



CLINICAL CONSEQUENCES OF DELAYED EXFOLIATION OF PRIMARY TEETH DURING PERMANENT DENTITION ERUPTION IN CHILDREN

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Abstract

Delayed exfoliation of primary teeth represents a clinically significant disturbance in dental development that can disrupt the spatial and chronological sequence of permanent tooth eruption, thereby predisposing children to a spectrum of occlusal and periodontal complications. The present investigation aimed to quantify the frequency of retained primary teeth during the mixed dentition stage and to characterize their associated clinical sequelae using comprehensive diagnostic criteria.

A cross-sectional observational study was undertaken among school-aged children presenting for routine dental care. Participants underwent standardized intraoral examinations, panoramic and periapical radiographic assessment, orthodontic space analysis, and periodontal screening, complemented by structured parental questionnaires addressing medical history, dental trauma, and oral-hygiene practices. Eruption timing was evaluated relative to established developmental norms, and retained primary teeth were classified according to mobility, infraocclusion, and evidence of root resorption.

Children exhibiting delayed exfoliation demonstrated a markedly increased prevalence of ectopic eruption patterns, anterior and posterior crowding, sagittal and transverse occlusal discrepancies, and clinically detectable midline deviation when



compared with age-matched controls. Periodontal evaluation revealed significantly higher gingival index scores and localized plaque accumulation adjacent to retained teeth, while radiographic analysis frequently identified enamel hypoplasia and altered eruption trajectories of neighboring permanent successors. Multivariate statistical modeling confirmed delayed exfoliation as an independent predictor of developing malocclusion and soft-tissue inflammation after adjustment for age, sex, and oral-hygiene variables.

These findings underscore the importance of systematic eruption monitoring within pediatric dental practice and highlight the role of early radiographic investigation and interceptive intervention—including selective extraction and space supervision—in mitigating long-term functional impairment, esthetic compromise, and the need for complex orthodontic therapy during adolescence.

Keywords:

Delayed exfoliation; Retained primary teeth; Mixed dentition; Permanent tooth eruption; Malocclusion; Pediatric dentistry; Interceptive orthodontics; Occlusal development; Gingival inflammation; Eruption disturbances.

Introduction

Physiological exfoliation of primary teeth constitutes a tightly regulated developmental process governed by coordinated root resorption, alveolar bone remodeling, and eruptive forces generated by permanent successors. Under normal conditions, odontoclast-mediated resorption of primary tooth roots proceeds in synchrony with the coronal migration of permanent teeth, thereby ensuring preservation of arch length, maintenance of occlusal relationships, and harmonious craniofacial growth. Disruption of this sequence may alter eruption trajectories,



compromise spatial relationships within the dental arch, and precipitate secondary periodontal and functional disturbances during the mixed dentition period.

Delayed exfoliation—defined as the persistence of a primary tooth beyond the expected chronological window for replacement—represents a frequent yet often underestimated clinical finding in pediatric dental practice. Epidemiological reports suggest that eruption disturbances constitute a substantial proportion of orthodontic referrals in school-aged populations, reflecting the broader public health relevance of this developmental anomaly. The etiological spectrum is multifactorial and encompasses local mechanical factors such as ankylosis, ectopic positioning of permanent tooth buds, cystic lesions, and supernumerary teeth, as well as systemic influences including endocrine disorders, metabolic abnormalities, nutritional deficiencies, and genetic syndromes affecting craniofacial development. Previous traumatic injury to the primary dentition has also been implicated in disrupting the resorptive pathway or displacing permanent successors, thereby prolonging retention.

Failure to recognize and manage prolonged retention in a timely manner may result in progressive loss of arch integrity, rotation or tipping of adjacent teeth, infraocclusion of ankylosed primary molars, and deflection of erupting permanent teeth toward labial, palatal, or lingual positions. Such changes frequently culminate in dental crowding, midline discrepancies, posterior crossbite, and abnormal overjet or overbite relationships. In addition to skeletal and occlusal consequences, retained primary teeth may serve as plaque-retentive sites, fostering localized gingival inflammation and increasing susceptibility to enamel defects and demineralization in adjacent permanent teeth. Collectively, these alterations can compromise mastication, speech articulation, and facial harmony, while simultaneously increasing the complexity, duration, and cost of subsequent orthodontic therapy.



Despite the recognized clinical importance of eruption disturbances, regional data describing the prevalence of delayed exfoliation and its specific sequelae remain limited, and diagnostic thresholds for differentiating physiological variation from pathological retention continue to be debated. Moreover, relatively few investigations have integrated clinical, radiographic, and occlusal parameters within a single analytical framework to identify early predictors of unfavorable developmental outcomes.

Accordingly, the present study was designed to systematically evaluate the complications associated with delayed exfoliation of primary teeth in children during the mixed dentition stage and to delineate clinical and radiographic indicators that may facilitate early identification and interceptive management. By clarifying these relationships, the study seeks to contribute evidence supporting proactive monitoring strategies and targeted interventions aimed at preserving arch integrity and reducing the need for complex orthodontic correction in later adolescence.

Literature Review

Disturbances in the physiological exfoliation of primary teeth and the subsequent eruption of permanent successors have been widely examined within pediatric dentistry and orthodontic research, owing to their potential to disrupt occlusal development and craniofacial harmony. Early longitudinal investigations established that prolonged retention of primary incisors and canines is frequently associated with deviation of the eruptive path of permanent teeth, often manifesting as labial or palatal displacement, rotational anomalies, or delayed emergence into the oral cavity. Radiographic analyses in such cases commonly reveal incomplete or asymmetric root resorption of the primary dentition, displacement of permanent tooth germs, and, in a subset of patients, ankylotic fusion between the primary tooth root and surrounding alveolar bone that mechanically impedes exfoliation.



Subsequent studies have focused on the consequences of retained primary molars, which appear to exert a particularly pronounced influence on posterior arch development. Infraocclusion secondary to ankylosis has been shown to encourage mesial tipping of adjacent teeth, loss of vertical alveolar height, and localized arch-length reduction, thereby increasing the likelihood of unilateral or bilateral posterior crossbite. Several orthodontic cohort analyses have reported a significantly greater prevalence of anterior crowding among children with persistent primary molars, suggesting that early spatial discrepancies may propagate anteriorly as permanent teeth attempt to erupt into an already compromised arch perimeter.

Periodontal implications of prolonged retention have also attracted scholarly attention. Investigators have described elevated plaque indices and gingival inflammation surrounding mobile or partially resorbed primary teeth, attributing these findings to altered tooth morphology, irregular marginal ridges, and difficulty maintaining effective oral hygiene in affected regions. Chronic gingivitis adjacent to retained teeth has been proposed as a contributing factor to transient attachment loss and to enamel surface alterations in neighboring permanent teeth, possibly mediated by sustained inflammatory activity and bacterial biofilm accumulation during eruption.

More recent research has expanded beyond local dental effects to explore potential systemic and developmental modifiers of exfoliation timing. Endocrine disturbances, nutritional deficiencies, and inherited skeletal growth patterns have been variably associated with delayed dental maturation, although the strength and consistency of these relationships remain debated. Advances in imaging modalities, including cone-beam computed tomography, have enhanced visualization of eruptive pathways and ankylotic segments, thereby refining diagnostic accuracy and facilitating early intervention planning.



From a therapeutic perspective, contemporary orthodontic literature increasingly supports interceptive approaches during the mixed dentition stage. Strategies such as selective extraction of retained primary teeth, space maintenance, guided eruption, and serial extraction protocols have been shown to reduce the severity of malocclusion and simplify comprehensive orthodontic treatment in adolescence. Nonetheless, authors caution that indiscriminate early extraction may precipitate space loss or unfavorable tooth migration if not accompanied by appropriate monitoring and appliance therapy, underscoring the need for individualized clinical decision-making.

Despite the breadth of existing scholarship, several knowledge gaps persist. Many published studies are limited by small sample sizes, narrow age ranges, or retrospective designs, which constrain the generalizability of their conclusions. Furthermore, epidemiological data describing the prevalence and clinical expression of delayed exfoliation in specific geographic or socioeconomic populations remain sparse. Few investigations have simultaneously integrated occlusal indices, periodontal parameters, radiographic findings, and systemic health variables within a unified analytical framework.

Collectively, the existing literature establishes delayed exfoliation of primary teeth as a multifactorial condition with significant implications for occlusal development and oral health, while simultaneously highlighting the need for region-specific, methodologically robust clinical studies. Such investigations are essential for refining diagnostic criteria, clarifying etiological pathways, and developing evidence-based protocols for early identification and interceptive management.

Methodology



Study Design and Setting

A clinic-based, descriptive cross-sectional investigation was conducted over an eight-month period in multiple pediatric dental outpatient facilities. The study was designed to evaluate eruption patterns and associated oral conditions during the mixed dentition stage and to compare children presenting with delayed exfoliation of primary teeth to those exhibiting age-appropriate physiological replacement. Standardized examination protocols were implemented across all participating centers to ensure methodological consistency, and all clinical assessments were performed by calibrated pediatric dentists and orthodontists who had undergone preliminary training sessions to reduce inter-examiner variability.

Study Population and Ethical Considerations

Children between 6 and 11 years of age attending routine dental visits or referred for eruption-related concerns were screened for eligibility. Inclusion criteria for the study group comprised the persistence of at least one primary tooth beyond the established chronological range for exfoliation, as determined by dental eruption charts and corroborated by radiographic findings. The comparison group consisted of age- and sex-matched children demonstrating normal exfoliation and eruption sequences.

Exclusion criteria included a history of previous orthodontic treatment, craniofacial syndromes, cleft lip or palate, known metabolic or endocrine disorders affecting skeletal development, and poor-quality radiographs precluding accurate assessment. Written informed consent was obtained from parents or legal guardians prior to enrollment, and verbal assent was secured from all participating children. The research protocol adhered to internationally accepted ethical standards for biomedical research involving minors and was approved by an institutional review committee.



Clinical and Radiographic Assessment

All participants underwent comprehensive intraoral examination under standardized lighting conditions using plane mouth mirrors and periodontal probes. Tooth mobility, infraocclusion, occlusal contacts, and eruption stage of permanent successors were systematically recorded. The presence of soft-tissue inflammation, plaque accumulation, and localized gingival enlargement adjacent to retained primary teeth was documented using validated periodontal indices.

Radiographic evaluation consisted of panoramic imaging supplemented, where indicated, by periapical radiographs to assess root resorption patterns of primary teeth, angulation and position of permanent tooth germs, alveolar bone height, and signs of ankylosis or pathological obstruction. Eruption timing was compared with age-specific reference standards to differentiate physiological variation from pathological delay.

Orthodontic analysis included measurement of anterior irregularity using Little's Irregularity Index, assessment of sagittal relationships through overjet determination, and evaluation of vertical overlap by overbite measurement. Transverse discrepancies and midline deviations were recorded to the nearest millimeter using digital calipers on dental casts or intraoral scans when available.

Questionnaire and Medical History Review

Parents or guardians completed structured questionnaires addressing prenatal and perinatal history, childhood systemic illnesses, medication use, nutritional status, previous dental trauma, oral hygiene practices, and family history of eruption disturbances. These data were incorporated to explore potential contributing factors and to control for confounding variables during statistical analysis.



Examiner Calibration and Reliability

Prior to data collection, examiners participated in calibration sessions involving repeated assessments of a pilot group of children not included in the final sample. Inter- and intra-examiner reliability for periodontal scoring and orthodontic measurements were evaluated using intraclass correlation coefficients and Cohen's kappa statistics, with values exceeding 0.80 considered indicative of acceptable agreement.

Statistical Analysis

All data were entered into a secure electronic database and subjected to descriptive statistical evaluation, including calculation of means, standard deviations, and frequency distributions. Normality of continuous variables was assessed using the Shapiro–Wilk test. Between-group comparisons were performed using independent-sample *t*-tests for normally distributed variables and Mann–Whitney *U* tests for nonparametric data, while categorical variables were analyzed using chi-square or Fisher's exact tests as appropriate.

Multivariate logistic regression models were constructed to examine the independent association between delayed exfoliation and the presence of occlusal anomalies or periodontal inflammation after adjustment for age, sex, oral hygiene indices, and trauma history. Statistical significance was established at a two-tailed probability level of $p < 0.05$.

Results

A total of enrolled participants completed the full clinical and radiographic evaluation and were included in the final analysis. Demographic characteristics, including age distribution and sex ratio, did not differ significantly between children presenting with delayed exfoliation of primary teeth and those exhibiting



physiological replacement patterns, thereby minimizing potential confounding related to developmental stage.

Occlusal Characteristics

Children in the delayed exfoliation group displayed a markedly higher prevalence of eruption disturbances affecting permanent incisors and canines. Ectopic eruption was observed with substantially greater frequency than in the control cohort, with radiographic examination frequently revealing labial or palatal displacement of erupting teeth relative to the alveolar ridge. Quantitative orthodontic assessment demonstrated significantly elevated anterior irregularity scores, indicating increased dental crowding within the incisal segment.

Sagittal and transverse discrepancies were also more common among children with retained primary teeth. Midline deviation exceeding 2 mm was recorded in a considerable proportion of affected participants, whereas such deviations were infrequently detected in children with physiological exfoliation. Posterior crossbite and rotational anomalies of newly erupted permanent teeth were likewise more prevalent in the delayed exfoliation group.

Table 1 summarizes the distribution of occlusal anomalies across both study groups, including the relative frequencies of anterior crowding, posterior crossbite, and rotational malalignment. Statistical comparison revealed significant between-group differences for each parameter ($p < 0.05$).

Periodontal and Soft-Tissue Findings

Clinical periodontal examination demonstrated significantly higher gingival index scores adjacent to retained primary teeth compared with homologous sites in the control group. Localized plaque accumulation and marginal erythema were frequently noted around partially resorbed or infraoccluded primary teeth,



suggesting that altered morphology and limited accessibility impeded effective plaque control.

Graphical comparison of mean gingival index values between groups is presented in *Figure 1*, which illustrates a clear elevation in inflammatory scores among children with delayed exfoliation. These differences remained statistically significant after adjustment for reported oral-hygiene practices.

Radiographic Observations

Radiographic assessment revealed that retained primary teeth commonly exhibited incomplete or asymmetric root resorption, while permanent successors often demonstrated angulated eruption paths or delayed vertical migration toward the occlusal plane. In several cases, enamel surface irregularities consistent with hypoplastic defects were identified on adjacent permanent teeth, particularly in regions where prolonged contact with retained primary crowns had occurred.

Multivariate Analysis

Multivariate logistic regression modeling identified delayed exfoliation as an independent predictor of anterior crowding, ectopic eruption, and localized gingival inflammation, even after controlling for age, sex, history of dental trauma, and plaque index scores. The strength of these associations supports a direct contribution of prolonged primary tooth retention to the development of both occlusal and periodontal disturbances during the mixed dentition stage.

Discussion

The present findings provide compelling clinical evidence that delayed exfoliation of primary teeth constitutes a disruptive factor in the orderly progression of permanent dentition and is closely linked to the development of occlusal



disharmony during the mixed dentition stage. Children exhibiting prolonged retention demonstrated significantly greater frequencies of ectopic eruption, anterior crowding, transverse discrepancies, and midline deviation, reinforcing the concept that temporal disturbances in tooth replacement exert cumulative effects on arch integrity and spatial balance.

Ankylosis of primary molars emerged as a particularly influential local factor. Infraoccluded ankylosed teeth were frequently associated with vertical alveolar growth restriction and mesial tipping of adjacent permanent teeth, mechanisms that have been proposed to precipitate progressive arch-length reduction and posterior crossbite formation. These observations align with biomechanical models suggesting that ankylosed teeth fail to follow the eruptive movement of the surrounding dentoalveolar structures, thereby creating occlusal depressions that redirect erupting successors and compromise intercuspation.

Radiographic evaluation proved indispensable in differentiating physiological variation in exfoliation timing from pathological retention attributable to displacement, agenesis, or altered angulation of permanent tooth germs. Panoramic and periapical imaging permitted visualization of root resorption patterns, eruptive trajectories, and alveolar bone morphology, facilitating more precise clinical decision-making than could be achieved through intraoral examination alone. The detection of enamel surface irregularities on adjacent permanent teeth further suggests that prolonged proximity to retained primary crowns or chronic inflammatory microenvironments may influence amelogenesis or post-eruptive mineralization processes.

The significantly elevated gingival index scores recorded around retained primary teeth highlight an important secondary pathway through which delayed exfoliation may compromise oral health. Irregular crown contours, partial mobility,



and infraocclusion appear to create plaque-retentive niches that hinder effective mechanical cleaning and promote localized gingival inflammation. Although the inflammatory changes observed in this cohort were largely confined to marginal tissues, persistent gingivitis during childhood has been proposed as a precursor to more advanced periodontal breakdown later in life, underscoring the preventive value of early intervention.

From a therapeutic perspective, the data support the implementation of interceptive strategies tailored to the underlying etiology and stage of dental development. Timely extraction of retained primary teeth, when accompanied by appropriate space supervision or maintenance appliances, may facilitate spontaneous realignment of erupting permanent teeth and mitigate the need for comprehensive orthodontic correction during adolescence. However, indiscriminate removal without consideration of arch length, eruption potential, or growth patterns may precipitate space loss or unfavorable tooth migration, emphasizing the necessity of individualized treatment planning.

The findings further underscore the importance of interdisciplinary collaboration between pediatric dentists, orthodontists, and primary healthcare providers. Routine surveillance of eruption timelines during health and school dental visits offers an opportunity for early detection of deviations from normative patterns, while parental education regarding eruption sequences and the importance of timely professional assessment may enhance compliance with recommended interventions.

Several limitations warrant consideration. The cross-sectional design precludes definitive conclusions regarding causality, and reliance on clinic-based recruitment may limit generalizability to broader populations. Longitudinal studies incorporating serial radiographic monitoring, quantitative assessment of growth patterns, and evaluation of genetic or systemic modifiers would provide valuable



insight into the temporal progression of eruption disturbances and the long-term effectiveness of interceptive measures.

Conclusions and Recommendations

Delayed exfoliation of primary teeth represents a clinically significant risk factor for the development of occlusal irregularities and localized periodontal inflammation during childhood. Prolonged retention disrupts eruptive sequencing, predisposes to space discrepancies and tooth displacement, and may complicate subsequent orthodontic management if left unaddressed.

Based on the present findings, the following recommendations are proposed:

- Routine monitoring of tooth eruption patterns during childhood dental examinations
- Prompt radiographic assessment when exfoliation deviates from expected developmental timelines
- Etiology-based interceptive extraction of retained primary teeth when indicated
- Application of space maintainers or guidance appliances to preserve arch integrity
- Structured parental education programs emphasizing eruption milestones and preventive care

Implementation of these measures may reduce the prevalence of complex malocclusion, improve periodontal health during the mixed dentition stage, and optimize long-term functional and esthetic outcomes.

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