**ADVANCEMENTS IN SPACE MAINTAINERS IN PEDIATRIC DENTISTRY**

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1. **INTRODUCTION:**

Pediatric dentistry has shifted from a conservative-restorative approach towards a concept of total pediatric patient care. Thus, all aspects of oral health care including diagnosis, prevention, oral medicine, restoration and correction of malocclusion are increasing the responsibilities of the pediatric dentist.1

A sequence of events occurs in an orderly and timely fashion as the occlusion develops from the primary dentition through the transitional (or mixed) dentition to the permanent dentition. These events lead to a functional, esthetic, and stable occlusion. When this sequence is disrupted, however, problems arise that might affect the final occlusal status of the permanent dentition.2

Early orthodontic intervention is carried out to improve dentoalveolar, skeletal and muscular

development before complete eruption of the permanent dentition. The early orthodontic intervention can be broadly classified as preventive orthodontics and interceptive orthodontics. This treatment is to intercept a developing problem or to correct existing early malocclusion.3

According to the American Board of Orthodontics in 1977, most participants considered early interventions as viable option in many malocclusion cases. Early treatment is advised for more benefits including better use of the patient growth potential, reduced need of extractions and orthognathic surgery, reduce risk of adverse iatrogenic effects, better patient compliance, and better and more stable results.4

When early loss of primary tooth occurs, corrective measures such as passive space maintenance, active tooth guidance with space regaining, or a combination of both may be needed to optimize normal process of occlusion development.

The premature loss of primary teeth due to caries, trauma, ectopic eruption, or other causes may lead to undesirable tooth movements of primary and/or permanent teeth including loss of arch length.5 Hence space supervision is important.

One of the main functions of the primary dentition is to maintain the arch length, so that the permanent dentition has sufficient space to erupt. The three important features of primary dentition are spacing, anthropoid spaces mesial to the maxillary canine and distal to mandibular canines, and straight or mesial step primary second molar occlusion.6

Exfoliation of primary teeth and eruption of permanent teeth is a normal physiological process. But sometimes there is a premature loss of primary tooth. In such instance, the best way to maintain the arch space is by placing a space maintainer. It was stated that, space maintainers not only maintain function and preserve arch length, but they also maintain esthetics.7

Space maintainers are orthodontic appliances that is used to replace one or more primary teeth and preserve the space for the successor permanent tooth. Where a deciduous tooth has been lost, a space maintainer will maintain the integrity of the arch and permit normal occlusal adjustments of the mixed dentition to occur. The growth potential of the jaws and factors which combine to produce normal occlusion must be understood so that the space maintainer does not become a disservice to the child and a source of embarrassment to the operator.8

With respect to the function of the space maintainers can be classified as functional, presenting advantages: restores mastication, extrusion prevents the antagonist is aesthetic.9

Although Digitalization in dentistry is not new concept, but it has just begun to be used in Pediatric Dentistry. Three-dimensional (3D) printing also known as additive manufacturing or rapid prototyping.10 It is a process of making 3D solid objects from a digital file. The digital 3D model is saved in ‘Standard Tessellation Language’ (STL) format and then sent to the 3D printer where the layer by layer design of an entire 3D object is formed.

A pediatric dentist is often the first person to encounter the effects of premature loss of primary teeth. Thus, it is essential on the part of the pediatric dentist to take early measures in preventing the deleterious effects on future developing dentition, psychology and personality of child.

Hence, Pediatric Dentist should have an active approach that may decrease the consequences of loss of arch length and the need for complex orthodontic treatment at a later stage. Considering all the pitfall of conventional space maintainers, this chapter focuses on the digital space maintainers in pediatric dentistry.

**DEFINITIONS AND TERMINOLOGIES:**

**Wright and Kennedy11** stated that space maintenance and space control are not necessarily synonymous.

**J.C. Brauer (1959)** the term ‘space maintainer’ refers to an appliance designed to retain a given area or space, generally in the primary and mixed dentitions.12

**Martinez and Elsbach (1984)** ‘space maintainers’ are the orthodontic appliances used to prevent loss of arch length.13

SPACE CONTROL: **Gainsforth in 1955** defined it as careful supervision of the developing dentition; it reflects an understanding of the dynamic nature of occlusal development.14

**Keith J. Ryan (1964),** space maintenance is the process of maintaining a space in a given arch previously occupied by a tooth or a group of teeth.15

**Boucher’s clinical dental terminology**, SPACE MAINTAINER is a fixed or removable appliance designed to preserve the space created by the premature loss of a tooth.16

FIXED SPACE MAINTAINER is a space maintainer not intended to be removable by the patient.

REMOVABLE SPACE MAINTAINER is a space maintainer designed for easy removal for cleansing and /or adjustment.

The term interceptive orthodontics includes timely management of hostile features of a developing occlusion. Interceptive orthodontics is defined as a phase of science and art of orthodontics employed to recognize and eliminate the potential irregularities and malpositions in the developing dentofacial complex.16

According to **Graber**, Interceptive orthodontics refers to the “Measures undertaken to intercept a malocclusion that has already developed or is developing, and the goal is to restore a normal function”.17

According to **Ackerman and Proffit (1980)**, Interceptive orthodontics can be defined as, “Elimination of existing interferences with the key factors involved in the development of the

dentition”17

**American Association of Orthodontists (1969)** defined it as that phase of science and art of orthodontics employed to recognize and eliminate the potential irregularities and mal positions in the developing dentofacial complex.18

**OBJECTIVES OF SPACE MAINTAINER:**

**Objectives: 1**

1. Prevent loss of arch length, width, perimeter by maintaining relative position of existing dentition.
2. For preservation of normal occlusal plane, primate spaces.
3. Preservation of integrity of dental arches.
4. Anteriorly helps in phonetics, esthetics and posteriorly in mastication in some cases.
5. To promote appropriate transition of the primary, mixed, and permanent dentitions.

**INDICATIONS AND CONTRAINDICATIONS OF SPACE MAINTAINERS:**

**INDICATIONS: (FINN)19**

1. In cases of early loss of anterior primary teeth.
2. To prevent emergence to deleterious habits like tongue thrusting due to premature exfoliation of anterior teeth.
3. For maintenance of esthetics anteriorly and reduction of psychological trauma.
4. In situations where there is chance of midline shifting due to unilateral loss of deciduous tooth/teeth.
5. To prevent supra-eruption of tooth from opposing arch into prematurely lost tooth space.
6. If the space maintainer would lessen the future orthodontic treatment.
7. To improve and restore physiology of child’s masticatory and dental health optimally.
8. When a supernumerary tooth prevents eruption of a permanent central incisor, the space may be held before operation and while the tooth moves into position.

**CONTRAINDICATIONS OF SPACE MAINTAINERS: (FINN)19**

1. If the radiograph of the extraction region shows that one-third of the root of succedaneous tooth is already calcified.
2. When the space left by the prematurely lost primary tooth is greater than the space needed for the permanent successor as indicated radiographically.
3. If the space shows no signs of closing.
4. When there is general lack of sufficient arch length and where space maintainer would further complicate existing malocclusion.
5. When succedaneous tooth is absent.
6. When there is no bone observed radiographically overlying the erupting permanent tooth, which suggests that tooth erupts in few months.
7. When space available as greater than that required for alignment of permanent teeth.
8. When reduction of tooth units aids orthodontic treatment and lead to a more acceptable occlusion.
9. When some or all the permanent teeth are missing children with high caries risk.
10. Uncooperative children
11. Children with poor oral hygiene
12. **PLANNING OF SPACE MAINTENANCE:2**

The following considerations are important when space maintenance is considered after the untimely loss of primary teeth.

1. Time elapsed since loss
2. Dental age of the patient
3. Amount of bone covering the unerupted tooth
4. Sequence of eruption of teeth
5. Delayed eruption of the permanent tooth
6. If the permanent teeth in the same area of the opposing dentition have erupted, it is advisable to incorporate an occlusal stop in the appliance to prevent supra-eruption in the opposing arch during the space maintenance period.
7. Presentation of problems to parents

1. **CLASSIFICATION OF SPACE MAINTAINERS**

According to **Hitchcock 20** in 1963, space maintainers may be classified in various ways:

1. Removable or fixed or semifixed.
2. With bands or without bands.
3. Functional or non-functional.
4. Active or passive.
5. Certain combinations of the above.

Space maintainers are classified by **Raymond C. Thurow21** in 1970 as:

1. Removable
2. Complete arch
3. Lingual arch
4. Extra oral anchorage
5. Individual tooth

**Hinrichsen (1962)22** classified space maintainers as follows:

1. Fixed appliances

Class-I a) Non-functional types

i. Bar type

ii. Loop type

b) Functional types

i. Pontic type

ii. Lingual arch type

Class-II Cantilever type (Distal shoe, Band & loop).

1. Removable

Acrylic partial dentures.

R.J. Andlaw and W.P. Rock (1987)23 quoted by Bratu E et al. (2005), classifies them in the following way:

1. Band / crown and loop

2. Palatal arch

3. Lingual arch

4. Stainless steel wire and composite

5. Removable space maintainers

**Graber (1994)**17 quoted by **Bratu E et al. (2005)** divides them into two major classes, with several subclasses:

1. Fixed space maintainers:

a. Functional

b. Non-functional Space maintainer with extension

d. Fixed lingual arch

e. Semi-fixed lingual arch

2. Removable space maintainers

**Digital space maintainers:**

Space maintainers that use CAD-CAM or 3D print technology with modern and biocompatible materials are called “Digital Space Maintainers”. Digital impressions have increased efficiency, more comfortable for the patient, and reduce long-term costs of the procedure. Digital impressions have been used routinely in other areas of dentistry, and expanding their use in Pediatric Dentistry could be beneficial for both patient and Dentist. Intraoral scans can also be performed by auxiliary team members if state laws allow, freeing clinicians for other tasks. For dental offices in geographical areas that do not have dental laboratories nearby, digital impression can be quickly transferred to a laboratory anywhere in the country, which reduces cost, limits damage of impressions/models because of shipping and handling, and reduces turnaround time for the case.24

**Materials used for fabrication of digital space maintainers**

1. **PEEK Polymer**

Polyetheretherketone have a unique mix of strong mechanical properties and are rigid, opaque, and biocompatible. Chemical resistance, high-temperature stability, dimensional stability, and a wide range of processing possibilities are all provided by the material. Patients allergic to metals or dislike the metallic taste or weight can use PEEK because it has a natural tooth-coloured appearance.

According to a 2015 study, PEEK has many advantages in orthodontics. making it a potential material for usage as an esthetically pleasing metal-free orthodontic wire.25 The framework and prosthetic teeth can be developed in the same design module for detachable, functional varieties of space maintainers releasing a fully integrated design. As a result, this technique is preferable to others that use self-curing resin and artificial teeth.

A 9- month follow-up study using PEEK polymer was done by Ierardo et al on three patients for the production of CAD-CAM space maintainer.26 They fabricated a lingual arch, a B&L, and a removable plate and obtained satisfactory results. Digital B&L SMs made of PEEK polymer were evaluated by Kun et al.27 in children with unilateral loss of either the first or second molars and were found to be 75% lighter than conventional SMs. In an in vitro investigation, Guo et al.28 compared digitally produced Removable Space Maintainers made of PEEK polymer to traditional Removable Space Maintainers (RSMs). Study results showed that digitally created RSMs fit the model well, indicating that the technique was suitable for clinical applications.28 This is because the conventional technique of manufacturing has too many steps that can lead to errors during polymerization shrinkage of self-curing resin and requires grinding and polishing of the RSM, which digitally designed RSMs would not require.



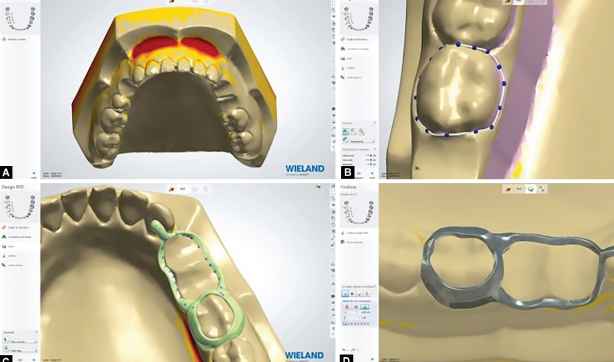
**Fig 1**: First case report” by Gaetano Ierardo of PEEK as a space maintainer26

1. **BruxZir:**

BruxZir is three to five times more fracture-tough than standard zirconia, with a flexural strength of up to 1,465 MPa.29 This gives the material an excellent impact resistance to the masticatory forces in the mouth. The material has got minimal thermal expansion, which will allow it to stay in the mouth without changing shape or becoming loose in the teeth. The first published paper on using digital technology to fabricate an SM was by Soni. While treating a 6-year-old female patient, the author employed BruxZir as the material for the device ([Fig. 4](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8754270/figure/F4/)). To keep the appliance in place, the SM was designed so that it was supported by both the canine and the primary second molar. This allowed for better appliance retention, prevented tooth tipping, and ensured that masticatory forces were distributed equally across the extracted tooth's region. There were no issues with the appliance after 6 months of testing.  
  


**Fig 2:** Intraoral photograph 6 months after placement of appliance, by HK Soni34

#### Trilor

Trilor is a CAD/CAM processed fiber-reinforced composite (FRC) resin. This is a metal-free, biocompatible alternative material. Main advantages include its Durability, elastic property, low weight, biocompatibility, and repairability. Beretta and Cirulli30 developed a metal-free CAD-CAM device to produce safe appliances for special needs patients, who require regular magnetic resonance imaging (MRI) in the head region to monitor certain diseases such as epilepsy or vascular problems. They fabricated a Nance palatal arch space maintainer using Trilor and directly bonded on the palatal surface of the first primary molar.  
  
**Fig 3**: Digital pattern acquisition, thanks to CAD software and design of the devices by Gaetano Ierardo26

### **Steps in Fabrication Using CAD/CAM Technology**

CAD-CAM processing begins with a traditional impression from the dentist, which is then digitized in the lab. Sirona introduced the first chairside CAD-CAM technology, the CEREC system, which allows dentists to design and fabricate restorations right in the dental office.31 By using chairside and laboratory CAD-CAM manufacturing methods, dental restorations/ appliances can be made more rapidly.

There are three general steps in the digital restoration workflow:

**Step 1:** After taking a dental impression and pouring the model, the models are digitalized using an additional oral scanner.

**Step 2:** Light beams strike the scanned object from all angles, and miniature cameras film it. The outcome is a cloud of points since the scans are multiple and detected across the entire model. The virtual model is created by connecting the dots and reconstructing a pattern of tiny polygons.

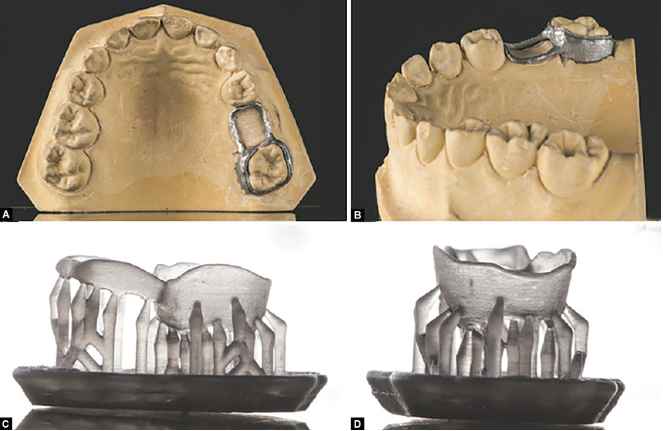
**Step 3:** After obtaining a virtual model, it is instantly integrated into the CAD (computer-aided design) software system. Using the zoom, rotate, and panning tools, the model can be viewed from various angles and magnifications, making it easier to analyze it and develop a personalized device. This technology enables the creation of devices and the determination of numerous variables such as material thickness, retention, undercuts, and cementation space.

**Step 4:** At this point, the file is transferred to the CAM, where milling begins the device's fabrication. This is a manufacturing method that involves subtracting a block of chosen material from a previously specified form using CAD software (in about 1 hour).

### **Three-dimensional (3D) Print Technology**

In this technology, a digital file may be used to construct a layer-by-layer design for a 3D object of any shape or geometry. The digital 3D model is saved in STL format and then sent to the 3D printer where the layer by layer design of an entire 3D object is formed. This creation of the 3D-printed object is achieved using additive processes. Each of these layers can be observed as a thin sliced horizontal cross-section of the eventual object.

A cross-section of the final object is represented by each of these layers. Pawar33 was the first one to use digital 3D printing to fabricate space maintainers, with one using titanium-based powdered metal and the other clear photopolymer resin. He pointed out significance of 3D printing in pediatric dentistry.

  
**Fig 4:** (A and B) Metallic three-dimensional-printed space maintainer of titanium-based powdered metal material and (C and D) using a clear photopolymer resin” by Bhaggyashri Pawar33

Advantages26-29 of digitally fabricated space maintainer devices and their impact

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| --- | --- |
| **Advantages** | **Impact/ outcome** |
| 1. Esthetic | Increased patient acceptance |
| 2. Metal-free | Advantageous for patients with metal allergy, nickel allergy and special care needs patient who periodically requires to undergo MRI |
| 3. Precise | Reduced deformation and errors, breakage and de-cementation |
| 4. Quick fabrication time | Reduced no. of visits hence improved patient compliance |
| 5. Single unit appliance | High strength of the device thus avoiding fracture and reducing the failure rate. |
| 6. Smooth surface | Makes it easy to clean and polish causing less plaque accumulation leading to better gingival health. |
| 7. Lightweight | Increased comfort |
| 8. No band pinching required | No gingival lacerations/ Trauma |

### **Disadvantages34**

* Overall expensive treatment.
* Lab assistance is required.
* Fabrication expertise is required.

**Future perspective:**

Further studies are needed to determine the longevity, influence on gingival health, patient compliance, cost effectiveness and acceptability of digitally manufactured space maintainers, or “Digitainers”, additional clinical and comparative research is required. Future research should include low-cost materials. Furthermore, 3D printing in pediatric dentistry has yet to be fully investigated. Using it makes innovative advancements because of its accuracy and perfection.

**Conclusion:**

Pediatric dentistry's space maintainers have taken a giant stride towards custom orthodontics. Appliances fabricated using digital techniques are reliable and long-lasting. Thanks to recent technology for eliminating time-consuming manual fabrication stages. With the arrival of digital age, more and more `CLINICIANS' will likely begin to use it in their daily practices.

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