Case Report

Precision-Based 3D-Printed Band and Loop Space Maintainer: A Digital Solution for Early Tooth Loss

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Abstract:

Premature loss of primary molars can result in loss of arch circumference, leading to drifting of adjacent teeth, malocclusion, and even impaction of permanent successors. Space maintainers play an essential role in preventive orthodontics by preserving arch integrity. The band-and-loop type is the most commonly used, but conventional fabrication involves multiple clinical and laboratory steps and carries risks such as poor adaptation or solder joint failure. With advances in digital dentistry, three-dimensional (3D) printing offers superior accuracy, reduced human error, and improved appliance reliability. This case report presents the fabrication of a 3D-printed band-and-loop space maintainer as an efficient and precise alternative to the conventional design.

Key words: *3D printing, band and loop, space maintainers, preventive orthodontics, digital dentistry*

INTRODUCTION

Dental caries represents a major public health concern globally and often results in the premature loss or extraction of affected teeth.[1] Baume (1950) highlighted that the primary dentition plays a critical role in determining the space required for the normal eruption and development of permanent successors.[2] In addition, the primary dentition is integral to the proper growth and development of the jaws, as well as the functional aspects such as speech and mastication. The dimensions and spacing of the dental arches are key determinants influencing space closure following the early loss of primary teeth.[3] The premature loss of even a single primary tooth may result in disturbances within the dental arch, including the migration of adjacent teeth, malocclusion, and the potential need for prolonged orthodontic treatment in the future. Furthermore, compromised mastication due to tooth loss can adversely impact the development of facial and jaw musculature, temporomandibular joint function, as well as the child's nutrition and overall systemic health.[4] To mitigate these complications, the use of space maintainers is essential, as they facilitate the uninterrupted eruption of permanent teeth and help preserve the integrity of the dental arch.

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The American Academy of Pediatric Dentistry defines space maintenance as the preservation of the present dentition placement to avoid loss of arch length, width, and perimeter.[5] The term *space maintenance* was first introduced by J.C. Brauer in 1941, who described it as then process of preserving space in the mouth that was previously filled by one or more teeth.[6] In other words, space maintainers are appliances—either fixed or removable, unilateral or bilateral and functional or non-functional—designed to maintain the integrity of the arch length following the intentional or premature extraction of a tooth or teeth.

Evidence suggests that both clinicians and patients generally favor a well-constructed fixed space maintainer over a removable appliance.[7] Fixed space maintainers, typically composed of bands or stainless-steel crowns with an attached soldered wire, are the most commonly used option for managing posterior tooth loss.[8]

The band-and-loop space maintainer remains the treatment of choice for unilateral tooth loss and may also be used for bilateral loss of primary molars, provided the permanent incisors have not yet erupted. However, several limitations affect the fabrication and longevity of conventional band-and-loop maintainers, such as inadequate band adaptation, multiple visits, possibility of metal allergy and fracture of the soldered loop often necessitate repeated repairs or remaking of the appliance.[3,9]

To overcome these limitations, several efforts have been made to increase patient's comfort, reduce fabrication time, and better adaptation to the individual anatomy of each child.

The digital workflow was implemented in dentistry in the 1980s and has been used ever since then. 3D printing has become a subject of great interest in pediatric dentistry in fabrication of space maintainers. "Digital Space

Maintainers" are space maintainers that use 3D printing or CAD-CAM technology and contemporary, biocompatible materials.[10]

In line with the growing integration of digital tools in pediatric dentistry, the following case report demonstrates the fabrication and clinical delivery of a 3D-printed band and loop space maintainer.

CASE REPORT

A 5 year old female patient reported to the Department of Pediatric and Preventive Dentistry of our institute with a chief complaint of pain in right lower back tooth region since 4-5 months. There was no relevant medical history as reported by patient's parents. The patient had undergone pulpectomy followed by stainless steel crown i.r.t. 75, one year back.

Intra-oral examination revealed that there was deep occlusal caries i.r.t. 84 and a stainless steel crown i.r.t. 75. An intro-oral periapical radiovisiography revealed coronal radiolucency involving enamel, dentin, pulp and extending to the furcal region (figure 1). Since the prognosis of the tooth was poor, treatment plan of extraction of tooth no. 84 followed by fabrication of a band and loop space maintainer using 3D printing technology was made and explained to the parents.
Informed consent was obtained from the patient's parents, followed by extraction of tooth no. 84. A two-step impression procedure was carried out with addition silicone, wherein a putty impression was made first, followed by a light-body was wash impression to enhance the marginal and occlusal accuracy and was poured to make a cast (figure 2). The retrieved cast was sent to the 3D printing laboratory for scanning and printing a metal-based space maintainer.

DESIGN AND FABRICATION PROCEDURE

The dental cast was scanned using a 3D digital dental scanner (Medit T500, Medit Corp., Seongbukgu, South Korea), and the band-and-loop appliance was designed in accordance with the conventional space maintainer using DentalCAD 2.2 Valletta software (Exocad GmbH, Darmstadt, Germany) (figure 3). The finalized digital model was then printed using a titanium-based powdered metal material (Ti64 Gd23; LPW Technology Ltd., Cheshire, UK) through Micro Laser Sintering Technology, an additive manufacturing process that ensures high precision and material integrity (figure 4).

The printed space maintainer was tried in patient's mouth (figure 5); the post- operative occlusion was checked and found satisfactory. Further, the 3D printed space maintainer was cemented using glass ionomer cement (Shofu Hy-Bond Glasionomer CX-Smart Luting Cement, Japan).

At six months follow up visit (figure 6), the space maintainer appeared intact. The patient is on follow-up, and no complication is noted. Once the permanent tooth is ready to erupt, the appliance will be removed.

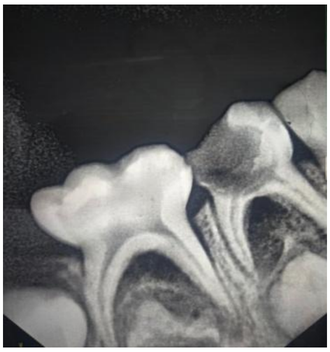

Figure 1: Pre-operative intraoral periapical radiographs of mandibular right first primary molar.

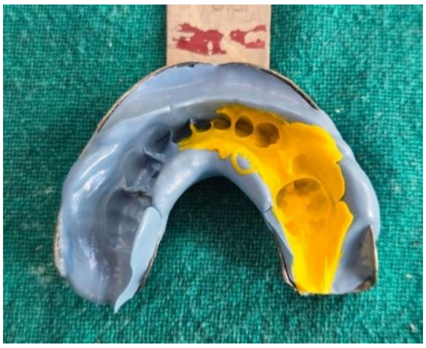

Figure 2: Two-step impression using addition silicone

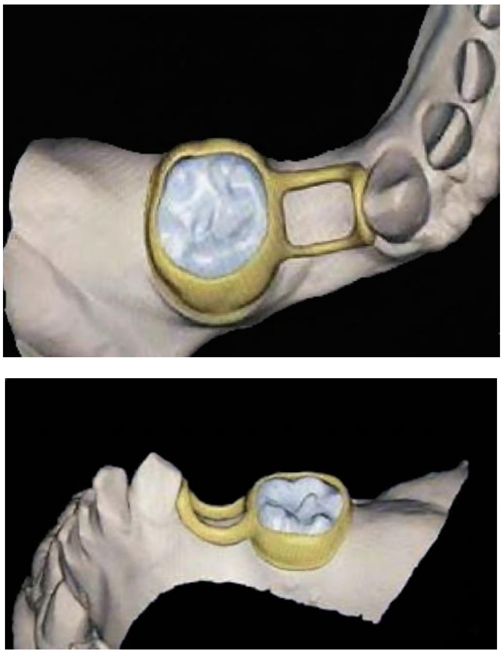

Figure 3 (a) and (b): Designing of 3D printed band and loop space maintainer.

Figure 4 (a) and (b): 3D printed space maintainer on the cast

Figure 5 (a) and (b): Post-operative intra oral clinical (a) and radiograph (b) of 3D printed band and loop space maintainer cemented on mandibular right first primary molar after cementation

Figure 5(c): lateral view after cementation of space maintainer on mandibular right first primary molar.

Figure 6: 6 months follow up

DISCUSSION

Premature loss of primary teeth in children is still very common despite technological and scientific advances in dentistry and oral health prevention measures.[11] According to Richardson, the most severe space problems occur when the primary teeth, in particular, the first primary molars are exfoliated before the eruption of the first permanent molar.[12] Preservation of arch length throughout the primary, mixed, and early permanent dentitions is crucial for the proper development of the succeeding occlusion. Most of the space loss typically results from mesial drift of the posterior teeth rather than distal movement of the anterior segment, a pattern more pronounced in the mandible.[3] Therefore, maintaining the space created by premature exfoliation of primary teeth is essential until the permanent successors erupt.

Various appliances can be used for space maintenance depending on the child's age, development and occlusion of dental arches. In cases of premature loss of primary first molars, it is important to place a band and loop space maintainer on the primary second molar prior to the 'dynamic' eruption phase of the first permanent molar, because the force of eruption of the permanent molar will exert significant mesial force on the primary second molar.[13] Thus, it is important that the space created by premature loss of primary teeth be maintained until eruption of permanent successors.

There are certain challenges reported while constructing the conventional space maintainer which may lead to its failure. Baroni et al. (1994) mentioned solder breakage as one of its important reasons. At times, it is difficult to control the flame while heating the arch wire.[14] According to Hill, overheating of the arch wire during the soldering procedure caused breakage of the appliance.[15]

The present design of space maintainer offers several advantages over the conventional band and loop space maintainer. Band pinching and transferring the band on the impression is not only challenging in pediatric patients but also a cumbersome task which is eliminated in the present design. The 3D design of the appliance is made using CAD-CAM software that allows maximum precision with least possible flaws. One of the many advantages of 3D printing is that it allows the appliance to be printed in one single unit. This drastically reduces the chances of breakage of the appliance. The use of 3D printing technology minimizes human errors and lessens extensive laboratory procedures.

PEEK, PMMA, Zirconia, Titanium alloy powder, Cobalt-Chromium alloy powder are the materials commonly used for fabrication of 3D printed space maintainers. PEEK material is esthetic it can be utilized for 3D printing as well as milling purposes. Zirconia blocks can be used for milling purposes. Titanium alloy powder, Cobalt- Chromium alloy powder can be used for 3D printing through laser sintering.[4]

Pawar et al. (2019) reported the first instance of band-loop space maintainers printed via 3D printing being manufactured. They used micro laser sintering technology in conjunction with powder metallurgy and digitally developed a space maintainer using a 3D model. The authors found that compared to traditional approaches, the design and production of space maintainers were more convenient and time efficient when cutting-edge digital technology was incorporated. This demonstrates that 3D printing technology encourages potential in the field of pediatric dentistry.[16] Khanna et al. (2021) found that space maintainers developed using CAD-CAM demonstrated excellent results, while the conventional ones showed depression and microfractures of the appliance due to occlusal forces.[3] Rathi et al. (2023) described single-visit fabrication and delivery of 3D-printed esthetic space maintainers in children with attention-deficit hyperactivity disorder.
The technique allowed quick, single-appointment appliance fabrication and delivery, illustrating the clinical utility of 3D printing in special-needs pediatric patients.[17] However, it also presented challenges such as high costs, the need for specialized training, ongoing equipment maintenance, and software limitations.[16] Hence, balancing these disadvantages with the benefits is essential for routine dental practices.

Various in-vitro studies have evaluated different parameters related to 3D printed space maintainers. The study by Tamburrino et al (2023) has first reported DLP technology for 3D printing the band and loop space maintainer by using resin (OD-Clear MF Bio monomer free‖, 3Dresyns) which in their finite element analysis study reported excellent mechanical properties such as Flexural strength exceeding 110 MPa, an elastic modulus ranging from 2 to 3 GPa, and a tensile strength exceeding 50 MPa.[18]

The study by Barakat et al. (2023) evaluated and compared the bond strength between conventional and 3D printed band and loop using Universal testing machine. The authors have reported that bond strength is higher in 3D printed space maintainer group as opposed to conventional band and loop space maintainer group.[19] The study by Tocuk and Yilmaz (2022) evaluated the fit and retention between conventional and 3D space maintainer and results of the study reported that there is no significant difference between both the groups.[20]

In the present case, it was noted that the band did not require any alteration while cementation. The time required for fabrication of 3D printed band and loop space maintainer also was less which reduced the number of appointments. On clinical examination, after six months, there were no signs of plaque accumulation and gingival inflammation. Owing to the design and finish of the 3D printed band and loop space maintainer, the patient did not report any discomfort associated with it.

CONCLUSION

This case report highlights the transformative potential of 3D-printing technology in pediatric space management. The digitally designed, 3D-printed band and loop space maintainer provided superior precision, excellent adaptation, and enhanced clinical efficiency compared with the conventional technique. Its seamless fabrication process reduced operator dependency and minimized laboratory-related errors, resulting in a highly accurate and durable appliance. This case clearly demonstrates that 3D printing can significantly elevate the quality and predictability of space maintenance in pediatric patients.

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