cleft lip and palate. Notably, these anomalies were predominantly located within the cleft area. Microdontia of the lateral maxillary incisors exhibited the highest prevalence, succeeded by rotations of the central maxillary incisors, agenesis of the lateral maxillary incisors, and supernumerary teeth [26].

Common Observed Dental Anomalies

Hypodontia

The prevalence of hypodontia in children with cleft has been reported to range from 28% to 66% [28,37]. Permanent teeth are more often affected (52.7%) than primary (16.2%). The prevalence of hypodontia increases strongly with the severity of cleft [38]. Multiple hypodontia was found more frequently in the subjects with bilateral cleft lip and palate and those with unilateral cleft lip and palate [38]. Jamilian et al., in their study, did not reveal any significant difference between the genders in the prevalence of hypodontia, which differs from the healthy population because the female gender is prone to hypodontia [39]. The teeth most commonly affected by hypodontia are the maxillary lateral incisor, followed by the upper and lower second premolars [37,40], with the maxillary second premolar being the more frequently missing tooth [27,38]. The location of hypodontia can be inside and outside the cleft region, but it's more frequent on the cleft side of maxillary dentition [27,41]. When agenesia is found outside, this can suggest a genetic background and usually affects the contralateral incisor, or less often, the second premolar in the maxilla or in the mandible [25,42]. Other authors claimed the hypodontia may be due to local conditional effects of cleft, such as surgery for cleft palate would increase the risk of losing the tooth germs of permanent teeth such as the maxillary second premolars and/or lateral incisors. Korolenkova et al. found primary periosteoplasty and reduced blood supply associated with palatal defects as a reason of agenesia of maxillary central and lateral incisors [24]. These findings suggest that the hypodontia in cleft patients is influenced by environmental factors [38]. Furthermore, primary bone grafting in cleft patients lowers the prevalence of hypodontia [43,44].

Supernumerary Teeth

The prevalence of supernumerary teeth in cleft patients ranges from 4.6 to 42.0%, which is higher than in the general population [28,39] . It is more commonly found at the lateral incisor region adjacent to the cleft [45]. The prevalence of a supernumerary lateral incisor in patients with a left ranged from 5.1% to 22.1% [29]. In the study of Pradhan et al. (2020) conducted in Nepal, supernumerary teeth were mostly the maxillary laterals, both inside and outside the cleft. Aetiology of Supernumerary teeth has not been fully recognized, it may be explained by fragmentation of the dental lamina during cleft formation [29] or lengthening of the pre-canine section of the oral epithelium caused by cleft and thus an extension of the dental lamina, which can develop into a supernumerary tooth [27,46]. The division of the lateral incisor's tooth bud situated across the clefted nasopalatal sulcus may also lead to supernumerary teeth [27,46]. The clinical solution is usually the extraction of the additional tooth, but sometimes there are difficulties in differentiating the normal tooth from an additional tooth. A Cone-Beam Computed Tomography (CBCT) examination is obligatory for good clinical assessment and treatment planning in the case of supernumerary teeth [29]

Tooth Shape and Size Anomalies

In patients with cleft the upper incisors are often affected with shape anomalies. The lateral incisor in the cleft area is often peg-shaped or hypoplastic [47-49]. In a sample of 90 patients (aged 4-20 years) affected by cleft, Rullo et al. found the upper lateral incisor microdontia revealed 5.6% of the examined individuals [47]. In a study by Tan et al., 12.5% of 60 examined patients had macrodontia [45]. An interesting finding is that posterior teeth can be bigger in size than in the healthy population, which suggests a multiple-teeth-size disorder in patients with cleft [48]. Jamilian et al. reported asymmetries in teeth dimensions comparing cleft and non-cleft side, where Maxillary central and lateral incisors were larger on the non-cleft side in the mesiodistal dimension compared with the cleft side. Upper central incisors and first molars are significantly larger mesiodistally on the non-cleft side [48].

In a retrospective study conducted by Küchler et al, taurodontism, which result failure or late invagination of Hertwig's epithelial root sheath, and lack of shift of the root furcation, was found in 15.2%. of the examined cleft patients [50].

Tooth shape and size anomalies cause asymmetry in the dental arch and poor aesthetic appearance. It demands orthodontic alignment followed by prosthetic restoration of hypoplastic or deformed teeth.

Tooth Impaction

Tooth impaction in patients with cleft can affect different teeth: upper incisors, canines, and premolars. Canines are the most commonly affected teeth [39]. The frequency of impaction varied highly in the literature, ranging from 0% to 58% [51]. Jamilian et al. in the Iranian population revealed the maxillary canines were the most commonly impacted teeth in both unilateral and bilateral cleft lip and palate patients [39]. In the literature both genetic and anatomical factors are described as etiological factors of tooth impaction in cleft patients. Narrowed clefted maxilla and lack of space may also cause impaction. In the cleft are, a secondary bone grafting should improve eruption of an upper lateral incisor and canine; therefore, lack of exact treatment can be the reason of upper canines' impaction. A Polish study by Pastuszak et al. did not confirm any relationship between bone grafting, maxillary expansion or extraction of non-resorbed primary canine, and prevalence of upper canine impaction [52]. In non-cleft patients, there is a positive correlation between the occurrence of hypodontia or reduced size of maxillary lateral incisors and canine impaction, but this was not confirmed in the population with cleft [52]. Patients who suffer from tooth impaction may demand complicated surgical and orthodontic procedures to achieve the tooth and align the dental arch.

Teeth Malposition

In children, the maxillary teeth are more frequently in an abnormal position. A narrow and short upper arch means a lack of space, which ultimately leads to crowding [45]. Rotations, ectopic eruptions, and transpositions are the most common. Tan et al. found the rotations of central incisors is a common problem in the area of the cleft with a prevalence of 86.7% and A significantly greater frequency of rotations was found in females [45]. Transposition of maxillary canine and first premolars was found in 5.5% of bilateral, 8% of right, and 3.3% of left unilateral clefts in the study of Eslami et al. [12]. Common teeth malposition in cleft patients is palatal eruption of upper lateral incisors and upper second premolars due to lack of space and class III tendency [53]. All described teeth displacement demands comprehensive orthodontic fixed appliance therapy.

Management Strategies: A chronological Framework

Effective management of dental anomalies in cleft lip and palate (CLP) needs multidisciplinary approach tailored to developmental stages. Below (table 2) is a timeline outlining key interventions from infancy through adolescence.

Table 2: Timeline of Key Interventions

Stage	Interventions	Dental Anomalies Addressed
Infancy	NAM, primary lip repair, caregiver education	Arch alignment, feeding support
Early Childhood	Palate repair, preventive care, radiographic screening	Enamel defects, supernumerary teeth
Mixed Dentition	Bone grafting, expansion, interceptive orthodontics	Hypodontia, impaction, crowding
Adolescence	Comprehensive orthodontics, orthognathic surgery, prosthodontics	Malocclusion, missing teeth, aesthetics

Emerging Technologies in Cleft and Craniofacial Care

Technological advances are significantly altering the field of cleft and craniofacial treatment. Three-dimensional (3D) printing has fundamentally transformed the fabrication of dental prosthetics, surgical guides, and anatomical models [54]. Custom-designed 3D-printed obturators and dental appliances can now be meticulously designed with high precision to accommodate the unique anatomy of each patient, thereby improving function, aesthetics, and comfort—especially in complex cases involving congenital anomalies [54].

Furthermore, artificial intelligence (AI) is increasingly being incorporated into treatment planning. AI-powered tools can help health care professionals in the analysis of radiographic images, predicting growth patterns, and optimizing the timing and sequence of interventions such as orthodontics or orthognathic surgery [55]. These advanced technologies not only improve diagnostic accuracy and efficiency but also facilitate a more personalized approach to patient management.

Conclusion

This review highlights the prevalence and significance of dental anomalies in children with cleft lip and palate (CLP). These anomalies, including hypodontia, supernumerary teeth, tooth shape and size abnormalities, impaction, and malposition, are more common and severe in CLP patients compared to the general population. Clinically, early detection and intervention for dental anomalies in CLP patients are vital for optimizing oral function and aesthetics. Multidisciplinary care involving various dental specialists is necessary. Addressing dental anomalies in CLP children is paramount for enhancing their oral health, psychosocial well-being, and overall quality of life. Research should focus on understanding the complex aetiology of these anomalies, tracking dental development longitudinally, and exploring innovative treatment modalities to improve outcomes.

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