Submitted: 20 April, 2024 Accepted: 04 June, 2024 Published: 03 November, 2024 DOI:10.22514/jocpd.2024.123

Journal of Clinical Pediatric Dentistry

REVIEW

Clinical indications for the diagnosis and treatment of functional posterior crossbite in pediatric population: a narrative review with clinical description

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Abstract

The present manuscript aims to provide an updated overview of the clinical management of functional posterior crossbite (FPXB) in growing subjects which can be helpful for orthodontists and pediatric dentists in daily practice. Database searches were performed until December 2023 to evaluate the published literature on the topic. The most pertinent articles were chosen for the review from the retrieved articles. No restrictions regarding the year or language of publication were applied. Additional studies were included by manually searching the references of the included studies. The manuscript has been structured for a narrative purpose. Although there is evidence of spontaneous correction in the transition from deciduous to mixed dentition, the literature suggests initiating the treatment early to increase the success rate. Early treatment involves reducing the risk for potential temporomandibular disorders and adaptations at the level of skeletal, dental, and muscle components. Recent advancements in tridimensionali (3D) imaging systems can also help define the appropriate treatment time case-by-case. Considering the prevalence and the multiple etiological factors involved in the development of FPXB in the pediatric population, orthodontists and pediatric dentists should decide the treatment time for this condition with a careful evaluation of the risk/benefit ratio.

Keywords

Functional posterior crossbite; Mandibular shift; Maxillary expansion; Interceptive orthodontics

1. Introduction

The posterior crossbite is one of the malocclusions frequently occurring in deciduous and mixed dentition, with a prevalence ranging from 7% to 23% [1–3]. It often presents unilaterally due to a functional shift of the mandible towards the affected side [4]. This condition, known as functional posterior crossbite (FPXB), is often determined by a mild transverse deficiency of the maxilla which leads to occlusal interferences and subsequent functional lateral deviation of the mandible towards the side affected by the crossbite [5]. In most cases, the treatment of FPXB requires maxillary arch expansion [6] to enhance the transverse diameters of the upper maxilla and restore proper mandibular posture.

Depending on the etiology of transverse deficiency of the maxilla, the expansion of the upper arch can be skeletal, by applying orthopedic forces to promote separation of the palatine-median suture, or dento-alveolar, by applying orthodontic forces (lower range) facilitating expansion primarily at the alveolar process level [7]. Moreover, it is known that functional forces from the muscles of the face and mouth play a crucial role in shaping dental arches and maxillary development. By redirecting and modifying these forces using functional appliances such as Frankel functional regulators, it may be possible to guide the natural growth of the maxilla and surrounding structures. These appliances may be helpful in widening the maxillary arch, improving dental alignment, and fostering a more harmonious relationship between the maxilla and mandible [8, 9].

Regardless of the type of maxillary expansion, interceptive treatment of FPXB has remarkable clinical relevance in growing patients. In this regard, the persistence of FPXB over time can influence the development of morphological/structural alterations affecting skeletal, dento-alveolar, and muscular components. These changes are the result of compensatory adaptation aimed at maintaining stable function and occlusion but may lead to asymmetry in untreated individuals [10, 11].

Since compensatory asymmetry increases with time, early treatment FPXB is often recommended to create conditions for normal occlusal and craniofacial development [12, 13] and to reduce the risk for occlusal compromises during the treatment with fixed appliance in permanent dentition. However, there is also evidence of spontaneous resolution of FPXB in the transition from primary dentition and early mixed dentition [14, 15], which raises concerns in relation to treatment timing and opportunity.

Considering the high prevalence of FPXB in the orthodontic pediatric population, there are several contributions in the literature addressing occlusal and functional factors related to this malocclusion, as well as treatment effectiveness. Such evidence comes from well-conducted case descriptions; less evidence from clinical trials and systematic reviews is also available, however, they are focused on single specific topics such as treatment effectiveness [16] or functional sequelae [17, 18]. Instead, there is a lack of updated contributions providing a comprehensive overview of FPXB and clinical indications for treating this malocclusion. Malandris [19] and Kennedy [20] reported a detailed review of the clinical management of unilateral posterior crossbite with mandibular shift; however, since almost 20 years have passed since this contribution, and new technologies have been integrated into orthodontic research and clinical diagnosis, the present manuscript aims to provide an updated overview on the clinical management of FPXB in growing subjects, which can be helpful for orthodontists and pediatric dentists in daily practice.

2. Materials and methods

A search strategy was carried out until December 2023 through a combination of MeSH terms and free text words pooled through boolean operators ("AND", "OR") on PubMed and Scopus databases. The following research strategy was applied: ((functional posterior crossbite) OR (mandibular shift) OR (unilateral posterior crossbite)) AND ((maxillary expansion) OR (interceptive treatment) OR (interceptive orthodontics)). Articles related to the diagnosis and treatment of functional posterior crossbite in growing patients were included, without the application of year or language restrictions. An additional manual search was performed by selecting references in the included studies. Therefore, additional articles have been considered if relevant to the clinical indications for the diagnosis and treatment of functional posterior crossbite in the growing patients. Two authors selected the most pertinent articles and eventual disagreements were resolved after consulting a third author.

3. Results

To better address clinical indications and, considering the different types of information available from the literature, the text was organized generating specific domains that covered the most significant clinical topics related to the treatment of FPXB in growing subjects. The explanation of retrieved information was supported by iconographic clinical representation of the topic object of interest.

3.1 Aetiology

The development of FPXB involves a combination of dental-skeletal and neuromuscular functional factors. A small maxillary to mandibular intermolar dental width ratio stands out as the predominant variable associated with FPXB, with its origin potentially rooted in genetic or environmental influences. However, environmental factors appear to exert a more substantial influence on functional aspects during the developmental phase. Notably, conditions such as upper airway obstruction, characterized by hypertrophied adenoids or tonsils, and allergic rhinitis leading to mouth breathing, have demonstrated correlations with the initiation of posterior crossbites [21, 22]. These subjects often present an increased lower face height due to the adaptive changes in head posture caused by chronic oral breathing patterns [23]. Among environmental factors, non-nutritive sucking habits can contribute to the development of posterior crossbites [24, 25]; solid evidence would confirm that if sucking habits persist up to or beyond 48 months 7 up to 10 children develop anterior open bite, posterior crossbite or increased overjet, with posterior crossbite accounting for 29% of the malocclusions observed when sucking habit persists beyond 4 years of age [19].

Both functional and non-nutritive habits negatively influence the transverse growth of the maxilla (along the midpalatal suture) or the expansion of the alveolar processes and dento-alveolar arch at an early age, determining similar signs of malocclusion such as crossbite, anterior open bite and increased overjet. In this regard, factors such as tongue position and size, mouth breathing, non-nutritive sucking behaviors (such as digit or pacifier sucking), and jaw-posture habits play roles in the emergence of a posterior crossbite [24–26]. However, functional and non-nutritive habits can differently influence the vertical and sagittal skeletal facial growth patterns; for example, pacifier users seem to be more susceptible to developing dento-alveolar deformities, at least at the early stage, while oral breathers can develop greater lower face height with facial skeletal divergence and long-face syndrome (Fig. 1A–F). Such difference underlines the necessity for an extremely accurate differential diagnosis for planning the appropriate orthodontic treatment strategy, especially when they are in combination with other treatments. In case of oral breathing patterns, patients should be referred to the otolaryngologist to identify the site and the reason for increased airway resistance, and the orthodontic treatment should be coordinated with such information in order to avoid the risk for relapse; instead, pacifier users without significant skeletal disharmonies may benefit from interceptive orthodontic treatment supported by myofunctional therapy. In this regard, it should be considered to implement habit correction strategies. Ideally, these strategies should be applied before initiating orthodontic treatment.

Moreover, when an ectopic eruption occurs in the primary or permanent dentition, it can contribute to the development of crossbite. Ectopic eruption can occur when there is inadequate space in the dental arch for the tooth to emerge properly. This might happen due to factors such as crowding of teeth, small jaw size, or the presence of supernumerary teeth. When a tooth erupts in an abnormal position due to space constraints, it can potentially lead to crossbite by interfering with the normal alignment of opposing teeth [27–29].

It is important to point out that associations between nonnutritive sucking habits, airway obstructions, neonatal intubation and posterior crossbites do not necessarily suggest a cause-and-effect relation [20].

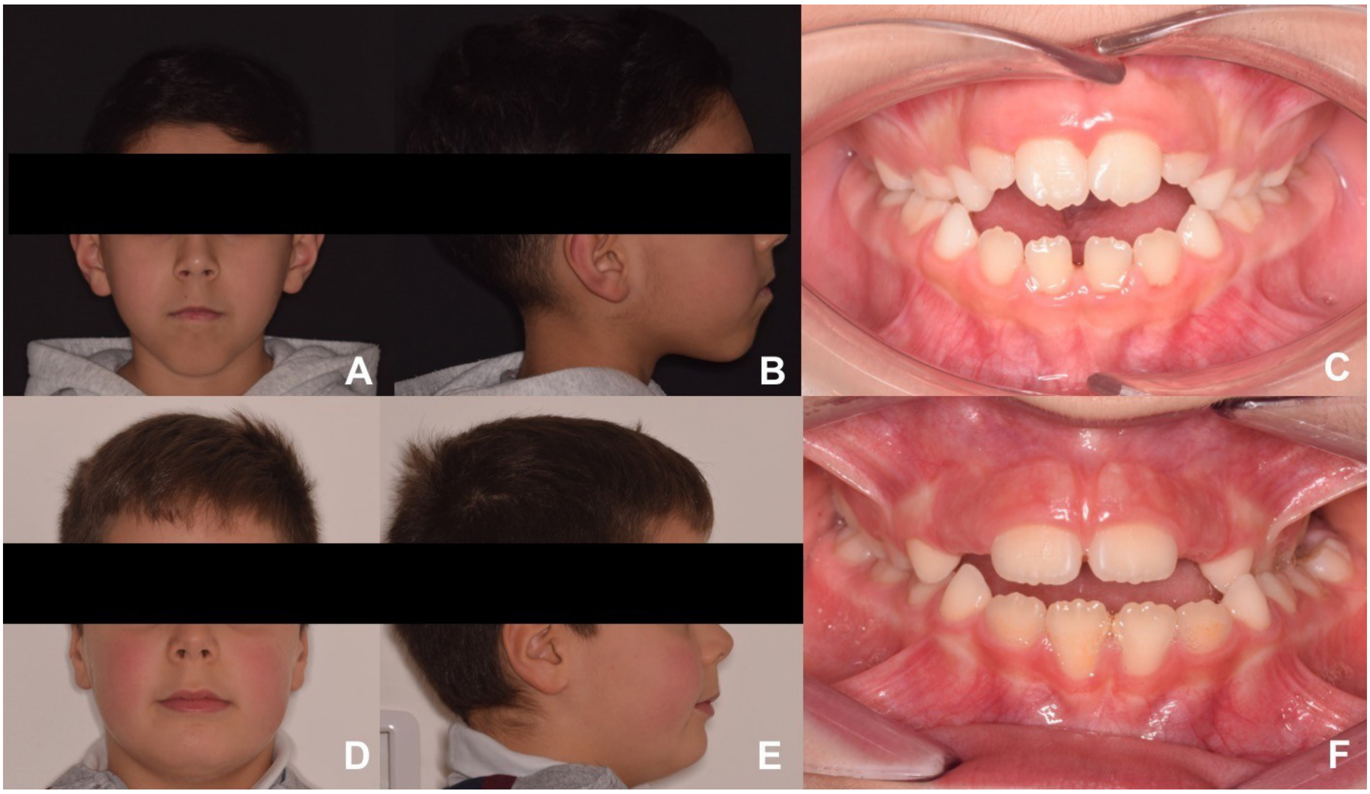


FIGURE 1. Example of different phenotypes of subjects affected by posterior crossbite and anterior open bite. (A–C) Oral breathers with skeletal higher facial angle and long-face syndrome. (D–F) Pacifier users with normal vertical facial growth developing dento-alveolar deformities.

3.2 Diagnosis

Functional posterior crossbite (FPXB) is clinically characterized by a unilateral crossbite accompanied by a functional shift of the mandible toward the side affected by the crossbite. The lateral shift of the mandible in functional crossbite (FXB) leads to a skeletal (and often dental) midline deflection toward the side of the crossbite. It is often associated with transverse maxillary constriction with marginal ridges in line and the absence of simple dental crossbite while assessing inter-arch relationships in centric occlusion (CO). In this regard, FPXB differs from bilateral crossbite (CB) in the degree of severity of maxillary constriction (skeletal or dento-alveolar) since FXB exhibits a lesser maxillary to mandibular width discrepancy [30].

In Functional Posterior Crossbite (FPXB), the side affected by the crossbite typically exhibits a partial or complete Class II molar relationship, while the non-crossbite side demonstrates a Class I relationship due to rotational mandibular closure (Fig. 2A–C). This condition is associated with an asymmetric condyle position, where the non-crossbite side is situated downward and forward in the fossa, while the crossbite side is centered within the fossa [4, 31]. In FPXB, an evident discrepancy exists between centric occlusion (CO) and centric relation (CR). Hence, it is crucial to conduct a differential diagnosis with a true unilateral crossbite, wherein CO and CR usually align. This differentiation can be readily established by assessing the transverse inter-arch relationship in CR, confirming the presence of functional mandibular asymmetry (FPXB) or intra-arch asymmetry (true unilateral posterior crossbite (UPXB)) causing the unilateral crossbite (Fig. 2D).

Additionally, extra-oral examination may reveal asymmetry of the mandibular chin concerning the facial midline, thereby diminishing facial aesthetics. Such distinction is important not only to establish the appropriate treatment but also to plan the appropriate biomechanics since, in case of maxillary expansion, the appliance should provide more expansion on the CB side in true UPXB whereas conventional symmetric appliance framework is generally adequate for treating both FPXB and bi-lateral crossbite (Fig. 3A–D) [10].

Despite the recent enhancement in digital radiology and 3D imaging systems that can provide a detailed analysis of anatomical structures, the diagnosis of FPXB is still based mainly on clinical inspection. Concerning the radiological dataset, it is important to adequate the radiation exposure to the clinical necessity for diagnosis and treatment plan, according to the A.L.A.R.A. (As Low As Reasonably Achievable) and A.L.A.D.A. (As Low As Diagnostically Acceptable) principles [32]. Some indications for the use of 3D image examinations in these cases could be the management of impacted canines, transpositions, or ectopic and impacted teeth [33]. In this regard, in the absence of relevant significant skeletal disharmonies or suspicious oral breathing patterns, the cephalogram cannot be prescribed.

3.3 Indications for early treatment

3.3.1 Risk of altered function and TMJ disorder

Occlusal interferences represent the clinical factor triggering FPXB. Although there is a consensus that occlusal factors do

FIGURE 2. Example of FPXB. (A–C) The side affected by the crossbite typically exhibits a partial or complete Class II molar relationship, while the non-crossbite side demonstrates a Class I relationship due to rotational mandibular closure. (A,D) Discrepancy exists between centric occlusion (CO) and centric relation (CR): This differentiation can be readily established by assessing the transverse inter-arch relationship in CR, confirming the presence of functional mandibular asymmetry (FPXB) or intra-arch asymmetry (true UPXB) causing the unilateral crossbite.

FIGURE 3. Differential diagnosis between FPXB and true UPXB. (A,B) FPXB featuring mild maxillary constriction and symmetric morphology of the palate. (C,D) true UPXB featuring maxillary constriction with significant reduction of the hemilateral diameter on the crossbite side.

not play a significant role in the etiology of temporomandibular joint (TMJ) pain and dysfunction [34, 35], the presence of occlusal interferences has been identified as a potential trigger for bruxism [36] and tooth surface loss. In this regard, stress-related grinding or clenching habits are considered to exert a more substantial influence [37, 38]. The extent to which malocclusions in the primary dentition and, in general, at developmental ages, contribute to long-term temporomandibular disorders remains a subject of debate. Nevertheless, posterior crossbites with a shift in closure consistently correlate with TMJ problems [36, 37]. This correlation is thought to result from asymmetric condylar positioning and contralateral dental arch asymmetry [31]. These asymmetries lead to the displacement of the mandible during jaw movements, influencing the alignment and activity of jaw muscles [18]. While these alterations may not significantly impact jaw function in younger children, over time, jaw muscles adapt to the abnormal mandibular position, resulting in modifications to their thickness, particularly on the side affected by the crossbite [38]. Also, since FPXB alters normal occlusion and the orientation/alignment of jaw muscles, it can compromise normal chewing function by reducing the effectiveness and efficiency of food grinding [18]. Hence, in the absence of consolidated evidence of the causative role of malocclusion in determining TMJ disorders, even so, the early correction of FPXB is advocated to restore normal chewing and swallowing function.

3.3.2 Compensatory inter-arch asymmetry

The available evidence suggests that FPXB determines an asymmetric position of the condyles in the glenoid fossa when compared to subjects with normal occlusion [4, 31], with restoration of symmetry following early treatment [39, 40]. Instead, untreated posterior crossbites in adult patients result in alterations in mandibular symmetry and rotational position relative to the cranial base [41–43]. For this reason, as previously mentioned, early treatment of FPXB is advocated to avoid the persistency of the condylar asymmetry during the growing stage which could interfere with mandibular function and bone remodeling, and could muscle, skeletal, and joint adaptations in crossbites primarily occur during early development [44]. In this regard, early correction of FPXB by expanding the maxilla has been demonstrated to establish condyle and dental symmetry [39] and realign mandibular rotation [4].

Most of the studies analyzing the asymmetry in subjects with FPXB had been focused on the mandible [31, 45]. On the contrary, few studies have focused on the maxillary morphology and reported that FPXB in mixed dentition could be associated with asymmetric development of the maxillary arch [10, 46]. In this regard, recent evidence would suggest that FPXB can be associated with an asymmetric pattern of development of the maxilla [10]. Using the digital surface analysis technique, it was found that FPXB in mixed dentition could be associated with a symmetric contraction of the basal bone and asymmetry of the alveolar processes, with the crossbite side being narrower than the non-crossbite side. Such asymmetry may develop as an adaptive and compensatory process aiming at invalidating functional deviation caused by the mandibular shift toward the crossbite side (Fig. 4A–F) [47].

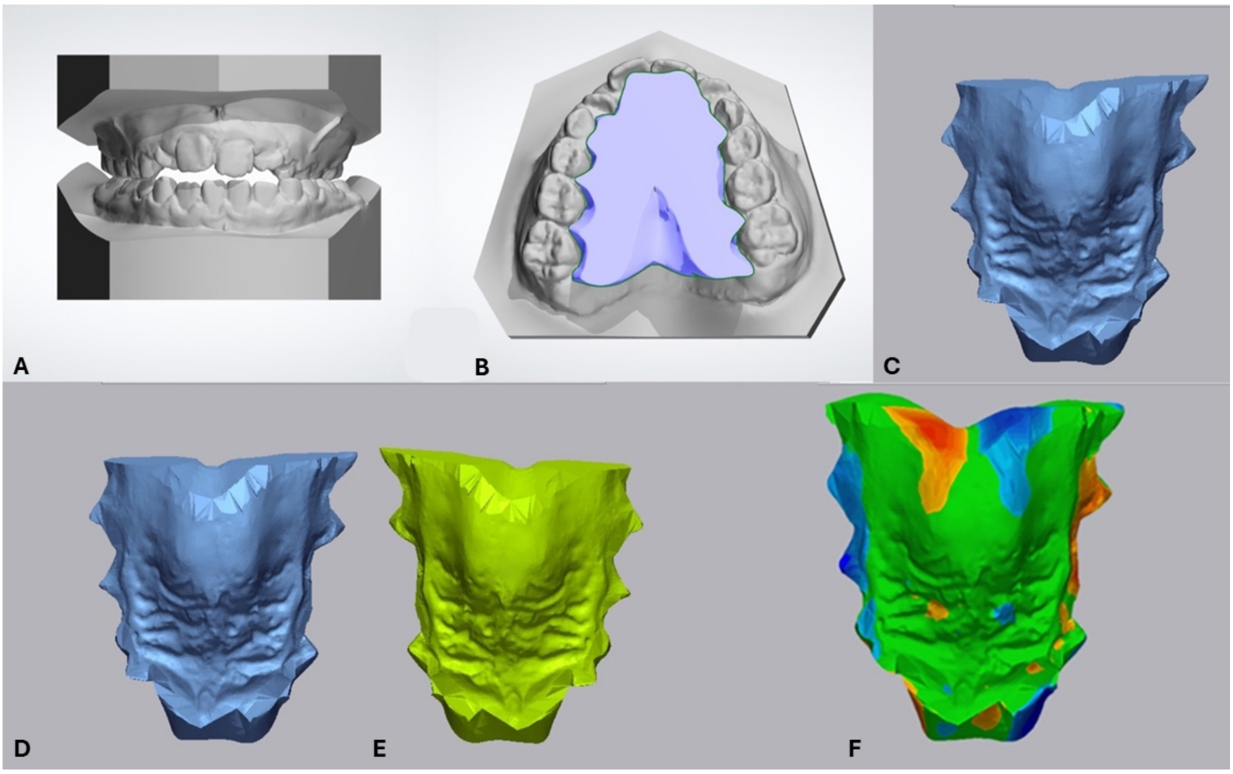
This means that subjects with FPXB often present symmetric skeletal constriction of the palate with asymmetric morphology of the alveolar process. This recent evidence is of great clinical relevance when considering the future application of orthodontic biomechanics in permanent dentition procedures (see treatment section), and introduces the risk of maxillary asymmetry as a factor for establishing early treatment. In this regard, even more recent evidence suggested that maxillary asymmetry improves one year after treatment of FPXB with rapid maxillary expansion [47]. Thus, although the primary goal of treating FPXB is the correction of the malocclusion and of the associated altered mandibular function, recent evidence would suggest that the early treatment of this condition is important to favor a more harmonious and symmetric development of the palate.

3.3.3 Facial aesthetics

In the era of social media and network communication, facial and smile attractiveness represents an essential factor supporting self-esteem and social relationships, even among young individuals [48]. Being focused on facial attractiveness, laypersons are increasingly becoming familiar with concepts of facial and soft-tissue aesthetics. This new awareness explains why specific skeletal malocclusions are consistently perceived as aesthetically displeasing by patients or their caregivers, potentially causing varying degrees of distress based on individual values and self-confidence [49, 50]. In the case of FPXB, the lateral shift of the mandible generates the asymmetry of the lower facial third upon closure, leading to lower midline discrepancy and chin deviation toward the side affected by the crossbite (Fig. 5A–D). For this reason, it is not rare that parents or caregivers seek orthodontic consultation after having noticed the appearance of mandibular asymmetry. In this regard, although functional adaptations represent the primary indications for early treatment of FPXB, the awareness of aesthetic deterioration from parents or caregivers could represent an important factor for requiring orthodontic consultation.

3.3.4 Primary dentition *vs.* mixed dentition treatment *vs.* permanent dentition treatment

Since up to 45% of posterior crossbites in the primary dentition reach self-correction during the development of the dentition, the routine treatment of this malocclusion in the primary dentition as opposed to the early mixed dentition period has been questioned [19]. According to the results of a recent retrospective study [51], about three-quarters of cases with a posterior crossbite in the deciduous dentition underwent autocorrection in the mixed dentition. On the other hand, 4% of children develop a new crossbite in mixed teeth. Therefore, in cases with a posterior cross-bone of the deciduous tooth, it may be reasonable to wait for the first permanent teeth to occur before the management is initiated. The treatment of FPXB in the primary dentition becomes justified when the absence of treatment exposes the child to the risk of enduring long-term detrimental consequences (see above). Maxillary expansion at late deciduous dentition was also suggested since it allows first permanent molars to erupt with normal transverse positions (*i.e.*, without crossbite) [19]. Before contemplating any treatment, it is essential to assess the child's ability to



F I G U R E 4. Example of digital procedure used to assess palate morphology. (A–C) Palate segmentation. (D,E) Palate model mirroring. (F) Superimposition of the original model with the mirrored model with deviation analysis. Using this analysis, recent studies have confirmed that subjects with FPXB present a symmetric mild constriction of the palate with asymmetric development of the alveolar processes, being that the CB side is narrower than the non-CB side due to functional occlusal adaptations. Green color = range of tolerance, blue-tone colors = negative values (constriction), red-tone colors = positive values (expansion).

F I G U R E 5. Lower facial asymmetry (mandibular shift) in a young female featuring FPXB. (A) Extra-oral frontal view. (B–D) Intra-oral photographs.

cooperate with appliances or other corrective therapies and to confirm the presence of an intact dentition not undergoing significant changes during the correction phase.

Watchful waiting has been proposed as well, particularly when the patient is in the transition from primary to mixed dentition stages [10, 13]. This dental age period represents a critical growth phase during which adaptive lower facial and dento-alveolar asymmetry commence development [52]. Watchful waiting can be supported by 3D imaging systems such as the usage of mirroring process and deviation analysis of maxillary intra-oral scan [13]; this technology allows for addressing the potential development of asymmetry and can represent an extraordinary tool for establishing the appropriate treatment timing in the timeframe between late deciduous and early mixed dentition (Fig. 4A–D).

Except for those cases where patients could be exposed for a medium/long-term period to the potential sequelae of FPXB in deciduous dentition, the early mixed dentition can represent the appropriate stage for treating this malocclusion. The most significant reasons to postpone the treatment of FPXB at early mixed dentition and, thus, to watchful waiting in deciduous dentition are:

- To follow watchful waiting for potential self-correction, avoiding unnecessary treatment in subjects observed at the late deciduous dentition.

- To monitor the potential occurrence of adaptive compensatory asymmetry of the upper and lower alveolar process, since it generally occurs at this dental age.

- To apply maxillary expansion in a period when the midpalatal suture is still premature, favoring the predominance of skeletal effects compared to dentoalveolar tipping. At this stage, it is still possible to anchor the appliance to deciduous dentition (for example, bands on the upper second deciduous molars) which contributes to reducing dental tipping on permanent dentition (upper permanent first molars). In this regard, dental tipping can generate iatrogenic occlusal interferences that may affect the effectiveness of the main treatment objects, that is, re-establishing the normal CO-CR occlusal relationship.

- To improve maxillary arch length deficiency secondary to maxillary constriction, because the permanent incisors are afforded more space before or during eruption than if the crossbite is treated at a later age.

On the contrary, it is not recommended to postpone the treatment of FPXB in permanent dentition for the following reasons:

- Subjects would be exposed to a higher risk for temporomandibular joint (TMJ) dysfunction and deviation from normal facial aesthetics in the long term.

- Subjects would be exposed to the development of compensatory skeletal asymmetry on both maxillary and mandibular alveolar processes, introducing the necessity for dental compensation (>dental tipping) or occlusal compensations during treatment with fixed appliances.

- In The case of maxillary expansion, the presence of osseous interdigitations of the midpalatal suture at this stage [47] implies the necessity to increase the rate of screws expansions (rapid maxillary expansion protocol) increasing dentoalveolar side effects. Also, since the alveolar process is more constricted at the CB side compared to the non-CB side [10], the activation of the jackscrew can produce insufficient transverse correction at the CB side and over-correction at the non-CB side, thus requiring further complex biomechanical strategy to compensate such asymmetry with fixed appliance in order to reestablish the correct CO-CR relationship.

3.4 Treatment options

Concerning treatment in the primary dentition, selective grinding is considered helpful to correct FPXB, as long as there are no signs of transverse maxillary arch constriction, *i.e.*, inter-canine width differential >3.3 mm and no discrepancy in intermolar width (<1 mm) [19]. In this regard, posterior crossbites with an intermolar arch width differential exceeding one millimeter will necessitate upper-arch expansion through the use of a removable or fixed appliance, even supported by selective grinding. The prevalent and effective expansion appliances employed in the primary dentition encompass the removable upper expansion plate with a jackscrew and fixed lingual arch appliances. Despite numerous studies exploring the impacts of correcting posterior crossbites, the clinical significance of most outcomes remains inconclusive. For mild forms of unilateral posterior crossbite linked to a functional shift, selective grinding of premature contacts in primary teeth stands out as the sole clinically validated treatment approach for correction in the primary dentition. Another approach, developed by Prof. Pedro Planas, consists of the additive technique involving the use of crowns for managing crossbite in deciduous teeth, a method known as Planas Direct Tracks (PDTs) [53]. PDTs work by creating inclined planes on the teeth using composite resin, which guides the mandible into a corrected position during function. This approach helps modify the child's chewing cycle and encourages bilateral chewing, thus correcting the malocclusion over time. It is a cost-effective and relatively simple technique that can be performed by general dentists, making it accessible even in public health settings [54].

Since the main cause of FPXB is a mild constriction of the maxilla, the routine treatment of this condition requires the increment of the upper arch diameters, in the form of skeletal or dento-alveolar expansion, depending on the etiology of the malocclusion.

Concerning dento-alveolar expansion, quad-helix or bi-helix appliances can represent a valid treatment option since they do not require the patient's compliance. Generally, it is sufficient to gently press the appliance framework between anterior rings using a three-peak plier to obtain a symmetric dento-alveolar expansion (Fig. 6A–D). However, this procedure can be accomplished at their chairside by the orthodontist or pediatric dentist. Alternatively, a removable appliance including a jackscrew can be a valid alternative (Fig. 7A,B). In this case, parents or caregivers can perform the appliance activation at home; the turning frequency of the jackscrew should be set to 1 activation each every fifth to seventh day to favor dento-alveolar adaptation, avoiding the risk for appliance displacement occurring with faster activations. The appliance must be made with well-fitting clasps to prevent displacement. The removable appliance can be designed with

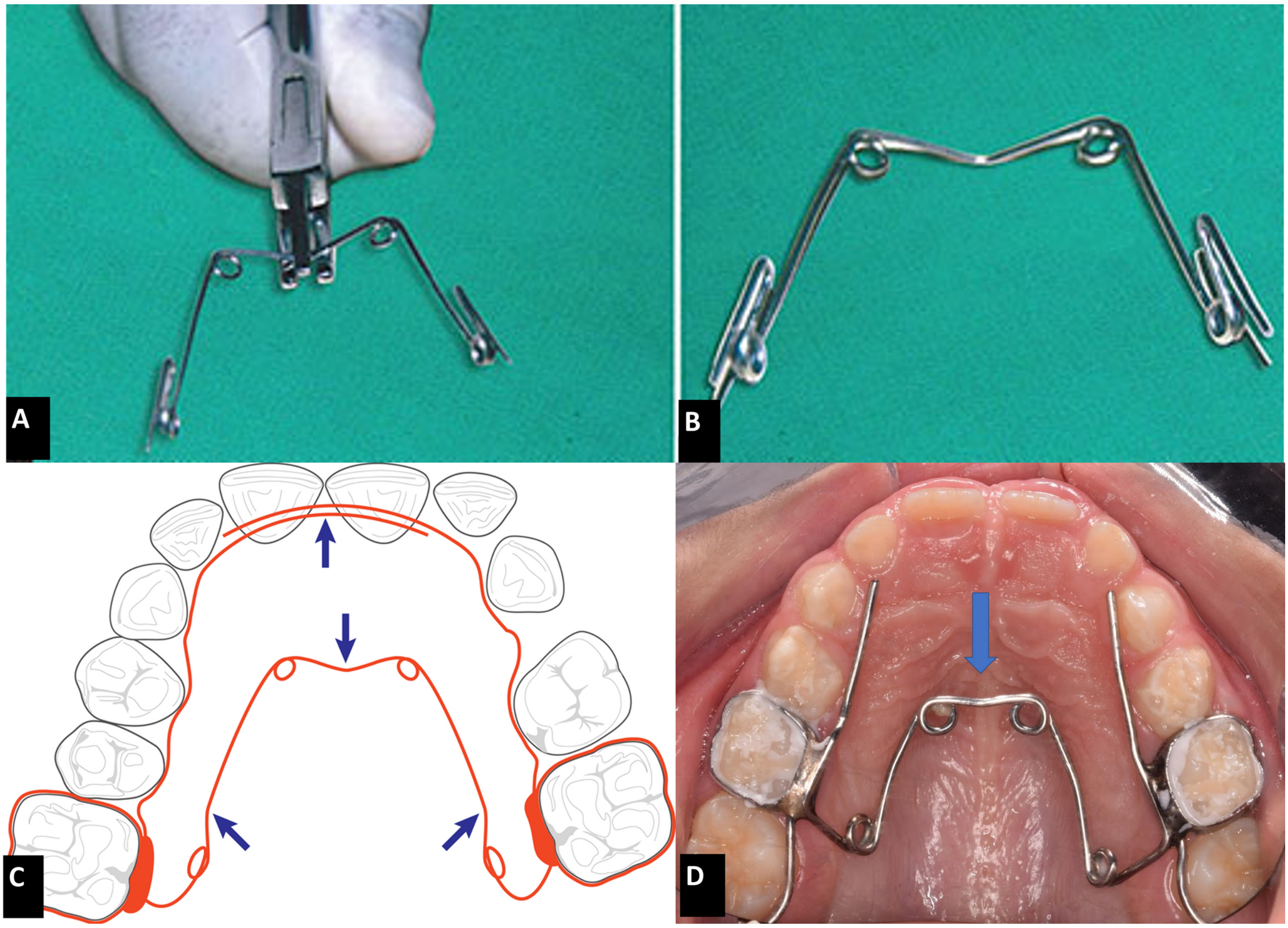


FIGURE 6. Example of quad-helix appliance and activation for dento-alveolar expansion. (A,B) Extra-oral activation. (C) Drawing showing the appropriate site to apply bends. Generally, it is sufficient to gently press the appliance framework between anterior rings using a three-peak plier to obtain a symmetric dentoalveolar expansion. (D) Intra-oral view.

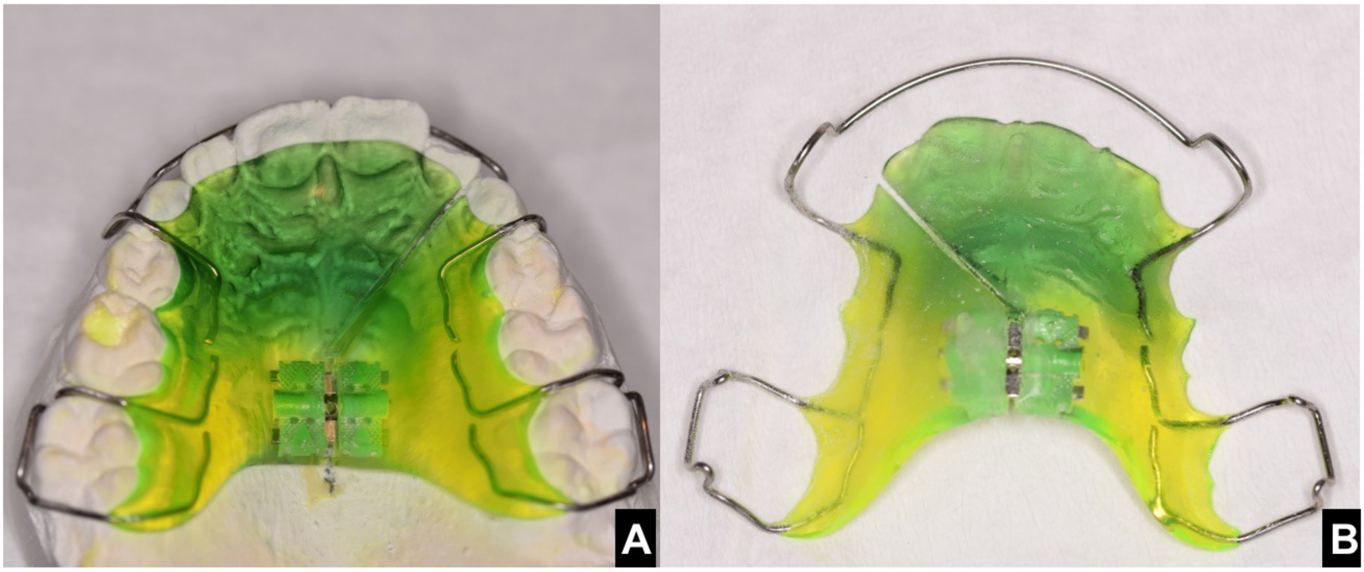


FIGURE 7. Removable appliance including jackscrew can be a valid alternative. (A) Occlusal view. (B) Inner view.

an asymmetric cut of the resin which introduces different anchorage support between both sides, in case of necessity for slight asymmetric expansion. Nevertheless, caution should be used when opting for a removable appliance since poor compliance may result in a relapse of the previous expansion and lower success rates [55].

To obtain skeletal expansion at the midpalatal suture, fixed expanders, in the form of Haas or hyrax designs are generally used (Fig. 8A,B). The resin included in the Hass expander could be helpful to mitigate the transmission of forces to the dentition due to the support of the palatal vault. In the mixed dentition stage, a slow expansion protocol is sufficient to generate skeletal expansion of the maxilla. For this reason, the rate of expansion is a quarter turn of the screw every two or three days and the estimated time to correct the crossbite is 6–12 weeks.

If crossbite was not intercepted previously in the mixed dentition, rapid maxillary expansion is advocated in the early permanent dentition stage, due to its ability to induce a more significant degree of skeletal expansion and result in less dental tipping compared to other slower expansion protocols. The recommended rate of expansion is 1–2 quarter revolutions of the screw per day, and the anticipated duration for correcting the crossbite ranges from 2 to 6 weeks. Patients should be informed that an initial midline maxillary diastema will be created. Throughout the retention phase of treatment, this diastema will gradually close, often involving dental tipping as transeptal fibers approximate the central incisors. The usage of customized computer-aided design and computer-aided manufacturing (CAD-CAM) molar bands can be helpful in increasing the efficiency of the crossbite correction since it is possible to include an occlusal metal bite-block that allows to start of the expansion from the CR, that is, without the of presence occlusal interferences (Fig. 9A–D). Moreover, rapid maxillary expansion may also be performed in the late mixed dentition, as in this stage the median palatine suture may not be completely ossified (variations between patients). In fact, it has been demonstrated that there are different stages of maturation of the median palatine suture and that the most advanced stages of ossification are reached at ages often subsequent to those of the late mixed dentistry [56].

Figs. 10,11,12,13 describe a full case of a child affected by FPXB treated with a maxillary expander featuring customized CAD-CAM molar bands.

Both slow and rapid maxillary expansion require overexpansion, reaching a stage where the lingual cusps of the upper molars make contact with the buccal cusps of the lower molars. The appliance should be retained *in situ* for an extended duration, ranging from 4 to 6 months, and at least equivalent to the time necessary for correcting the crossbite. In cases where a screw functions as the active mechanism, stabilization can be achieved using a ligature wire or composite material to prevent relapse. However, although rapid maxillary expansion results in overall increases in maxillary arch widths, it has been demonstrated that some of the width gains achieved will be reduced during the fixed appliance treatment, and significant relapse will be reasonably observed over the long term, particularly in the inter-canine width [57]. Since at this stage (permanent dentition) patients could feature a consolidated adaptive compensatory asymmetry of the alveolar processes [10, 47, 58], it is possible that after completion of the expansion protocol, they reach overexpansion at the non-CB side and insufficient correction of the fossa-cusp relationship at the CB side. For this reason, the asymmetric design of ancillary components can be integrated into the appliance framework to increase the anchorage at the non-CB side and favor more dentoalveolar expansion at the CB side, net of skeletal expansion occurring at the midpalatal suture (Fig. 14A–D).

Given the multifactorial nature of the transverse skeletal discrepancy in the upper maxilla, before initiating maxillary expansion, it is crucial to adopt a multidisciplinary approach involving the otolaryngologist and speech therapist. As the pediatric patient is still in an early developmental stage, eliminating the etiological factors responsible for maxillary constriction may allow for natural width development once the causative factors are removed. In such circumstances, since the primary goal of the orthodontist is to eliminate occlusal interferences, they may opt for minimal expansion in conjunction with occlusal grinding in the deciduous dentition. Subsequently, palatal expansion could be considered if the removal of etiological factors proves insufficient in restoring the width growth of the upper maxilla.

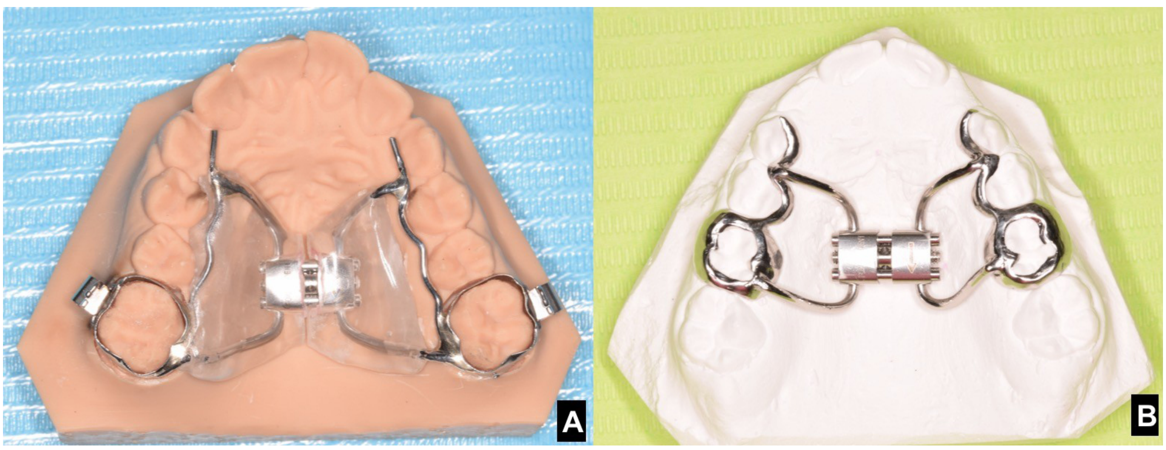


FIGURE 8. Designs of fixed maxillary expanders used for opening mid-palatal suture. (A) Haas expander. (B) Hyrax expander.

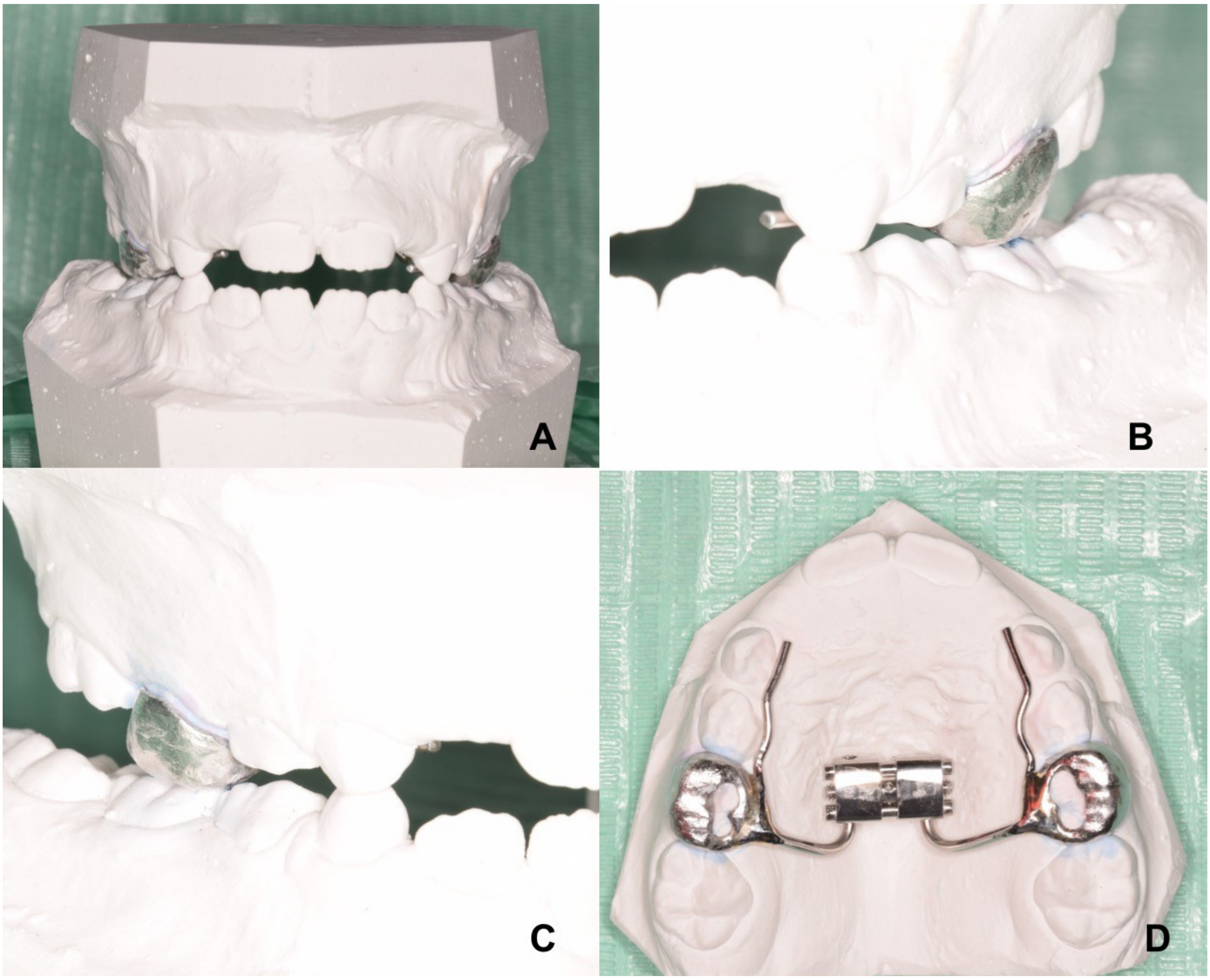


FIGURE 9. Example of customized CAD-CAM molar bands for maxillary expansion. (A–C) Occlusal metal bite-block can help increase the efficiency of the crossbite correction since it is possible to start the expansion from the CR without the of presence occlusal interferences. (D) Occlusal view of metal bites block included into the customized bands.

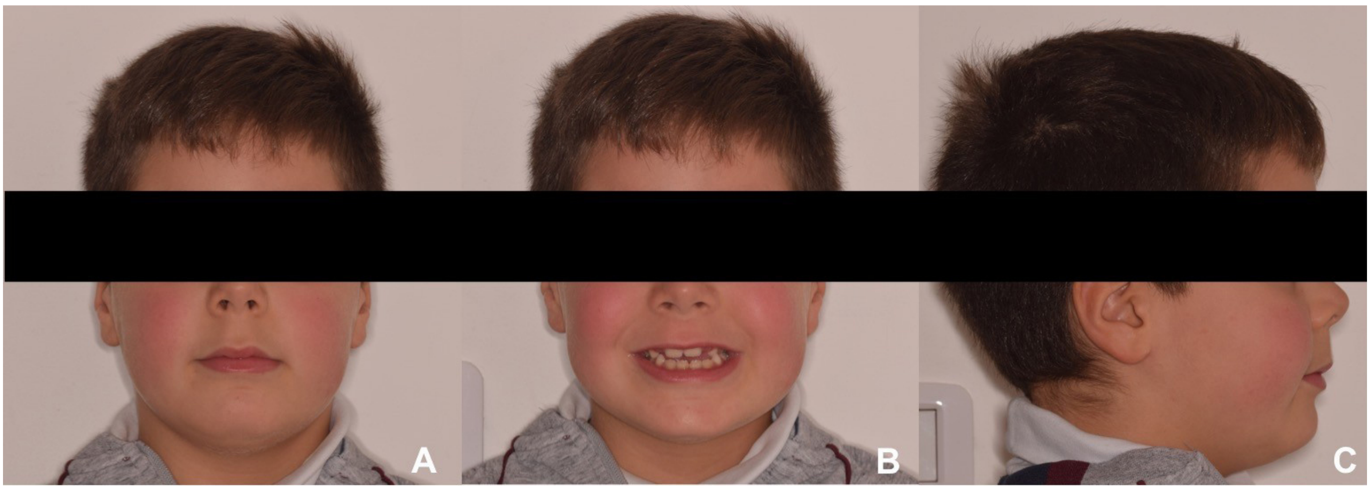


FIGURE 10. Extra-oral photographs of a male child presenting FPXB. (A) Frontal view in the rest position. (B) Frontal view while smiling. (C) Right profile view.

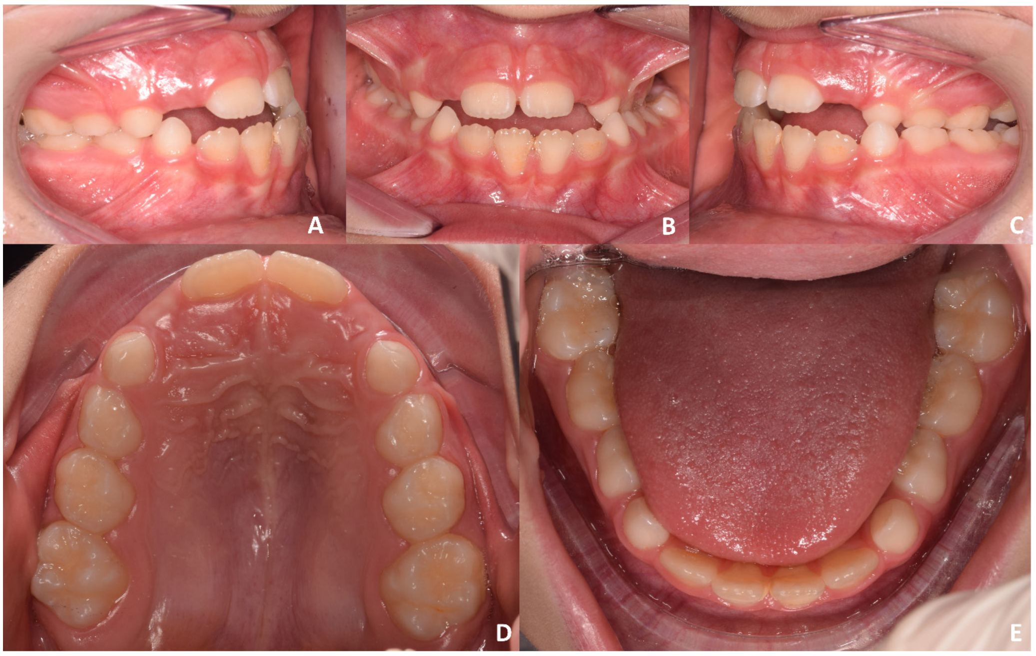


FIGURE 11. Intra-oral photographs of a male child presenting FPXB. (A) Right lateral view. (B) Frontal view. (C) Left lateral view. (D) Upper occlusal view. (E) Lower occlusal view.

FIGURE 12. Intra-oral photographs of the post-expansion stage. (A) Right lateral view. (B) Frontal view. (C) Left lateral view.

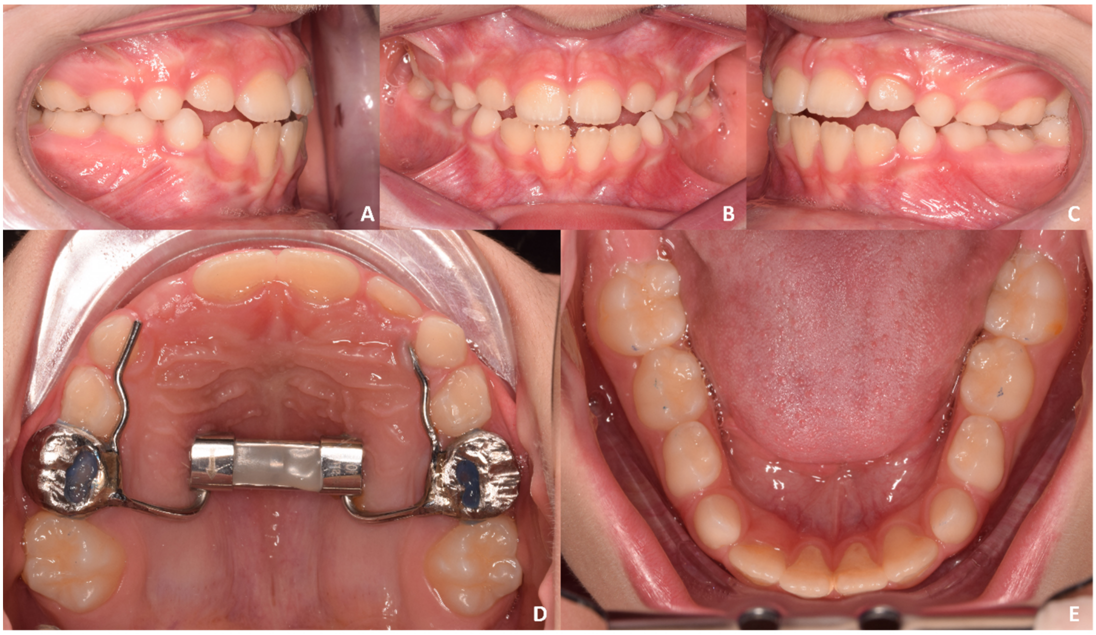


FIGURE 13. Intra-oral photographs of the final retention stage. (A) Right lateral view. (B) Frontal view. (C) Left lateral view. (D) Upper occlusal view. (E) Lower occlusal view.

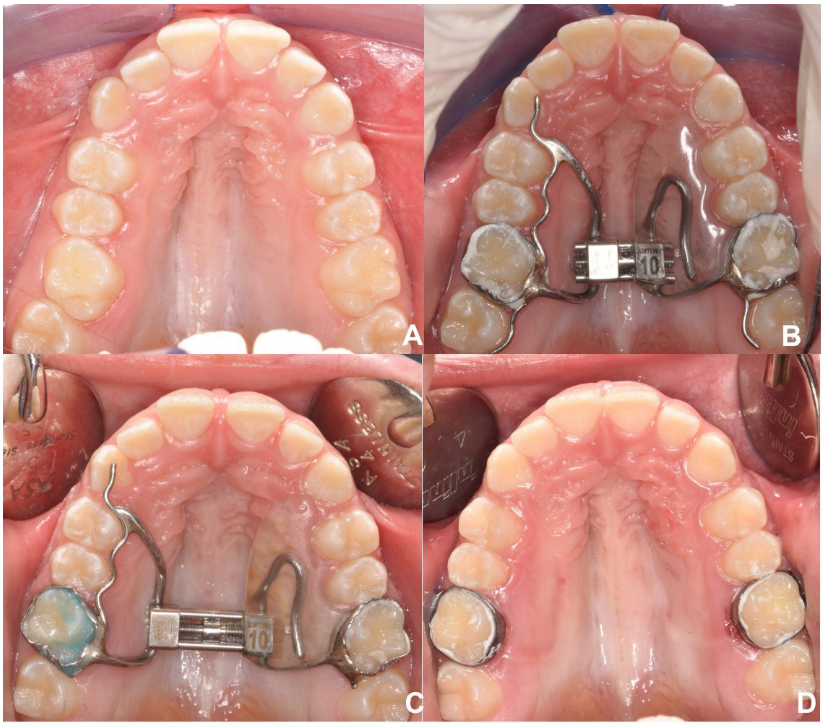


FIGURE 14. Example of extreme alveolar adaptation to the FPXB in a young female in permanent dentition. In this sub-optimal clinical condition, it is possible to include a resin pad on the non-CB side to favor dissipation of the forces exerted on the dentition during maxillary expansion, to recover a symmetric morphology of the alveolar processes (more expansion on the CB side). (A) Pre-treatment condition (asymmetry). (B) Expander in place with asymmetric design of the resin pad. (C) Post-expansion stage. (D) Post-retention stage with symmetric palate morphology almost recovery.

Another group of approaches includes skeletal anchorage systems which are advanced orthodontic solutions that use mini-implants or mini-screws to provide a stable and reliable anchor for various dental movements. Bone anchorage options for treating posterior crossbite include the hybrid Hyrax and micro-implant-assisted rapid palatal expansion (MARPE). Common outcomes of bone-anchored treatments include consistent disruption of the circummaxillary suture, greater forward displacement of the maxilla, fewer adverse effects from tooth-borne expansion, reduced clockwise rotation of the mandibular plane, and suitability for postpuberty or more mature patients [59]. These devices are particularly effective in promoting larger and more successful skeletal growth in adolescents compared to traditional dental-anchored expanders. However, the placement of mini-screws is a minor surgical procedure, which can be intimidating for children, and complications such as infection, implant failure or irritation could occur. Moreover, skeletal anchorage systems can be more expensive compared to traditional orthodontic appliances. Finally, in younger patients, alternative treatments such as maxillary expanders anchored on deciduous teeth can achieve effective and stable results without the need for skeletal anchorage. This more conservative approach respects natural dental development and avoids the risks associated with more aggressive skeletal interventions, making it more appropriate and safer for children [60, 61].

Tables 1 and 2 summarize the key aspects of various treatment options for managing posterior crossbite in children, highlighting their indications, advantages, and disadvantages to aid in treatment planning and decision-making.

Figs. 15,16,17 show the decisional algorithm involved in the clinical management of unilateral posterior crossbite in growing individuals.

4. Conclusions

The present manuscript has proposed an overview of the clinical indications for the treatment of FPXB based on the available literature on this topic. In the light of the data reported, the following recommendations can be drawn:

- Early treatment of FPXB is indicated to avoid or reduce the risk for asymmetric adaptations at the level of skeletal, dental, and muscle components.

- Early treatment can begin in deciduous dentition if watchful waiting exposes patients to long-term detrimental consequences. In the case of transition from late deciduous to early mixed dentition, watchful waiting for a medium-time period may be considered if asymmetric adaptations have not occurred. Such conditions can be monitored using modern 3D imaging systems editing .stl files of intra-oral scans.

- Occlusal grinding (removal of occlusal interferences) is the primary approach in mixed dentition, supported or not by the expansion of the maxillary arch. When maxillary expansion is advocated, a quad-helix appliance or a removal expansion plate should be used, according to the clinical characteristics and patients' compliance.

- In the mixed dentition stage, maxillary expansion using a slow activation rate is encouraged to optimize skeletal ex-

TABLE 1. Indications and advantages of posterior crossbite treatments in pediatric population.

Treatment option	Indications	Advantages
Selective grinding of deciduous teeth	Minor posterior crossbites, functional crossbites with occlusal interference	Simple, non-invasive, cost-effective, no need for special equipment, can be performed by general dentists.
Planas direct tracks	Functional crossbites, early intervention in young children	Modifies chewing cycle, cost-effective, low need for patient cooperation, easy to perform by general dentists.
Removable upper acrylic splints with jack screw	Moderate to severe crossbites, when patient compliance is good	Adjustable, removable, less invasive than fixed appliances, can be removed for cleaning.
Quad-helix	Moderate to severe crossbites, particularly those needing significant expansion	Continuous force application does not rely on patient compliance, effective for significant corrections.
Customized CAD-CAM deciduous molar bands for fixed maxillary expansion	Severe crossbites, need for precise fit and customization in subjects with stable deciduous molars	High precision, customized fit, effective for significant corrections, comfortable for patient, more conservative for permanent molars.
Conventional fixed maxillary expanders with bands on the first molars	Severe crossbites, older children with permanent first molars	Effective for significant corrections, reliable, does not rely on patient compliance.
Bone-borne maxillary expansion	Severe crossbites, adolescents, and young adults requiring skeletal changes	Produces skeletal changes, less dental tipping, stable long-term results, effective for older patients.

CAD-CAM: Computer-aided design and computer-aided manufacturing.

TABLE 2. Disadvantages of posterior crossbite treatments in pediatric population.

Treatment option	Disadvantages
Selective grinding of deciduous teeth	Limited to minor corrections, potential over-reduction, requires precise technique to avoid damage.
Planas direct tracks	Requires regular follow-up, resin tracks may need adjustments, potential for resin fractures.
Removable upper acrylic splints with jack screw	Relies heavily on patient compliance, potential for loss or breakage, less effective for severe cases.
Quad-helix	Can cause discomfort, may affect speech, potential for irritation of soft tissues, fixed nature may be restrictive.
Customized CAD-CAM deciduous molar bands for fixed maxillary expansion	Higher cost, requires specialized equipment, potential for discomfort during fitting.
Conventional fixed maxillary expanders with bands on first molars	May cause discomfort, can lead to decalcification around bands, longer treatment time.
Bone-borne maxillary expansion	Invasive procedure, higher cost, potential for surgical risks, requires specialist intervention.

CAD-CAM: Computer-aided design and computer-aided manufacturing.

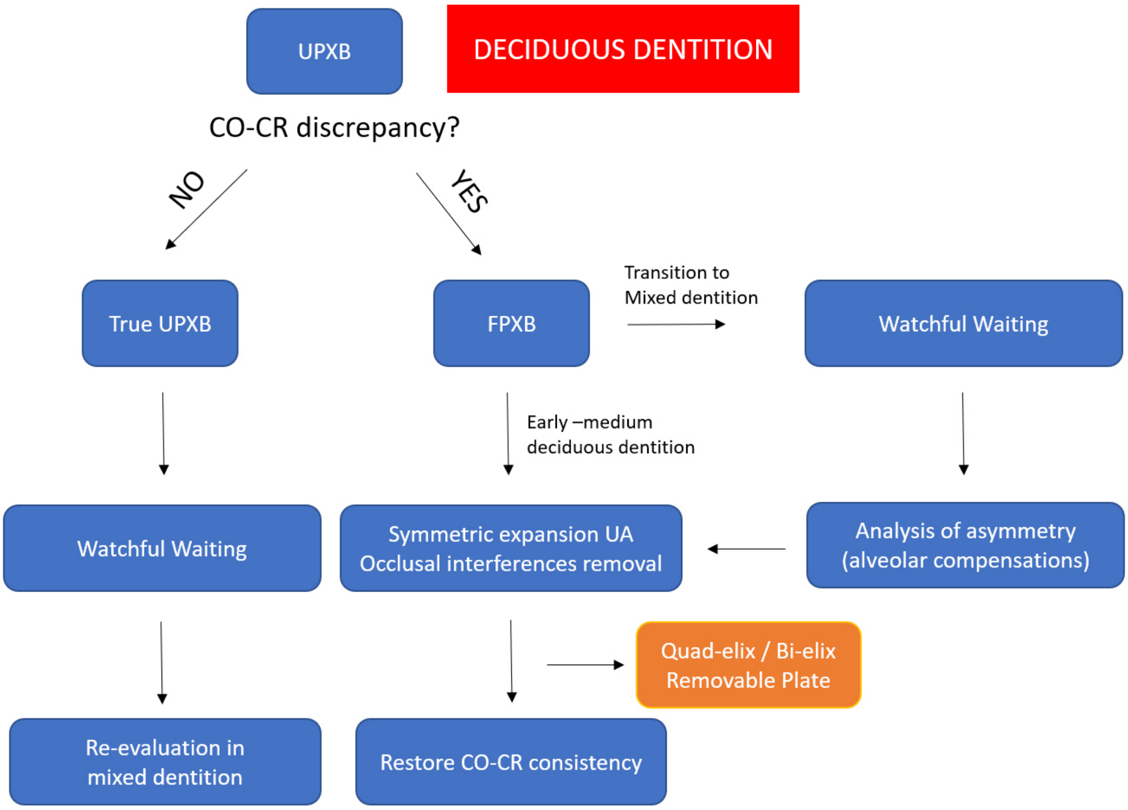


FIGURE 15. Decisional algorithm for treating unilateral posterior crossbite in the deciduous dentition. CO-CR: centric occlusion-centric relation; FPXB: functional posterior crossbite; UPXB: unilateral posterior crossbite; UA: upper arch.

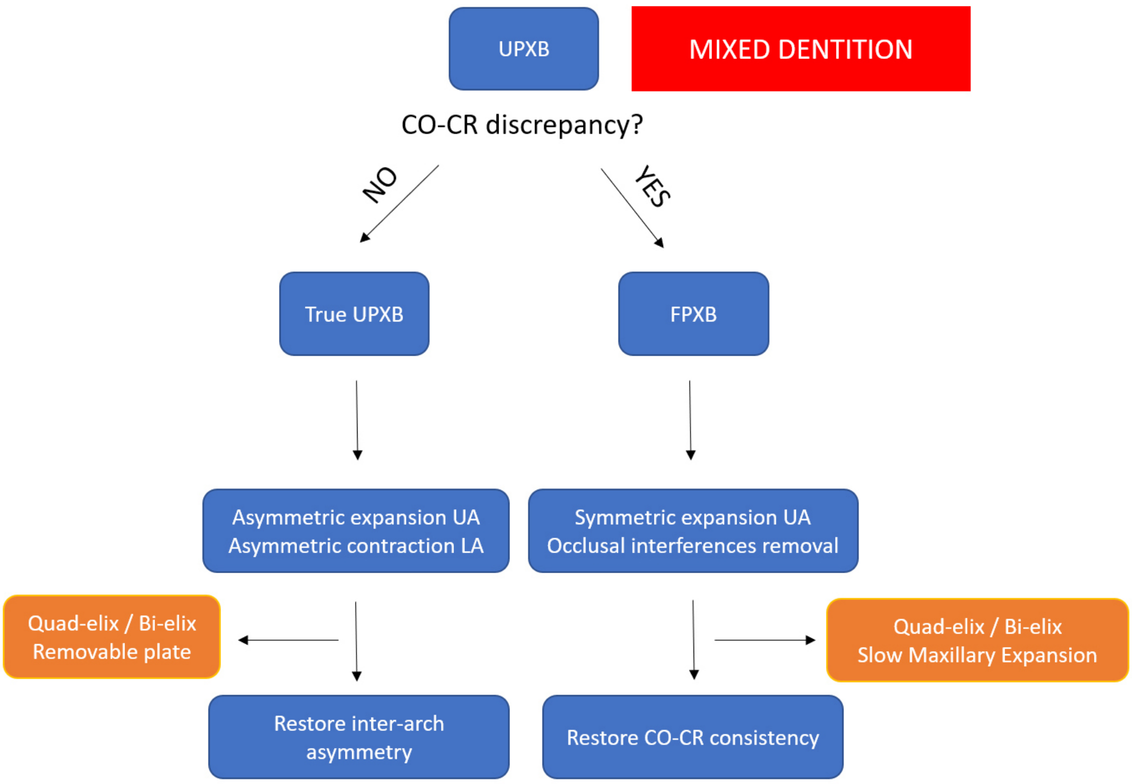


FIGURE 16. Decisional algorithm for treating unilateral posterior crossbite in the mixed dentition. CO-CR: centric occlusion-centric relation; FPXB: functional posterior crossbite; UPXB: unilateral posterior crossbite; UA: upper arch; LA: lower arch.

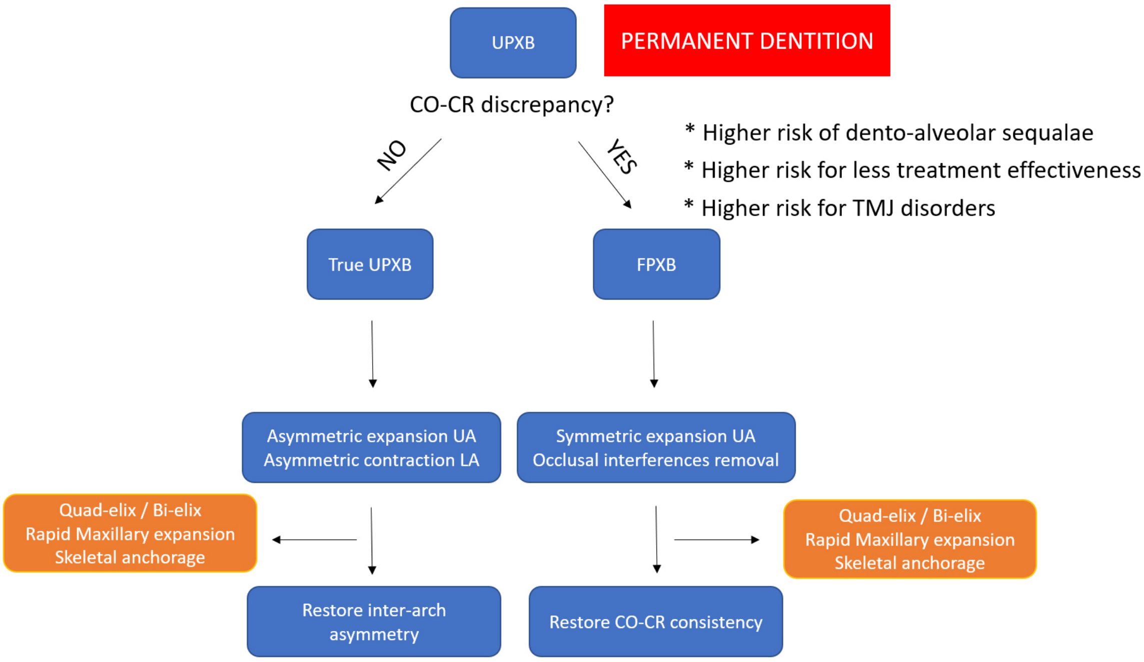


FIGURE 17. Decisional algorithm for treating unilateral posterior crossbite in the permanent dentition. CO-CR: centric occlusion-centric relation; FPXB: functional posterior crossbite; UPXB: unilateral posterior crossbite; UA: upper arch; LA: lower arch.

pansion, minimizing dentoalveolar side effects. The usage of palatal resin support (Haas expander) may help distribute activation forces to the skeletal and soft-tissue components.

Although it is still possible to expand the maxillary arch in permanent dentition, the treatment of FPXB should not begin at this stage due to the presence of significant adaptations that can influence maxillary morphology and dento-alveolar compensations in both arches (asymmetry) and that can compromise the stability of the treatment outcome. In this regard, it is often necessary to recur to complex designs of appliance's framework or post-expansion biomechanical remedial to reestablish a correct balance between both arches.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

ALG and AP—designed the research study; wrote the manuscript. AP—performed the research. ALG, GI and RL—analyzed the data. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Patients (parents) signed the consent form for images acquisition and publication.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest. Antonino Lo Giudice is serving as one of the Editorial Board members of this journal. We declare that Antonino Lo Giudice had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to VG.

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How to cite this article: Antonino Lo Giudice, Alessandro Polizzi, Rosalia Leonardi, Gaetano Isola. Clinical indications for the diagnosis and treatment of functional posterior crossbite in pediatric population: a narrative review with clinical description. Journal of Clinical Pediatric Dentistry. 2024; 48(6): 12-28. doi: 10.22514/jocpd.2024.123.