

Digitainers—Digital Space Maintainers: A Review

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ABSTRACT

To summarize the limitations of commonly used space maintainers (SMs) and provide an insight into the field's technological advances to overcome them, this review was conducted. With the rapid advancement of digital technologies, there is always something new to learn while also redefining the current fads. Digital workflow is not a new concept in dentistry, but it has only just begun to be used in pediatric dentistry. The curiosity to explore has led to the development of digital devices as SMs. They appear potential for usage in children because of their impressive advantages of precision, comfort, and a time-saving approach. This workflow helps lessen fear and improve children's cooperation and enthusiasm for dental appointments by cutting down on chairside time and shortening procedures.

Keywords: 3D printing, CAD/CAM, Digital technology, Pediatric dentistry, Space maintainers.

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BACKGROUND

The importance of maintaining the primary dentition until its normal physiological exfoliation is not only in terms of esthetics, mastication, speech but also in aiding the normal eruption and guidance of their permanent successors.¹ It is possible that ectopic eruption or premature primary tooth loss from caries and/or trauma will cause undesirable primary and permanent tooth movements, including a loss in arch length.² If you do not have enough arch length, you are more likely to have malocclusions such as crowding and ectopic eruption as well as tooth impaction.³ Effective maintenance of the edentulous space is necessary to avoid or eliminate these negative effects.⁴ As stated by the American Academy of Pediatric Dentistry (AAPD), space maintenance is the preservation of present dentition placement to avoid loss of arch length, width, and perimeter.⁵

After using the term "Space maintenance", in 1941, JC Brauer went on to explain that it was the process of preserving a space in the mouth that had previously been filled with one or more teeth. Fixable or moveable, unilateral or bilateral, space maintainers (SMs) are all options. Fixed space maintainers (FSMs) can be more difficult to keep clean, whereas removable space maintainers (RSMs) are more convenient.¹ Fixed space maintainers, on the other hand, need less patient compliance, are easier to maintain, and are more comfortable for the patient. Determining whether to employ removable or fixed equipment is dependent on various criteria, such as the stage as a stage of dental development, number of lost teeth, occlusion, dental arch involved, age of the child, and ability to cooperate.⁶ Fixed unilateral SMs include the band and loop (B&L), crown and loop (C&L), direct bonded (DB), glass fiber-reinforced composite resin (GFRCR), and distal end shoe (DES). Fixed bilateral SMs include the lower lingual arch (LLA), Nance, and transpalatal arch (TPA).

DRAWBACKS OF CONVENTIONAL SPACE MAINTAINERS

Pediatric dentists have long used and recommended conventional SMs, but there are several drawbacks to this approach. Researchers have found a link between RSM and FSMs and an increased

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periodontal index score and an increased risk of oral cavity bacteria growth.^{7–9} Nickel is a common and severe allergen. Nickel sensitivity was found to be higher in children who had intraoral devices that contained nickel.¹⁰ Those with SMs have a higher nickel release than patients with stainless steel crowns.¹¹ In their investigation, Bhaskar and Subba Reddy found that in an artificial salivary media, B&L SMs release nickel at concentrations ranging from 4.95 to 7.78 ppm and chromium at concentrations ranging from 1.70 to 4.54 ppm.¹² To avoid any probable health risks to children, the authors recommend using an alternative stainless steel alloy or covering it with a biocompatible substance.

The drawbacks associated with the commonly used SMs are discussed below.

Band and Loop

When a single, unilateral, or bilateral maxillary or mandibular primary molar is lost early, B&L SMs are most typically utilized.¹³ It has some disadvantages and failures, despite high patient compliance, like

- Loss of cement or de-cementation: The most prevalent reason for failure as cited.^{14–18}
- Breakage: Poor construction quality is the second documented reason for B&L SM failures. This includes overheating the wire while soldering, thinning of the wire by polishing, flux residue on the wire, and failing to enclose the wire in the solder.^{14,19}

- Soft tissue lesions: Plaque retentive areas in poorly constructed SM loops cause calculus development and tissue overgrowth. Ulceration of the buccal mucosa due to loop impingement causes discomfort. Lingual displacement and blanching around the teeth are also caused by the ill-fitting band.^{20,21}

Lower Lingual Arch Space Maintainer

In comparison to unilateral SM, bilateral SMs are said to endure less. Among the most common adverse effects associated with these appliances were tongue interferences, increased occlusal load, and a longer arm span, all of which could interfere with the eruption of permanent teeth.^{13,14,22,23}

Nance Space Maintainer

Soft tissue lesions: The acrylic button that makes contact with the anterior palate is thought to be a major cause of appliance failure.^{13,21}

Besides the drawbacks discussed, conventional SMs also present with limitations such as:²⁴

- Requires a minimum of two appointments to be made.
- Gives the impression that children who are uncooperative or who have a gag reflex would find it difficult.
- Expensive and time-consuming laboratory work is necessary.

Technique-sensitive stages of processing, such as band displacement during cast pouring.

EVOLUTION OF SPACE MAINTAINERS

The disadvantages of conventional SM led to the development of its variants such as DB SMs, fiber-reinforced composite (FRC) SMs, and prefabricated SMs. Clinicians prefer resin-bonded SMs because of their ease of fabrication, reduced appointment count, and consequently improved patient comfort. They also do not need an annual inspection like other FSMs; thus, they can be utilized instead of conventional FSMs.²⁵ These procedures are also long-lasting, low-risk, and low-cost in terms of repair and reversibility. Their long-term viability, on the other hand, is still debatable.¹⁶ Resin fiber SMs can be considered as successful only for a short period, according to Saravanakumar et al.²⁶

The majority of FRC SM failures occur due to:

- Debonding at the enamel-composite interface. This is because of the primary tooth's prismatic enamel, which may interfere with resin retention,^{24,27-29} poor surface preparation, moisture contamination, and disruptions during the adhesive setting process. These are all factors to consider.³⁰
- Debonding of fiber-composite interface/fracture of fiber frame: It is possible that the bonding margins between teeth and FRC at either end of the framework will be weakened by the compressive and tangential forces of the fiber frame.^{17,28,31}

New designs and materials for SMs are required to overcome the aforementioned disadvantages. Space maintainer appliances are now being fabricated using digital workflow instead of the traditional analog workflow because of the advantages this offers.

DIGITAL WORKFLOW IN PEDIATRIC DENTISTRY

Dentistry adopted the digital workflow in the 1980s and has been using it ever since. The use of CAD-CAM technology in pediatric dentistry has shown tremendous success in recent years. Improved patient compliance and acceptance of treatments are two main advantages. There are a few published case studies demonstrating the effectiveness of digital restorations in pediatric patients over

the short and long term. Esthetic dentistry for adults and children is increasingly utilizing ceramic materials and CAD/CAM technologies. Numerous studies have found indications of the use of CAD/CAM technology in primary and permanent tooth structures.

A case study examined the benefits of resin nanoceramic CAD/CAM restoration for the primary second molar of a patient with a missing permanent second premolar successor.¹⁵ This restoration had a 3-year follow-up that showed the resin nanoceramic CAD/CAM restoration had both esthetics and function.³² CAD/CAM PICN (polymer-infiltrated ceramic network) endocrown on a primary second molar with pulpotomy exhibited excellent marginal fit, anatomical shape, and minimal discoloration 9 months later.³³ A 2-year follow-up showed that using in-office CAD/CAM technology on a young patient with amelogenesis imperfecta improved quality of life and resulted in satisfactory results. Smile restoration, less clinical work, and dental structure preservation were all possible with this procedure.³⁴ The digital impression approach, according to Yilmaz and Aydin, is more convenient and preferred by youngsters than the traditional impression method.³⁵

This opens the door to using modern metal-free ceramic constructs to restore children's dentition, resulting in stronger, more attractive, and more effective restorations.³⁶ In the long run, CAD-CAM technology that is quick, precise, and does not require a lot of time may be the best option for pediatric patients.

DIGITAL SPACE MAINTAINERS

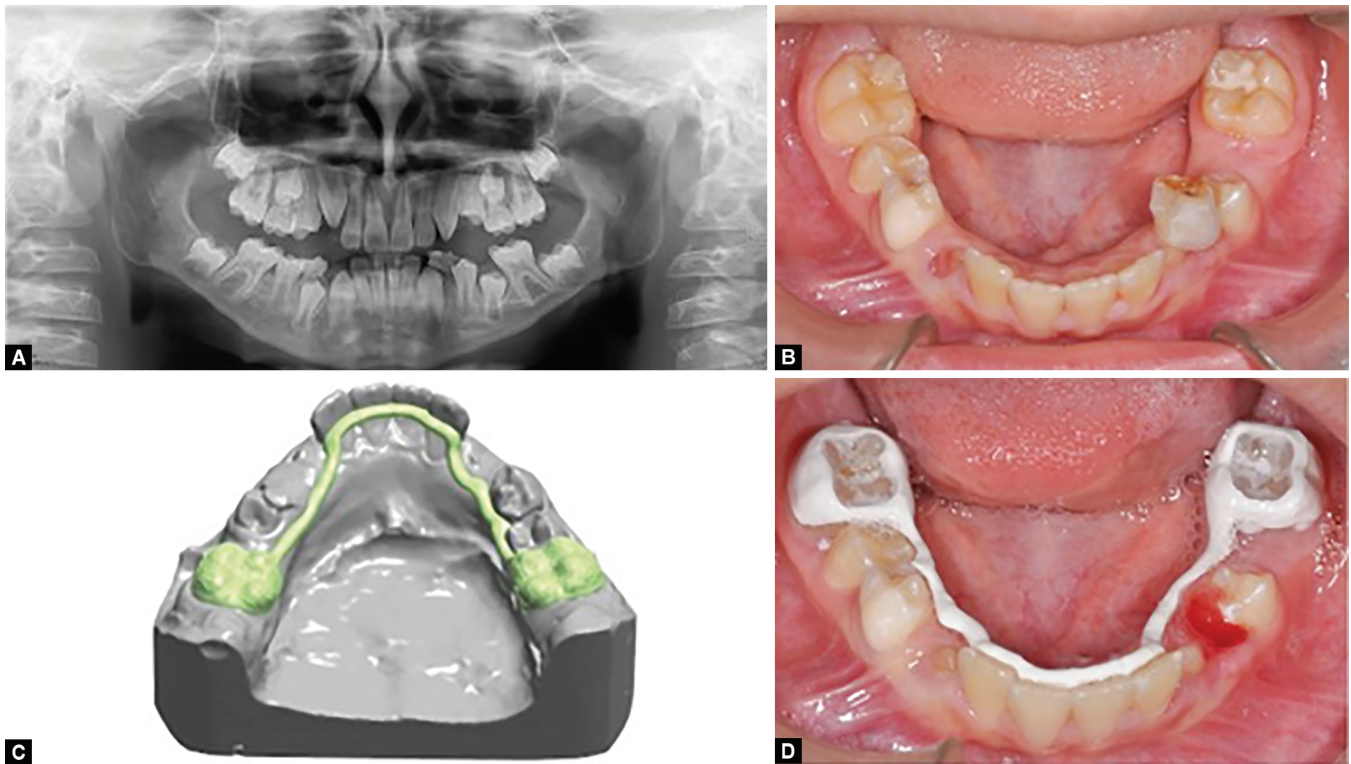
Space maintainers that use CAD-CAM or 3D print technology with modern and biocompatible materials are called "Digital Space Maintainers". The above-mentioned challenges and drawbacks of traditional manufacturing could be overcome by using this technology.

Materials Used for Fabrication of a Digital Space Maintainer

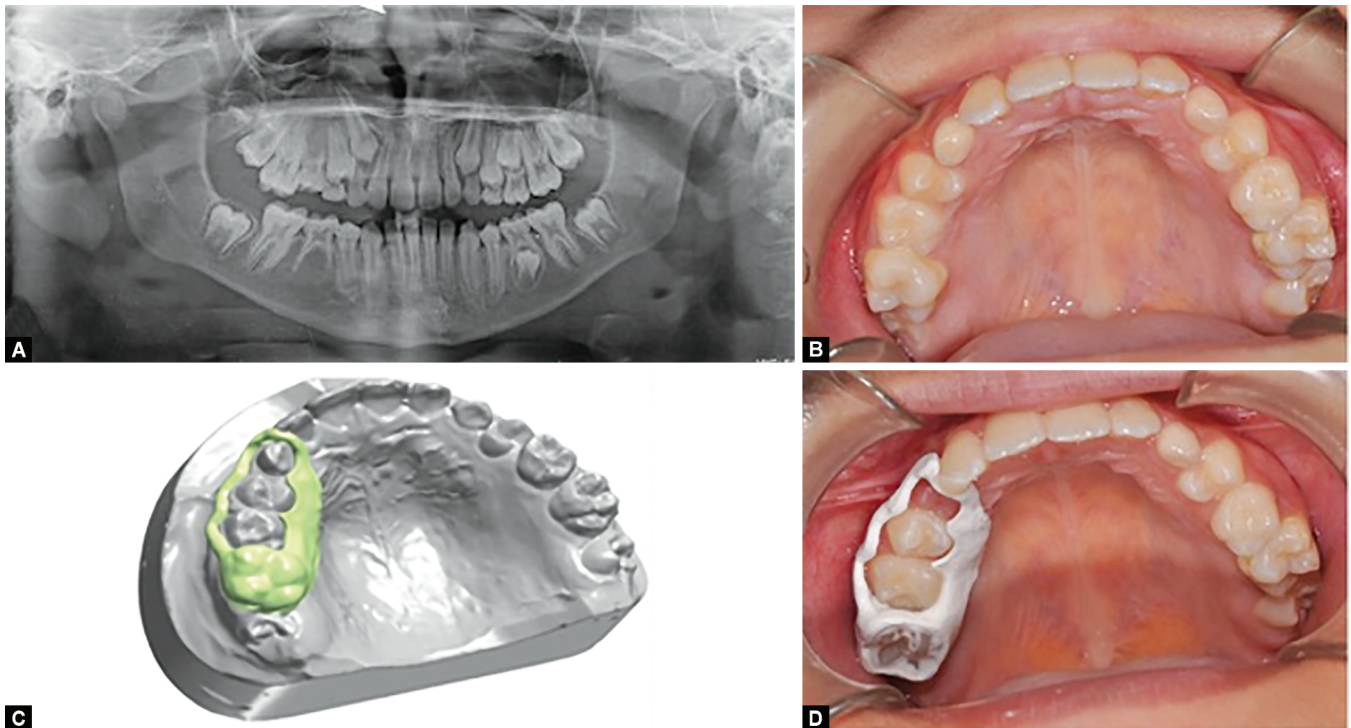
PEEK Polymer

Materials made from 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.³⁷ Patients who are allergic to metals or dislike the metallic taste or weight can use this material because it has a natural tooth-colored appearance.³⁸ PEEK offers several favorable features in orthodontics, according to a 2015 study, making it a potential candidate for usage as an esthetically pleasing metal-free orthodontic wire.³⁹ The framework and prosthetic teeth can be developed in the same design module for detachable, functional varieties of SMs, releasing a fully integrated design. As a result, this technique is preferable to others that use self-curing resin and artificial teeth.⁴⁰

Using PEEK polymer for the production of CAD-CAM SMs was the subject of a study done by Ierardo et al.⁴⁰ They created a lingual arch (Fig. 1), a B&L (Fig. 2), and a removable plate (Fig. 3). After a 9-month follow-up, it became clear that all three patients were extremely pleased with the devices. Digital B&L SMs made of PEEK polymer were evaluated by Kun et al.⁴¹ 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.⁴² compared digitally produced RSMs made of PEEK polymer to traditional RSMs. Study results showed that digitally created RSMs fit the model well, indicating that the technique was suitable for



Figs 1A to D: "First case report" by Gaetano Ierardo, Source is licensed under CC BY-NC-SA 4.0

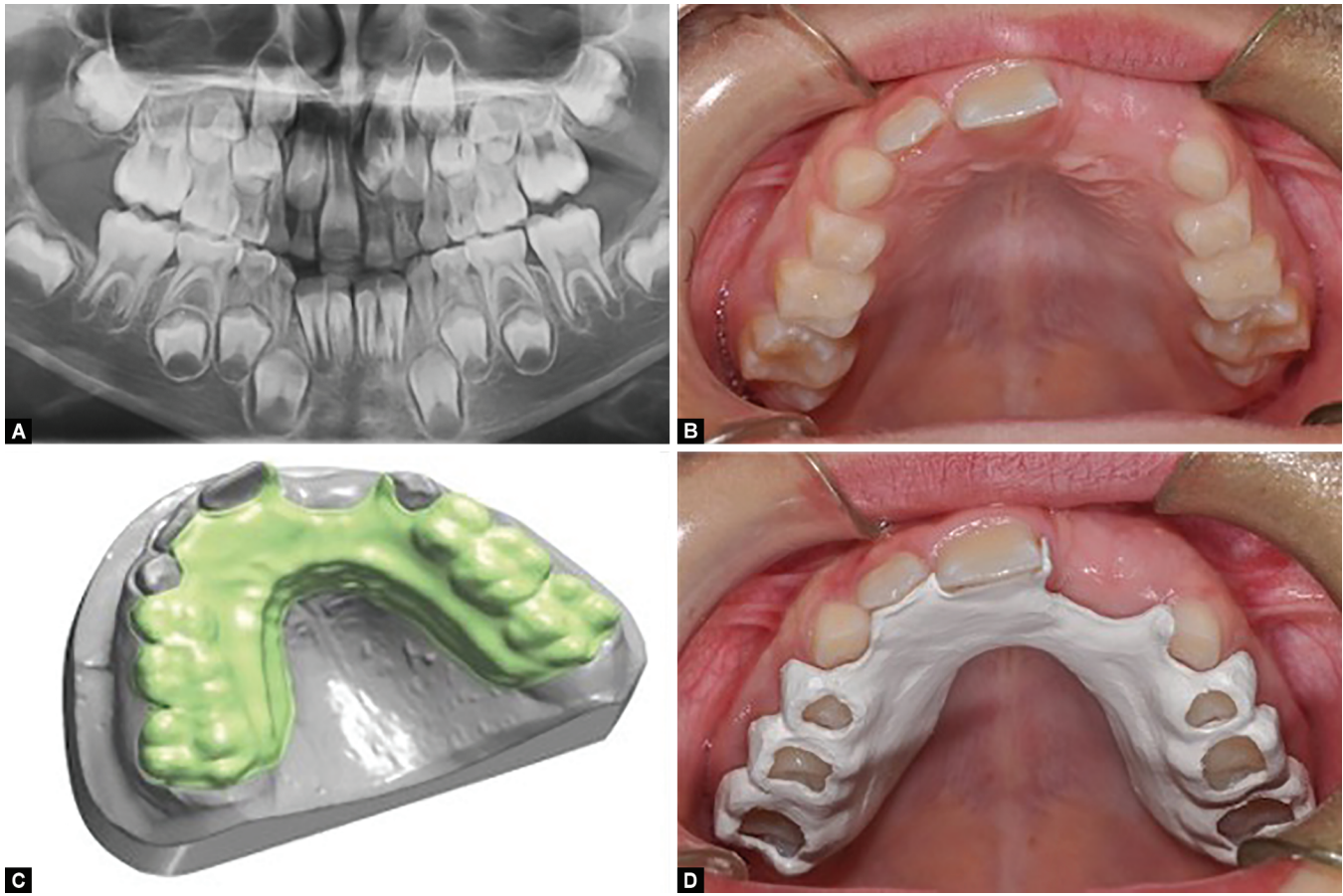


Figs 2A to D: "Second case report" by Gaetano Ierardo, Source is licensed under CC BY-NC-SA 4.0

clinical applications.⁴² 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.

BruxZir

BruxZir is three to five times more fracture-tough than standard zirconia, with a flexural strength of up to 1,465 MPa.⁴³ This gives the material an excellent impact resistance to the masticatory forces in the mouth. Because of its minimal thermal expansion, the material



Figs 3A to D: "Third case report" by Gaetano Ierardo, Source is licensed under CC BY-NC-SA 4.0

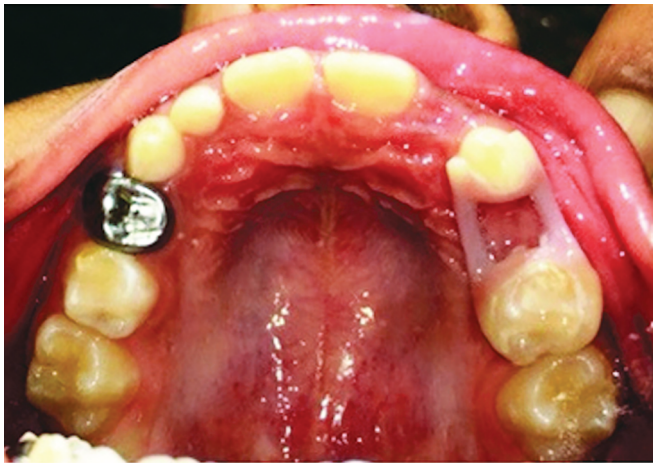


Fig. 4: "Intraoral photograph 6 months after placement of appliance." by HK Soni, Source is licensed under CC BY-NC-SA 4.0

will stay in the mouth without shifting shape or becoming loose in your teeth. The first published paper on using digital technology to fabricate an SM was by Soni.⁴⁴ While treating a 6-year-old female patient, the author employed BruxZir as the material for the device (Fig. 4). 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.

Trilor

Trilor is a CAD/CAM-processed FRC resin. Metal and zirconia are heavy materials; this metal-free, biocompatible alternative weighs 3–5 times less. Durability, elastic property, low weight, biocompatibility, and reparability are some of the benefits.⁴⁵ Beretta and Cirulli⁴⁶ developed a metal-free CAD-CAM device intending 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 SM using Trilor and directly bonded on the palatal surface of the first primary molar.

Steps in Fabrication Using CAD/CAM Technology

By using the CAD-CAM method, restorations can be virtually designed and then milled on an automated milling machine.⁴⁷ A dental laboratory is often where fabrication takes place. CAD-CAM processing begins with a traditional impression from the dentist, which is then digitized in the lab.⁴⁸ Sirona introduced the first chairside CAD-CAM technology, the CEREC system, which allows dentists to design and fabricate restorations right in the dental office.⁴⁹ By using chairside and laboratory CAD-CAM manufacturing methods, dental restorations can be made more rapidly.

There are three general steps in the digital restoration workflow: (1) Scanning the tooth geometry to capture digital data; (2) Digital

data manipulation with a software program to build the volume model for the restoration; and (3) Production technology to transform the volume model into the restoration.⁵⁰

The procedure used to fabricate a digital SM by Ierardo et al. (Fig. 5) is described below:⁴⁰

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 because 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

Additive manufacturing, layered manufacturing, and solid freeform fabrication are other terms for 3D printing. The basic notion behind this new technology is that a digital file may be used to construct a layer-by-layer design for a 3D object of any shape or geometry. A cross-section of the final object is represented by each of these layers. Pawar⁵¹ was the first to employ digital 3D printing to create SMs (Fig. 6), with one using titanium-based powdered metal and

the other clear photopolymer resin. As the author pointed out, 3D printing in pediatric dentistry has significant potential.

Advantages^{40–46}

The advantages of using a digitally fabricated SM device and its impact are summarized in Table 1:

Disadvantages⁴⁴

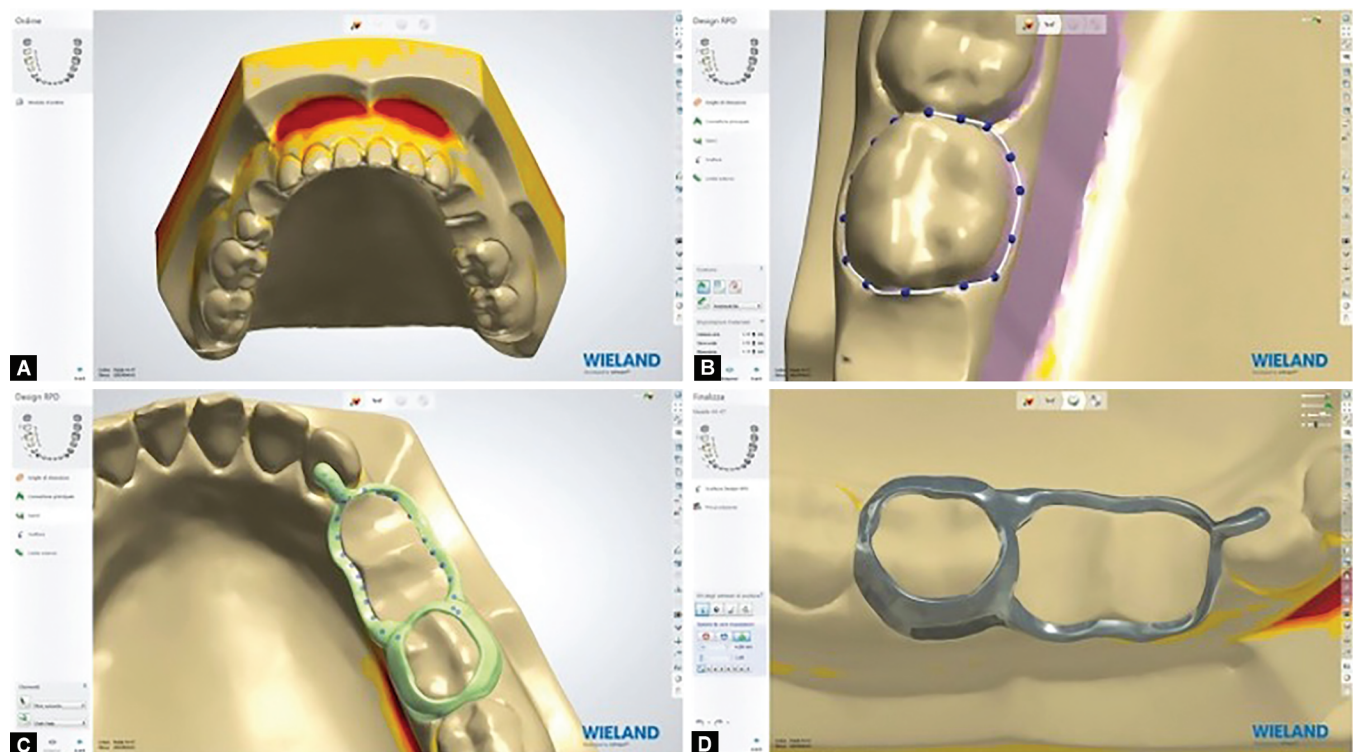
- Expensive.
- Lab assistance is required.
- Fabrication expertise is required.
- Expensive equipment is required.

FUTURE RESEARCH

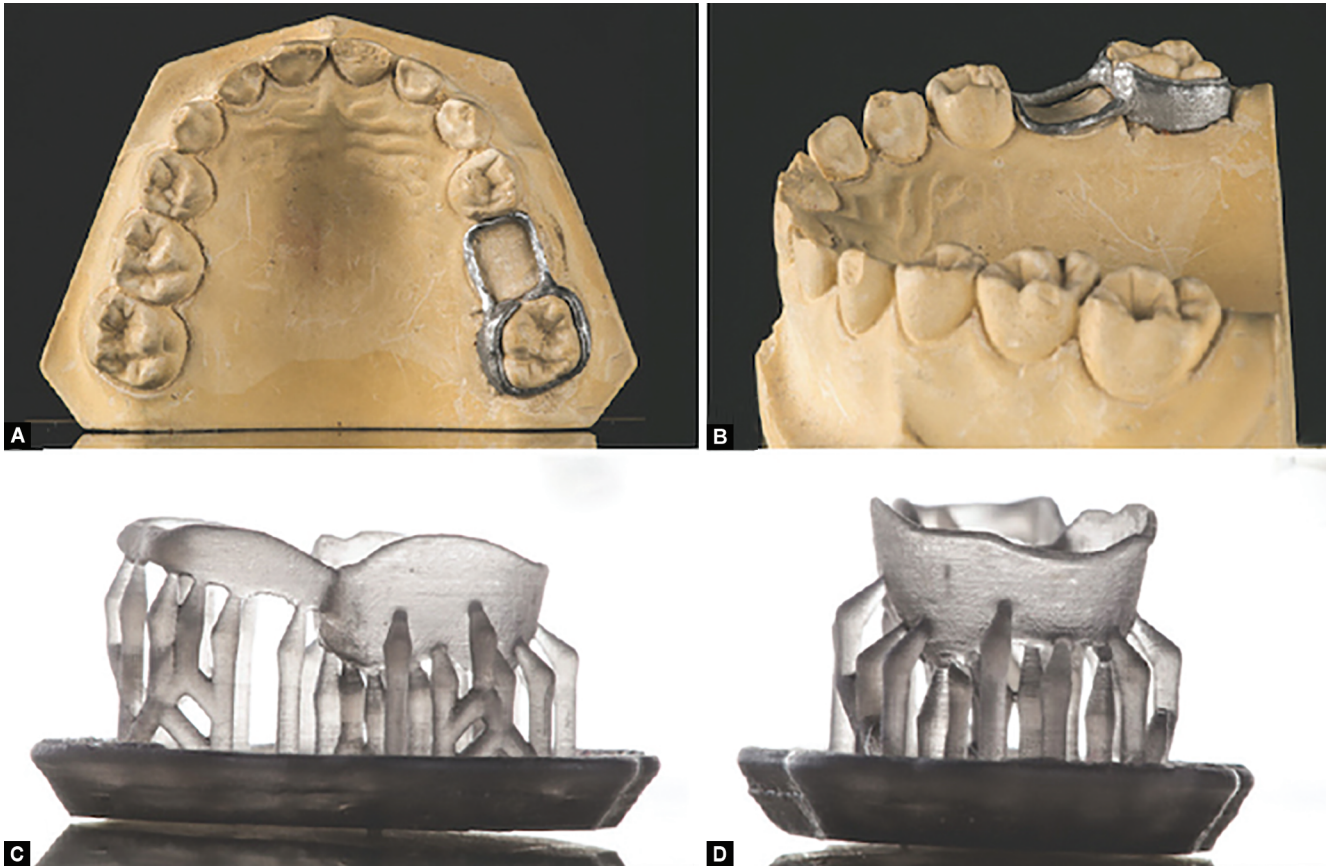
To determine the longevity, influence on gingival health, patient compliance, and acceptability of digitally manufactured SMs, or "Digitainers", additional clinical and comparative research is required. Future research should concentrate on low-cost materials. Furthermore, 3D printing in pediatric dentistry has yet to be fully investigated. Using it allows us to make innovative advancements because of its accuracy and perfection.

CONCLUSION

Dentistry's digital workflow is continually evolving and revealing fresh techniques. Pediatric dentistry's SMs have taken a giant stride towards custom orthodontics. Devices made using digital fabrication techniques be reliable and long-lasting. Time-consuming manual fabrication stages are eliminated thanks to CAD-CAM technology. It is possible that in the future, this way of investigating more materials will be used to develop more complicated appliances. Since the digital age has arrived and offers



Figs 5A to D: "Digital pattern acquisition, thanks to CAD software and design of the devices" by Gaetano Ierardo, Source is licensed under CC BY-NC-SA 4.0



Figs 6A to D: "(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 Pawar, Source is licensed under CC BY-NC-SA 4.0

Table 1: Advantages of digitally fabricated SM devices and their impact

| Advantages | Impact/outcome |
|------------------------------|---|
| 1. Esthetic | Increased patient outcome |
| 2. Metal-free | Especially advantageous for patients with metal allergy, nickel allergy and special care needs patient who periodically requires to undergo MRI in the head 'REGION' to monitor to specific disease as epilepsy or vascular problems. |
| 3. Precise | Reduced deformation and errors, breakage and decementation |
| 4. Quick fabrication time | Reduced no. of visits hence improved patients 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 required |

various advantages, more and more 'CLINICIANS' will likely begin to use it in their daily practices.

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