Primary failure of eruption: Further characterization of a rare eruption disorder

Sylvia A. Frazier-Bowers,a Karen E. Koehler,b James L. Ackerman,c and William R. Proffitd
Chapel Hill, NC, and Jacksonville, Fla

Introduction: Posterior open bite has several possible causes, including primary failure of eruption (PFE) that affects all teeth distal to the most mesial involved tooth, mechanical failure of eruption (MFE) (primarily ankylosis) that affects only the involved tooth or teeth, and soft-tissue interferences with eruption (other).

Methods: Radiographs and other clinical records for 97 cases of failure of posterior eruption submitted for consultation were analyzed to further characterize PFE and distinguish it from MFE.

Results: Of the 97 cases, 38 were judged to be clear-cut PFE; 19 were diagnosed as MFE; 32 were classified as indeterminate failure because they were too young to be certain of the distinction between PFE and MFE; and 8 were placed in the "other" category. Two subtypes of PFE were observed. In type 1, eruption failure occurred at or near the same time for all teeth in an affected quadrant. In type 2, a gradient of the time of failure was present, so that some further development of the teeth posterior to the most mesial affected tooth was observed before eruption failure. A family history of eruption problems was noted in 10 of the 38 PFE subjects (26%), and a pedigree analysis was done for 4 families. This was consistent with autosomal dominant transmission.

Conclusions: The distinction between PFE and MFE is clinically important because it determines whether all posterior teeth, or only individual affected teeth, will not respond to orthodontic force. Certain diagnosis often requires progress radiographs so that the pattern of eruption of teeth distal to the most mesial affected tooth can be observed. (Am J Orthod Dentofacial Orthop 2007;131:578.e1-578.e11)

Normal eruption of teeth is of fundamental importance to dentists and orthodontists. The normal eruptive process involves navigation through bone and oral epithelium in a precise, bilaterally timed sequence that must be coordinated with the growth of the jaws in all 3 planes of space. It is incorrect to think that an erupting tooth forces its way through the overlying tissues. Instead, the controlling element is resorption of overlying bone, tooth roots, and the alveolar mucosa. Experiments in dogs, and inadvertent experiments in humans, showed clearly that an eruption path is cleared, and then the tooth moves along the path that has been created for it.1,2

Eruption failure can be attributed to various environmental and genetic factors. Obstacles to eruption can include cysts, other teeth, bone, unfavorable tongue posture, and a digit habit. The obstruction can also be integral to the tooth in the form of fusion of cementum to bone. The resulting ankylosis prevents further eruption. Eruption failure due to mechanical obstruction might be considered a secondary failure, because the eruption mechanism is normal. If the obstruction is removed, eruption usually resumes; if not, the previously obstructed tooth or teeth can be moved orthodontically. Because an area of the periodontal ligament (PDL) is abnormal or absent when ankylosis occurs, permanently removing this type of mechanical obstruction is impossible. If a small area of ankylosis is broken by manipulating the tooth, it might be possible to move it for a short time, but reankylosis is inevitable.

The term primary failure of eruption (PFE) was coined by Proffit and Vig3 to describe a condition in which malfunction of the eruption mechanism causes nonankylosed teeth to fail to erupt. The primary identifying characteristic is failure of an affected tooth to move along the eruption path that has been cleared for it. Involved teeth can erupt partially and then cease to erupt, becoming relatively submerged although not ankylosed. Only posterior teeth are affected, so the result is a posterior open bite, and all teeth distal to the most mesial affected tooth also are affected. The condition is rarely symmetric and frequently unilateral, but it can affect any or all of the posterior quadrants. A

578.e1
key characteristic is an abnormal or complete lack of response to orthodontic force, so that affected teeth cannot be moved into their proper positions. A nonankylosed tooth with PFE is likely to become ankylosed when force is applied. Although the cause of PFE is unknown, it was presumed that a genetic disturbance with varying penetrance and expressivity is the most likely explanation, and subsequent reports of PFE have described a familial component.

Since the original article describing PFE, orthodontists have been sending patient records with unusual problems in eruption of posterior teeth to the University of North Carolina (UNC) for evaluation and consultation. By 2005, 112 cases had been obtained. Using this collection of clinical records, we further characterized PFE, offering guidelines to distinguish it from other causes of posterior open bite (especially first-molar ankylosis with which it easily can be confused in younger patients) and examining its hereditary nature.

MATERIAL AND METHODS

For inclusion in this study, the minimum record was a clear panoramic radiograph showing a problem with eruption of posterior teeth, but photographs, follow-up panoramic radiographs, and cephalometric radiographs were available for many patients. Any information from the referring orthodontist was recorded, such as patient demographics, significant medical and dental histories, family history, treatment approaches, and response to treatment if it was attempted. From the initial sample, 2 subjects were excluded due to successful orthodontic correction that was evidence of delay but not of failure of eruption, and 13 others were removed from the sample because of a missing panoramic radiograph, a suspected syndrome, or surgery in a location that might have interfered with eruption. The remaining 97 subjects in the study included 50 males, 46 females, and 1 sex unknown (data not provided). The sample population represented 24 states and Ireland, with ages ranging from 7 to 29 years. Dental age was established according to the method of Demirjian. Observation periods ranged from a single time to 9 years, with an average of 3 years. There was a reported family history of eruption disturbances in 9 families, comprising 15 of the 97 subjects.

The subjects were classified into 1 of 4 categories, based on their radiographic characteristics. PFE was the diagnosis if the characteristics listed in Table I (under PFE) were present. If the radiographic appearance was typical of ankylosis, with apparently normal eruption of teeth distal to the affected tooth (usually a permanent first molar), the diagnosis was mechanical failure of eruption (MFE), which acknowledges that a more rigorous definition of ankylosis was not possible from the records available for this study. A key distinguishing characteristic between PFE and MFE is whether distal teeth are normal or affected, but this cannot be determined in the early stages of development. Patients in whom the distinction could not be made were labeled as indeterminate failure of eruption (IFE). Eruption problems that were neither PFE nor MFE were placed in the “other” category.

Subjects whose referring orthodontist indicated a family history of eruption problems were interviewed, permission was requested to contact the family, and their families were recruited to participate in this study. This

<table>
<thead>
<tr>
<th>Table I. Diagnostic characteristics of posterior open bite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. PFE</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>2. MFE</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>3. IFE</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>4. Other</td>
</tr>
</tbody>
</table>

Fig 1. In sample of 97 subjects, 39% had PFE, 33% had IFE, 20% had MFE, which includes impaction and ankylosis, and 8% did not fit into any category (other).
study was reviewed and approved by the UNC Biomedical Institutional Review Board. Consent was obtained for each subject who participated and by the parents of the minors. When possible (4 of the 9 families that were identified), family members were interviewed (1 group at UNC, the other 3 families by telephone), and dental records obtained (in the UNC clinic or by the referring orthodontist). Participants were categorized as affected or unaffected. Based on these diagnoses, pedigrees were constructed and analyzed in a preliminary effort to determine the pattern of inheritance.

RESULTS

The number of subjects in each category is summarized in Figure 1. In 32 of the 97 subjects, a definitive diagnosis could not be made without additional longitudinal data (representative subject shown in Fig 2), and 19 subjects showed MFE (representative subject shown in Fig 3). Eight subjects did not fit the description of PFE or MFE (example shown in Fig 4).

The distribution of affected teeth in the PFE group is shown in Figure 5. A few subjects had affected teeth forward as far as the first premolars, but the frequency of affected teeth increased toward the second premolars and the first and second molars. In most cases, the subjects were too young to have much development of the third molars, and only third molars that were obviously affected were counted in the distribution.

The PFE group had 3 distinguishable forms. One group (17 of 38), designated type I, had a similar lack of eruption potential of all affected teeth with a progressive open bite from anterior to posterior (Fig 6).
second group (11 of 38), designated type II, had a tooth distal to the most mesial affected tooth with greater although inadequate eruption; therefore, the eruption potential varied among the affected teeth (Fig 7). Ten patients had both 2 types coexisting in different quadrants. There appeared to be no difference in the subtypes of PFE between those with and without a family history of eruption problems.

**Fig 4.** Subject with mild lateral open bite on right side and moderate lateral open bite on left, shown in A, panoramic, B, clinical photos, and C, cephalometric radiograph. There is no indication of failed eruption mechanism.
At least 1 ankylosed deciduous tooth was noted in 24 of the 97 subjects (PFE = 8, IFE = 12, MFE = 2, other = 2). Four subjects had hypodontia (IFE = 3, MFE = 1), 5 subjects had hyperdontia (PFE = 2, IFE = 2, MFE = 1), and 3 subjects had taurodontism (all 3 in IFE). No other dental anomalies were noted.

For the 29 subjects for whom cephalometric radiographs were submitted, skeletal classifications were noted. Of these, 26% were Class III, and one-third (35%) of those with PFE were Class III.

Twenty-six percent of the PFE subjects in this sample appeared to be familial (10 of 38). There was no obvious difference in the types of PFE expressed by family members vs the isolated cases. Figure 8 shows PFE in a mother and a daughter. Five other subjects in the sample reported familial eruption problems. Two subjects who were brothers were classified as IFE because they were too young for diagnosis, and the other 3 (classified as either IFE or MFE) were related to PFE subjects. Other than a high prevalence of ankylosed deciduous molars (5 of 15, or 33%), no other dental anomalies were found in the familial group.

Of the 9 families with a reported familial history of eruption problems, 4 pedigrees were constructed. One pedigree is shown in Figure 9. Pedigree analysis by inspection strongly suggests an autosomal dominant inheritance pattern. Both sexes were affected without preference; about half the members in the kindred were affected, and the trait did not skip generations. The possibility of an X-linked autosomal dominant inheritance pattern cannot be excluded; however, this mode of inheritance is extremely rare and therefore less likely.

**DISCUSSION**

New findings from this study indicate 2 distinguishable types of PFE that seem to be related to the timing of onset. In type I, the classic form described initially, loss of eruption potential appears to strike at a certain chronologic time, leading to a similar lack of eruption potential of all affected teeth. In type II, the timing of onset might be related to the stage of root development, leading to a varied eruption potential among affected teeth. In a significant number of subjects, a combination of the 2 types was found, and a few subjects showed PFE in 1 quadrant coupled with a single ankylosed tooth in a different quadrant. Therefore, PFE and ankylosis might be closely related, as the studies by Raghoobar et al.\textsuperscript{10,11} seem to show. Perhaps an abnormal PDL can lead to either condition.

In the small subset for whom lateral cephalograms were available, a high percentage of the subjects, especially those with PFE, had skeletal Class III relationships. This was not reported previously. In our study population, the possibility that lateral cephalograms were sent only when a skeletal discrepancy was present cannot be ruled out; therefore, the high percentage of Class III subjects might be a biased representation. Of the other articles on PFE, only a few account for the skeletal relationships of some of their subjects. Proffit and Vig\textsuperscript{3} reported a subject with a Class III relationship, Ireland\textsuperscript{6} had 2 Class I subjects, and Brady\textsuperscript{5} reported 1 of 2 with a Class II pattern. Dibiase and Leggat\textsuperscript{8} reported that both of their subjects were Class II. Because failure of permanent molars to erupt is so rare, finding a sample size large enough to study the characteristics is difficult.\textsuperscript{12-15}

Reports of a definite familial tendency associated with PFE indicate that the cause of the developmental disturbance in the PDL might be inheritable. In this study, 26% of the PFE cases were familial. Raghoobar et al.\textsuperscript{7} reported a heritable component to eruption failure in 10% of his cases, whereas other case reports provided studies of a few single families.\textsuperscript{5-9,16}

Pedigree analysis of the familial cases in this study was highly suggestive of an autosomal dominant inheritance pattern with complete penetrance and variable expressivity. Most of the familial studies in the literature also report an autosomal dominant inheritance pattern\textsuperscript{4,5,16}; however, Winter et al.\textsuperscript{16} reported a family as autosomal recessive.

Although no patients examined by Proffit and Vig\textsuperscript{3} in the original study had similarly affected relatives, they supposed that a genetic disturbance of varying penetrance and expressivity was the likely etiology. The current reports of affected families support this hypothesis\textsuperscript{4-8} and suggest that spontaneous mutations might account for the subjects with no previous family history. One can speculate that this genetic disturbance leads to a local disruption in metabolic activity.
or altered blood flow, which then hinders the eruption mechanism. Raghoebiar et al.,10 based on histologic examination of 26 molars from 20 patients, suggested that the mechanism is replacement of cementoblasts by osteoblasts due to a local disturbance in the PDL during the repair process of local physiologic resorption.

The best evidence of failure in the eruption mechanism is bone resorption that clears a path for the erupting tooth, without tooth movement. Affected teeth that were surgically exposed are generally reported to be easily movable in the crypt and not ankylosed. Although these teeth might have some slight response to orthodontic forces, the response is abnormal, and the teeth invariably become ankylosed before reaching occlusion. Case studies illustrate that not only do affected teeth fail to respond to treatment, but also adjacent normal teeth are adversely affected by intrusion to the level of the affected teeth (Fig 10). Raghoebar et al10 and Winter et al16 also concluded that ankylosis in the failed eruptive process can be a secondary rather than the initiating process and reiterated that orthodontic procedures designed to improve eruption are doomed to failure in patients with PFE.

In the diagnosis of eruption failures, the first step is to rule out local, systemic, and endocrine factors. Endocrine abnormalities (at least to this point) have not been identified in PFE or ankylosis patients. Ultimately, the principal differential diagnosis is mechanical obstruction (ankylosis) vs failure of the eruption mechanism. Distinguishing between the 2 is key to determining the prognosis for the affected teeth. Unfortunately, MFE and PFE can have similar presentations in the early stages. If so, a definitive diagnosis cannot be made without sufficient longitudinal data and therapeutic diagnosis (an attempt at orthodontically erupting the tooth or teeth that might or might not be affected).

The first encounter with these patients often occurs around age 8 or 9 when asymmetry in the eruption pattern of the permanent first molars is noticed. The conservative approach is to take a panoramic radiograph with the patient’s teeth together and recall him or her in 6 to 12 months to determine eruption progress. Evaluation at recall will show progress, no change, or relative submergence. If there is eruption progress, PFE and ankylosis can have similar presentations in the early stages. If so, a definitive diagnosis cannot be made without sufficient longitudinal data and therapeutic diagnosis (an attempt at orthodontically erupting the tooth or teeth that might or might not be affected).

Fig 6. Classic example of PFE type I in all 4 quadrants, showing cleared eruption path in A, panoramic film and B, clinical photos.
Fig 7. Subject with characteristics of PFE type II in A, panoramic radiograph and B, clinical photos, with C, Class III skeletal relationship. Affected teeth were easily surgically luxated and not ankylosed. Treatment with vertical elastics was not successful.
valuable clues. Differentiation between the 2 types of PFE cannot be made until at least age 14 or 15 when the second molar either completely fails to erupt or erupts partially and then stops.

Once PFE has been diagnosed, treatment options are disappointing and limited. Patients and orthodontists must often either accept the premolar occlusion or opt for more invasive techniques, which unfortunately are unlikely to succeed. In the mildest cases, teeth can be restored with onlays and crowns,\(^{17}\) but definitive restorations should not be placed before completion of vertical growth. For moderately severe cases, extraction of teeth with placement of implants might be an option, but bone grafts before implants are likely to be required. Another option could be a small segmental osteotomy to surgically reposition the teeth into occlusion, but there are few if any documented successes with this approach. In severe cases, a significant deficit in alveolar bone height precludes implant restorations and subapical osteotomy. One report of distraction osteogenesis to correct an extreme posterior open bite provides an interesting potential treatment alternative.\(^{18}\) Often the only feasible option is a removable prosthesis.\(^{19}\)

CONCLUSIONS

PFE is a rare condition that can lead to spectacular posterior open bites. It is difficult to diagnose at young ages, and even more difficult to treat due to the lack of response to orthodontic forces, but proper diagnosis can save the patient and the orthodontist years of frustration.

Fig 8. PFE in A and B, mother and C-E, daughter. Mother was affected in all 4 quadrants and was treated with multiple extractions. Daughter had ankylosed deciduous teeth and was bilaterally affected, although more severe on right side.
Fig 8. (Cont’d)
and disappointment. The observation that PFE can occur in families suggests that the developmental disturbance leading to PFE is heritable. Future studies to determine the genetic etiology of PFE are needed because this can aid in differential diagnosis, allow early identification of affected family members, and eventually lead to new treatment modalities.

An overview of types of posterior eruption problems, summarizing our current concepts, is given in Table II.

This study would not have been possible without the many concerned orthodontists who sent cases 1 or 2 at a time for evaluation. We thank Thomas Ahman, Loring Ross, Fidel Del Toro, and Peter Shapiro for

Fig 9. Pedigree of PFE subject. Analysis by inspection shows autosomal dominance with complete penetrance.

Fig 10. Attempt at orthodontic treatment led to intrusion of normal teeth mesial to affected teeth.
submitting many cases and their continued support of this research, and Christopher Planer and Melody Torain for their assistance with data collection and preparation of this manuscript.

REFERENCES


Table II. Overview of types of posterior eruption problems

<table>
<thead>
<tr>
<th>Classification</th>
<th>Number of affected teeth</th>
<th>Impact on neighboring teeth</th>
<th>Clinical appearance of ankylosis</th>
<th>Affected teeth visible intraorally</th>
<th>Typical treatment response</th>
<th>Proposed cause of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFE</td>
<td>Usually only first molars</td>
<td>Adjacent teeth normal</td>
<td>Yes</td>
<td>Maybe</td>
<td>Other teeth respond, affected teeth might respond to luxation</td>
<td>Ankylosis, possible other obstruction</td>
</tr>
<tr>
<td>PFE</td>
<td>Unilateral or bilateral, can involve whole quadrants</td>
<td>Distal teeth also affected</td>
<td>No</td>
<td>Usually some portion of at least 1 tooth</td>
<td>No response to orthodontic force</td>
<td>Failure of eruption mechanism</td>
</tr>
<tr>
<td>IFE</td>
<td>Too early to determine</td>
<td>Unknown at this stage</td>
<td>No</td>
<td>Maybe</td>
<td>Depends on final diagnosis</td>
<td>Ankylosis or PFE</td>
</tr>
<tr>
<td>Other</td>
<td>Any</td>
<td>Unknown</td>
<td>No</td>
<td>Yes</td>
<td>Might respond but tends to relapse</td>
<td>Possible tongue or soft-tissue interference</td>
</tr>
</tbody>
</table>