ZeroExpander: Metal-free automatic palatal expansion for special-needs patients

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Abstract

Background The aim of this paper is to illustrate a new concept for approaching maxillary expansion in paediatric orthodontics with a metal-free fixed automatic appliance in special-needs patients.

Case reports The ZeroExpander is a complete CAD-CAT full digital and automatic metal-free fixed device. It is designed to expand the maxilla in a pre-programmed automatic way using deciduous teeth as anchorage. Two cases of growing patients with a narrow upper arch are illustrated to present this innovative system, one in complete deciduous dentition and the second in mixed dentition. Both patients were successfully treated with palatal expansion. In the first case we present the use of PEEK, and in the second one the use of PA12.

Conclusion The ZeroExpander, fabricated using metal-free technopolymers and anchored on deciduous teeth, proved to be comfortable and efficient in treating palatal transverse deficiency, without the need of any compliance, even in young patients who must periodically undergo MRI.

KEYWORDS Automatic palatal expansion; Metal-free orthodontics; Self-driving orthodontics.

Introduction

Paediatric dentistry in the digital age and in a time of extreme sharing of all aspects of life must face increasing "customised" needs, in its essential integration with orthodontics, where the main actor on the scene is not only the primary tooth but the child as well. Starting from the basic assumption of a comfortable and efficient treatment approach, today it is possible to follow a fully digital workflow for diagnosis and therapy. The term CAD-CAT (Computer Aided Design-Computer Aided Technofacturing) [Beretta at al., 2021] must permanently replace CAD-CAM, because nowadays the term "manufacturing" is obsolete. The average compliance [Lanteri, Beretta et al., 2016] of the young patient and the use of "self" orthodontic devices [Beretta et al., 2019], led researchers to explore the new possibilities offered by the new polymeric materials and the new concept of "self-driving orthodontics" was developed by the authors. More than ever, in this historical phase, concepts such as this will find space.

Maxillary deficit [Lo Giudice et al., 2020] associated with uni- or bilateral crossbite or lack of space for the eruption of the lateral incisors and canines is one of the most frequently diagnosed malocclusions [Lanteri et al., 2016]. This condition can be related to both genetic and environmental factors.

The prevalence of posterior crossbite ranges from 6 to 30% in the general population, but since it is not a self-correcting condition it should be treated as soon as it is diagnosed by means of maxillary expansion devices [Ferro et al., 2016].

Maxillary expansion is a common orthodontic treatment to correct transversal upper-arch deficiency [Grippaudo, Quinzi, Marzo et al., 2020]. The chances of successfully expanding the maxillary bony base decline with the patient's age [Geran and McNamara, 2006].

The two clinical procedures for the correction of transverse maxillary deficit, that is rapid maxillary expansion (RME) and slow maxillary expansion (SME), have shown to have orthopedic effects in growing patients [Martina, 2012; Lo Giudice et al., 2017]. Rapid maxillary expansion produces high forces distributed in a short time-frame, while slow maxillary expansion is achieved with low forces distributed over a longer time period. Different studies have found that SME allows greater physiologic modification of the maxillary bone and surrounding complex, preventing the accumulation of large residual loads with a more stable bone remodeling [Gianolio et al., 2014].

In the early mixed dentition, a transverse discrepancy can be effectively solved by anchoring a fixed expansion device to primary teeth [Cozzani et al., 2007; Di Ventura, Lanteri, Beretta et al., 2019; Quinzi et al., 2019], thus avoiding unwanted effects on the permanent teeth [Rosa, 2016; Quinzi, Federici Canova et al., 2020]. Therefore, the clinician needs an accurate early diagnosis to classify the patient's maxillary deficiency and apply the most appropriate clinical protocols, and many appliances have been studied for varying degrees of orthodontic, orthopaedic or mixed maxillary expansion [Leonardi, 2011; Perillo, 2014]. Compliance, effectiveness and comfort for the young patient are crucial, as well as no need for further activation either in the dental office or at home. As such, the Leaf Self Expander [Beretta et al., 2019] does not rely at all on patient cooperation. Since the device employs light and continuous

forces, it causes no pain even in the early stages of expansion. The design of the Self Expander is similar to that of the Leaf Expander [Cossellu et al., 2020; Lanteri et al., 2018], except that it is equipped with three preactivated, nickel titanium double springs, which are compressed during fabrication in the laboratory. They recover their shape during deactivation, generating a constant force of 450 g for as much as 6–9 mm of calibrated expansion.

It may often occur to patients, owing to allergy or hypersensitivity to metal or specific diseases (such as epilepsy, autism or vascular problems) that require periodical MRI of the head district, or in emergency situations (particularly difficult to manage) to be required to remove the device [Beau, 2015; Ozawa et al., 2018], due to the magnetism generated by metals. For these reasons, in 2017 it was introduced, for the mid-term arch development control, a Nance modified space maintainer that is totally metal-free, aesthetic, easy to clean, light, comfortable and safe, particularly for some groups of patients. This appliance is obtained by a fully digital workflow, starting from an intraoral scan to the milling process of a machinable fiber-reinforced composite material (Trilor, Bioloren, Italy), without using a stone or prototyped model, which was the first step toward a new tailor-made orthodontics for special needs patients [Beretta and Cirulli, 2017]. However, this material is not elastic or resilient and not suitable for active treatments. The introduction of new materials, such as technopolymers, in digital orthodontics [Ierardo, 2017; Beretta et al., 2021] is offering new possibilities to clinicians. In particular, Polyether-ether-ketone (PEEK) and PA12 have ideal chemical-physical features that allow their use in orthodontics. Due to their biocompatibility, low plaque affinity and dimensional stability, they can be employed in the fabrication of orthodontic devices. PEEK is traditionally milled, while PA12 is 3D-printed. The introduction of new technologies is paving the way to a revolution in the field of orthodontics.

The aim of this article is to present a new way to expand the maxilla in paediatric orthodontics using a metal-free fixed automatic appliance anchored on deciduous teeth, named ZeroExpander®.

Appliance design

ZeroExpander is a fixed metal-free automatic maxillary expansion device designed with a complete digital CAD-CAT workflow using metal-free technopolymers (PEEK or PA12), completely individualised and tailor-made. PEEK is a semicrystalline linear polycyclic aromatic polymer that was developed in 1978 and later marketed for industrial purposes [Ma et al., 2014; Skirbutis, 2018]. By the late 1990s PEEK had become prominent as a high-performance thermoplastic polymer used in orthopaedic surgery. PEEK is a radiolucent material with thermal stability up to 335.8 °C. Its mechanical properties do not change during sterilisation and it has a flexural modulus of 140–170 Mpa. Young's elastic modulus is 3–4 GP, close to that of human bone, enamel and dentin. PEEK is hypoallergenic, nontoxic and biocompatible. PA12 is a biocompatible linear semi-crystalline/crystalline thermoplastic 3D-printed composite. Having a thermal stability up to 185 °C, it can be sterilised before use, and is one of the most promising materials for use in orthodontics due to its greater flexural strength and modulus than unfilled PA and other PA composites

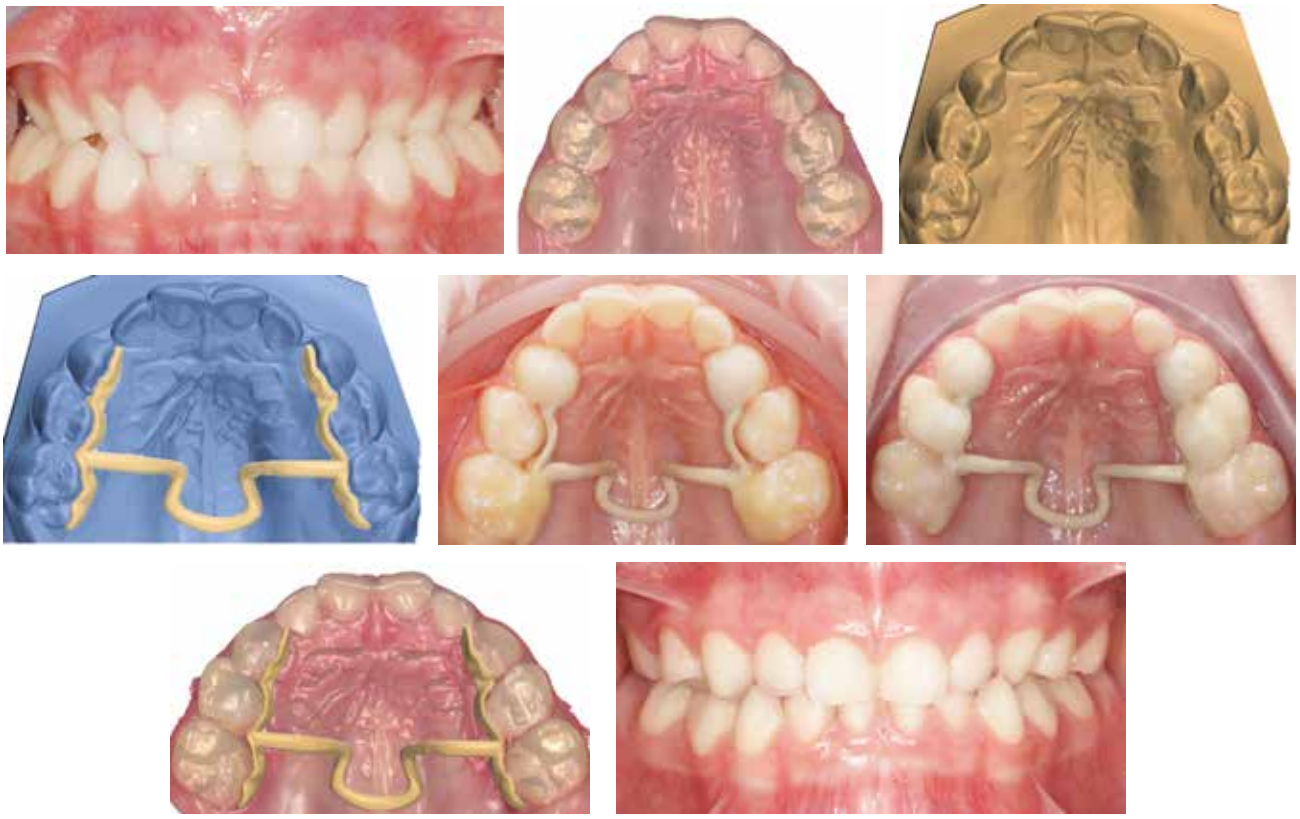

FIG. 1–8 A 5-year-old child with allergy to nickel, treated to correct a bilateral crossbite, due to a narrow palate, with a milled ZeroExpander made of PEEK, designed to obtain 5 mm of expansion and cemented using a bioactive cement, before eruption of the first permanent molars (design and project by Dr. Matteo Beretta and Gaetano Frascina, digital orthodontic technician, Bari, Italy).

FIG. 9-14 A 7-year-old child with ASD and the need to undergo periodical MRIs, treated to correct a lack of space at the upper arch and risk of PDC, with a printed ZeroExpander made of PA12, designed to obtain 6 mm of expansion and cemented on half bands to teeth 5.5 and 6.5 using Transbond LR (design and project by Dr. Matteo Beretta and Stefano Negrini, digital orthodontic technician, Ferrara, Italy).

[Rahim et al., 2016; Scherer et al.,2020].

The design of the ZeroExpander device starts from an intraoral scan (Trios, 3Shape, Denmark), and entails an initial virtual set-up of the STL files for expansion of the upper arch, obtained following the conventional criteria for calculating the expansion requirements in case of palatal transverse deficiency (3Shape Ortho Analyzer, 3Shape, Denmark). For the expansion the first and second deciduous molars and also the deciduous canines are generally used, unless in specific cases where it is necessary to use the first permanent molars. Today, the average pre-programmed expansion for the ZeroExpander is 6 mm (considering as reference point the 6 mm screw of the Leaf Expander and the Self Expander). The device is designed on the virtually expanded upper arch (using 3Shape Dental Designer software; 3Shape, Denmark), defining the anchor teeth according to the needs of treatment (generally hemibands on the second deciduous molars and bonded pads on the first molars and/or canines). After the project is generated the relative STL file is used for the milling process (for PEEK) and 3D printing (for PA12). The dimension of the expansion bar is calibrated to obtain an expansion force of about 450 g (as for the most common screws used for the Leaf and Self Expander) and it has an average diameter of 1.8 mm for PEEK and 2.2 mm for PA12. The central loop that contributes to the flexibility and resilience is custom-designed based on the palate of the patient, the type of expansion required and other features that can be added to the appliance. The clinical procedure entails etching and adhesive cementation, using preferably a self/light curing bioactive cement (Activa Bioactive Cement, Pulpdent, USA; Transbond Plus, 3M, USA), especially for PA12, or other materials (Transbond LR, 3M, USA; Relyx, 3M, USA), better performing with PEEK. The intraoral positioning on the anchoring teeth surface requires the transversal contraction of the device to fit the upper arch (acting on both sides simultaneously or one by one, depending on the clinical situation and the level of cooperation of the patient). The ZeroExpander, due to its shape memory, progressively expands like a compressed open coil spring (like a sort of preactivated Quad-Helix), until it reaches the original dimension at the end of a virtually planned expansion, in a very controlled and comfortable way for the young patient, on average in 4 months. Afterwards, it is generally kept in place for other 6 to 8 months to maintain the expansion, as we can see in the case of a 5-year-old child, treated with a ZeroExpander in PEEK (Fig. 1–8).

We also show a second case of an autistic 7-year-old patient (Fig. 9–14), who had to frequently undergo MRI scans, and who required a palatal expansion to prevent the possible inclusion of both upper canines (palatally displaced canines, PDC), also due to familiarity [Baccetti et al., 2009]. In this case we planned a 6 mm expansion and we decided to bond the device, made of PA12, only on the primary second molars, in order to make the device as sleek and comfortable as possible for the child and to facilitate speech and cleaning (Fig. 15).

Conclusion

The ZeroExpander, fabricated by means of a full digital process, without any kind of manufacturing by the orthodontic

FIG. 15 Clinical image from a video made with a smartphone at the end of cementation (with Transbond PLUS) and sent via whatsapp to show and remind the parents of a young special needs girl how to clean the mouth and the smooth surfaces of the ZeroExpander. Relative analgesia was used to increase collaboration.

FIG. 16 Panoramic x-ray of a young patient during treatment with ZeroExpander made of PEEK; the radiopacity of the material used for cementation is visible, but not the PEEK.

technician, using two different metal-free technopolymers, PEEK (milled) and PA12 (printed), anchored on deciduous teeth, proved to be effective and comfortable in treating palatal transverse deficiency, without the need of any compliance by the patient and parents. The expander can be used alone or as the initial phase of a paediatric orthodontic treatment, followed by the use of other devices. The possibility to use a metal-free fixed maxillary expander is very interesting also in young patients with special needs, especially those who must periodically undergo MRI or for whom it would be difficult to activate a traditional palatal expander either at home or in the dental office, due to compliance problems. Both polymers are radiolucent (Fig. 16), which is very useful when a panoramic radiograph is required during treatment, especially in a patient who has difficulty to stand still, since the absence of metal reduces the possibility of artifacts.

The research will continue, aiming to improve the design and also to test other suitable polymers, maybe more performing, but at this point the name ZeroExpander means, first of all, the possibility of limitless customisation of palatal expansion, starting from "point Zero" which, in our opinion, can also represent a possible future way to consider, for almost all orthodontic treatments, the concept of "self-driving orthodontics", fully pre-programmed before and digitally monitored during and after therapy, where the single patient, with his/her specific needs, is at the center of our attention, not only regarding the teeth and the type of appliance used.

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