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REVIEW ARTICLE

3D SPACE MAINTAINERS IN PEDIATRIC DENTISTRY: SCOPING REVIEW

Sunnypriyatham Tirupathi[1], Lamea Afnan[2,3], Sejal Shah[4], Marco Di Blasio[5]*, Maria Maddalena Marrapodi[6], Diana Russo[7], Gabriele Cervino[8], Giuseppe Minervini[9,10*]

[1] Department of Pedodontics and Preventive Dentistry, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, 600077 Chennai, India; dr.priyatham@gmail.com (S.T.)

[2] Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, 600077 Chennai, India; dr.lameamr@gmail.com (L.A.)

[3] Coorg Institute of Dental Sciences, Virajpet, 571218, Karnataka, India

[4] Department of Pediatric and Preventive Dentistry, Pandit Deendayal Upadhyay Dental College Hospital, Kegaon, 413002 Solapur, India; sejalsshah1995@gmail.com (S.S.)

[5] Department of Biomedical, Surgical and Dental Sciences, University of Milan, 20122 Milan, Italy; marco.diblasio@unimi.it (M.D.B.)

[6] Department of Woman, Child and General and Specialist Surgery, University of Campania "Luigi Vanvitelli", 80138 Naples, Italy; mariamaddalena.marrapodi@studenti.unicampania.it (M.M.M.)

[7] Multidisciplinary Department of Medical-Surgical and Odontostomatological Specialties, Oral Surgery Unit, University of Campania "Luigi Vanvitelli", 80138 Naples, Italy; diana.russo2@unicampania.it (D.R.)

[8] Department of Biomedical and Dental Sciences, Morphological and Functional images, University of Messina, G. Martino Polyclinic, 98125 Messina, Italy; gcervino@unime.it (G.C.)

[9] Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, 600077 Chennai, India; giuseppe.minervini@unicampania.it (G.M.)

[10] Multidisciplinary Department of Medical-Surgical and Odontostomatological Specialties, University of Campania "Luigi Vanvitelli", 80138 Naples, Italy; giuseppe.minervini@unicampania.it (G.M.)

***Corresponding Authors:** Marco Di Blasio, Department of Biomedical, Surgical and Dental Sciences, University of Milan, 20122 Milan, Italy; marco.diblasio@unimi.it (M.D.B.). Multidisciplinary Department of Medical-Surgical and Odontostomatological Specialties, University of Campania "Luigi Vanvitelli", 80138 Naples, Italy; giuseppe.minervini@unicampania.it (G.M.)

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ABSTRACT

Background: Conventional space maintainers in pediatric dentistry is a multistep, multi-visit process that involves paramount of patient co-operation and is a difficult especially in young un-cooperative children, and children with gag-reflex and children with special health care needs. Recent multiple case reports successfully describe 3D space maintainers and its effective use in multiple clinical scenarios. The aim of this current scoping review is to discuss the advances in terms of Computer aided design (CAD) and extent of use of 3D space maintainers and its use in pediatric dentistry

Methodolody: PubMed, Scopus, Web of Science databases were evaluated with pre-defined search strategy ((((CAD) OR (CAM)) OR (3d printing))) AND (Space maintainer). Google Scholar and Research Gate were also consulted with the search terms to include all the articles for this current scoping review.

Results: A total of 349 titles were screened rigorously by three independent evaluators and after duplicate exclusion, removal of irrelevant titles, finally led to inclusion of 18 articles for the qualitative synthesis of data.

Conclusion: 3D space maintainers seem to be an effective option for pediatric patients with gag reflex and single visit pediatric dentistry, however the amount of available literature is too sparse, well planned randomized control studies need to be planned to evaluate various parameters such as comfort, longevity and failures etc. 3D Space maintainers can be a game changer in single visit pediatric dentistry practice.

Keywords: Children, 3D space maintainers, CAD-CAM, Gag Reflex

INTRODUCTION

Dental caries is a major public health issue, often leading to premature tooth loss or extraction.[1-3] Primary dentition plays a crucial role in jaw growth, speech, and chewing abilities. Maintaining good oral hygiene promotes overall health of the child.[4,5] Space closure after premature loss of primary teeth is essential, especially in clinical scenarios with smaller jaw dimensions and deficient space. Early loss of primary first or second molars or proximal lesions can lead to various issues, including space closure, crowding of the permanent dentition, loss of arch circumference, drifting of adjacent teeth, impaction of succeeding teeth, midline shift, and impairment of function.[6]

Primary teeth play a critical role as the optimal space maintainers in preventive dentistry. Aside from their aesthetic, communication, and mastication functions, primary teeth serve in directing and aiding the emergence of permanent teeth. However, in clinical situations where early extraction is not an option due to severe cavities and substantial crown destruction, space maintainers are judged necessary.[7-9]

They serve to keep neighboring teeth in appropriate alignment for future orthodontic treatment. Making space maintenance essential in early space loss cases.[10,11] This method supports the maintenance of optimal masticatory and speaking function, while also reducing malocclusion caused by unwanted tooth movement. Various types of space maintainers, including those based on design, fixation, position, and location, are designed to prevent malocclusion in erupting permanent teeth caused by premature tooth loss.[12]

Amongst which conventional space maintainers have been recommended and preferred by practitioners for years. Conventional band and loop are a multistep and multi-visit process that involves adapting and trimming the band, band pinching, impression making, transfer of band material onto impression, stabilizing the band onto impression, duplicating cast, and soldering the loop, and then transferring the final band and loop intraorally in the second visit.[7,13-15] Studies have identified challenges faced by traditional space maintainers, including nickel sensitivity, poor construction quality, increased risk of dislodgment and ulceration, tissue irritation, increased gagging, increased occlusal load, and increased risk of root resorption.[16-19]

Advanced technologies and newer materials are preferable to traditional space maintainers due to their limitations. Some studies recommend utilizing technique-sensitive fiber-reinforced composite resin (FRCR)-based space maintainers, which may include components like polyethylene fibers, pre-impregnated salinized E-glass fibers with Bis-GMA, with or without PMMA, and CAD/CAM-aided ceramic- and polymer-based space maintainers, to address these challenges.[20-23]

Digitalization in dentistry is progressing with the development of 3D printing technology, which generates 3D objects from digital files. This technology is revolutionizing a variety of sectors, including medicine and dentistry, and it holds great promise in pediatric dentistry by offering innovative solutions for dental treatments. Digital space maintainers are individuals who use these types of technologies. Three-dimensional (3D) printing of space maintainers is a manufacturing process that employs computer-aided design and CAD/CAM technology to construct custom 3D space maintainers on a layer-by-layer basis.[24-26]

These space maintainers are also beneficial for patients who prefer a more aesthetically pleasing option compared to traditional metal appliances. Additionally, they can help reduce the risk of processing errors and the need for frequent appointments, leading to a more efficient treatment process. There is a gap in the literature for comprehensive studies that investigate the production of space maintainers through digital workflows, highlighting the necessity for further research in this area. This research aims to fill that gap by conducting a thorough analysis of space maintainers created using digital tools and techniques, contributing to the understanding of digital workflow in dental treatments. This scoping review is intended to offer an overview of the current literature on 3D space maintainers.

Methodology

Search strategy is depicted in Table 1. Electronic searches were performed in the databases: PubMed, Scopus, Web of Science, Google scholar. The search was conducted from inception to 1 march 2024. A broader search strategy was used to prevent missing articles.

Table 1. Search strategy

Search terms	PubMed	((((CAD) OR (CAM)) OR (3d printing))) AND (Space maintainer)
	Scopus	3d AND space AND maintainer
	Web of Science	3D and space maintainer
	Google Scholar and ResearchGate	3D Space maintainer
Search Dates	Inception to 1 March 2024 Last search was performed on 1 April 2024.	
Selection criteria	Inclusion	Clinical studies, Case reports, In-Vitro Studies,
	Exclusion	Space maintainers and other appliances in adults and narrative and systematic reviews

The search was performed using broad terminology ((((CAD) OR (CAM)) OR (3d printing))) AND (Space maintainer) in PubMed, 3d AND space AND maintainer in Scopus-, 3D and space maintainer in Web of Science.
The review was conducted according to PRISMA guidelines using PICO criteria.
P (Population: Children below 16 years);
I (Intervention: 3D printed space maintainers);
C (Control: conventional space maintainers);
O (Outcome: clinical parameters such as fit, retention and longevity).

Apart from these databases Google scholar first 200 articles were screened with the same search strategy. Research gate was also consulted and cross references were also consulted on this topic to extract all the available literature. Any clinical trial, case report, technical note, invitro study on the topic in children is included for qualitative data synthesis. Exclusion criteria is adult studies and narrative and systematic reviews.

RESULTS

Extensive literature search was carried out using pre-defined search strategy was carried out. A total of 349 titles were screened rigorously by three independent evaluators and after duplicate exclusion, removal of irrelevant titles, 19 articles were included for full text analysis out of which one article was excluded due to unclear description. Figure 1. PRISMA flow chart 18 articles were included for final data synthesis.[27-44]
The characteristics of included studies are presented in Table 2.

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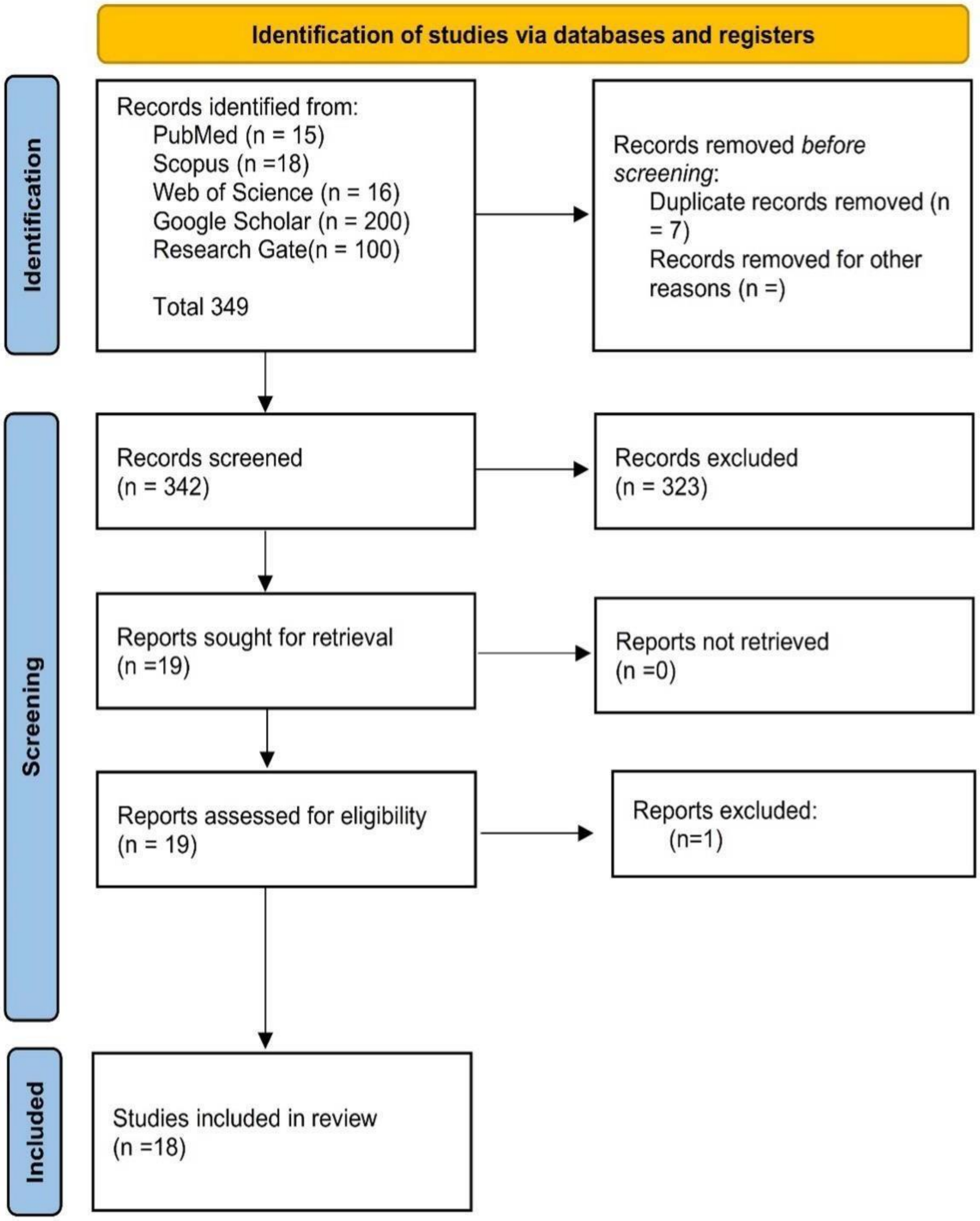

Figure 1. PRISMA Flow Chart

Table 2. The characteristics of included studies

S no	Author-year	Type of study	Age of Subjects	Type of Space maintainer	Scanning	Tooth preparation if any	Designing	Material used	Comparison	Methods to obtain fit and retention	Evaluated Outcomes	Conclusion
1	**Cengiz and Karayilmaz 2024** (1)	RCT	Seventy children (mean age: 6.99 ± 1.18) were divided into two groups	Band and Loop space maintainer	Direct intraoral Scanning 3Shape TRIOS® 3 MOVE (Copenhagen, Denmark).	Not mentioned	The design of SMs was carried out on the Dental CAD 2.2 Valletta (Exocad GmbH, Darmstadt, Germany) program	3D printing using Metal laser sintering of titanium alloy.	Traditional band and loop space maintainer.	Not mentioned Cementation was performed with glass-ionomer luting cement (Nova Glass-L, Imicryl, Konya, Turkey).	Survival of Space maintainers was compared between the groups	Failure rates are higher in 3D printed group and most of the failures are due to decementation. Sixteen (38%) SMs from the Traditional group and 25 (66%) SMs from the 3D printed laser sintered group were recorded as failed due to retention loss.
2	**Rathi et al 2023** (2)	Case report – 2 Cases.	5-6 years old Attention Deficiency Hyperactive Disorder (ADHD)	Band and loop Esthetic fixed space maintainer	Direct intraoral Scanning (Medit T500, Medit Corp., Seongbuk-gu, South Korea)	No crown preparation was performed	Dental CAD 2.2 Valletta (Exo-CAD GmbH, Darmstadt, Germany)	3D printing using Metal laser sintering of titanium and followed by adding opacifier and firing for aesthetics.	No comparison	Cementation was performed with glass ionomer cement. (Type 1, GC, Fuji, Tokyo, Japan)	Survival	6 months follow-up was uneventful
3	**Yangdol et al 2023** (3)	Case report	7 years old child with Autism Spectrum Disorder (ASD)	Band and Loop space maintainer	Indirect scanning was performed (The cast was scanned using a 3D shape digital lab scanner.	Not mentioned	3-Shape dental system software	3D printing using Metal laser sintering of cobalt-chromium alloy.	No comparison	Not mentioned	Not mentioned	Not mentioned
4	**Barakat et al 2023** (4)	In-Vitro Study	Not applicable	Band and loop space maintainers	Direct scanning of extracted 3-shape E2 scanner.	Not mentioned	3-Shape dental system software	Not mentioned	Conventional band and loop.	Phosphoric acid etchant (Universal Etchant Gel, 3M ESPE, USA) was spread over the enamel surface for 30 s and washed for 30 s. Excess water was eliminated using a spongy pellet, to get a moist enamel surface. A layer of the universal bonding agent (3M ESPE St Paul, MN, USA) was added to the etched enamel surface using a brush and cured for 20 seconds by using a light-curing device. Resin cement (G-CEM™ Capsule GC corporation, Tokyo, Japan) was spread to the surface of the tooth and cured for 40 seconds.	Bond strength was compared between conventional and 3D printed band and loop using Universal testing machine.	Bond strength is higher in 3d printed space maintainer group as opposed to conventional band and loop space maintainer group.
5	**Abdelshahed et al 2023** (5)	Clinical study	36 children with age range of 4-7 years.	Esthetic non-functional band and loop (PEEK Ridge, Ridge off,) versus conventional band and loop.	Indirect scanning was performed (The cast was scanned using an optical scanner (name not mentioned)	Not mentioned	Exocad	Milling of PEEK	Conventional band and loop.	In two PEEK groups, bands of PEEK were treated with sandblasting using aluminum oxide particles (110 µm) under pressure of 2 to3 bars to increase the surface area for cementation and by using Viso-link adhesive system made micro mechanical retention between luting cement and PEEK surface.	Survival	9 months follow-up PEEK group had lower failures as compared to the conventional band and loop group.
6	**Tamburrino et al 2023** (6)	Invitro	Not applicable	Esthetic Band and Loop space maintainer			Autocad	DLP Technique using Anycubic Photon Mono SE 3D printing machine and the adopted	-			Flexural strength exceeding 110 MPa, an elastic modulus ranging from 2 to 3 GPa, and a tensile

								resin, "OD-Clear MF Bio monomer free", supplied by 3Dresyns				strength exceeding 50 MPa
7	**Beretta et al 2022** (7)	Technique	3-5 years	Anterior fixed functional esthetic space maintainer	Intraoral scan (Trios, 3Shape, Denmark).	No preparation was performed	3-Shape, Denmark	3d printing of PEEK	No comparison	Etching and adhesive cementation, using preferably a self-adhesive or light-curing bioactive cement (Activa Bioactive Cement, Pulpdent, USA; Transbond Plus, 3M, USA) or other materials (Transbond LR, 3M, USA; Relyx, 3M, USA) to bond the PEEK structure to teeth	Survival	12 month follow up uneventful.
8	**Aboulazam et al 2022** (8)	RCT	20 children aged 5-7 years having unilateral extracted mandibular primary first molars	Posterior band and loop esthetic non-functional space maintainers.	Intraoral scanner "Primescan" (DentsplySirona. Germany)	No preparation was performed	Inlab 19 Software to Removable Partial denture (RPD) module	Milling according to BioHPP PEEK (Bredent. Germany) MCX5 milling machine (DentsplySirona. Germany).	Conventional band and loop space maintainer.	Internal surface was microsandblasted The abutment tooth was acid etched under partial isolation and cemented with the resin cement "Multilink R Speed" (Ivoclar Vivadent AG. Liechtenstein) and cured for 20 seconds	Comparison of comfort	6 month follow up uneventful. Patient satisfaction was more with PEEK space maintainers
9	**Rodrigues et al 2022** (9)	Technical report	Not mentioned	Esthetic Fixed space maintainer	Direct intraoral scan TRIOS 3, 3Shape, Copenhagen, Denmark	Not mentioned	Dental CAD, Exocad GmbH, Darmstadt, Germany	PrograMill CAM 4.1, Ivoclar; 5-axis milling device	No comparison	Not mentioned	-	Not mentioned
10	**Tocuk and Yilmaz 2022** (10)	In-Vitro Study	Not applicable	Band and Loop fixed space maintainer	-	-	-	-	CAD based band and loop is compared to conventional band and loop space maintainer	-	Fit and retention was evaluated between conventional and CAD CAM based space maintainer.	No difference in the fit of both the CAD based and conventional space maintainers.
11	**Gupta et al 2022** (11)	Case report	7 -8 years old	Distal Shoe space maintainer.	Direct intraoral scanning using CEREC Omniscan	Not mentioned	Not mentioned	Not mentioned	No comparison	Not mentioned	Survival	2 months follow up uneventful
12	**Khanna et al 2021** (12)	Case report.	6 years	Band and Loop Fixed Space maintainer.	Indirect scanning was performed (The cast was scanned using a 3D digital dental scanner (Medit T500, Medit Corp., Seongbuk-gu, South Korea)	Not mentioned	Dental CAD 2.2 Valletta (Exo-CAD GmbH, Darmstadt, Germany)	3D printing using Metal laser sintering of titanium	Conventional space maintainer.	Cementation was performed with glass ionomer cement. (Type 1, GC, Fuji, Tokyo, Japan)	-	Follow-up uneventful 6 months.
13	**Lee 2021** (13)	Case report	8 years	Fixed Esthetic reverse Band and Loop.	Direct intra-oral scanning using TRIOS Color Cart; 3Shape, Copenhagen, Denmark)	Conservative crown preparation on the First primary molar	3-Shape Software for designing	The SM was milled out of a zirconia block (1100 Enamel; DENTALMAX, Seoul, Korea).	-	Crown preparation on the primary molar and creating a rest on the permanent first molar. Air abrasion of the inner surface followed by cementation using a self-etching primer (ED PRIMER II; Kuraray Noritake Dental, Okayama, Japan) was applied to the primary first molar.33 The customized band and rest were luted	Longevity and survival	Follow up of 22 months without any complications

										with adhesive resin cement (Panavia F 2.0; Kuraray Noritake Dental) that included the functional monomer 10-methacryloyloxy-decyl-dihydrogen- phosphate (10-MDP)		
14	**Essawy et al 2021** (14)	Clinical study	13 children with unilateral loss of primary first molar	Fixed functional space maintainer	Indirect scanning of cast (InEos x5 Dentsply sirona	Not mentioned	Exocad Program (In lab dentsply sirona, Germany).	CAM milling of PEEK blocks.	No comparison	The abutment tooth was isolated, etched, and air dried after trimming, finishing, and polishing the space maintainer. The bridge was cemented using luting Rely X Unicem resin cement (3M ESPE Dental products, St. Paul, USA)	Survival	12 month Follow up uneventful
15	**Guo et al 2020** (15)	Original research- In Vitro Study	Not applicable as study was on standard models	Removable space maintainers (RSM)	Indirect scanning was performed (Scanning of Dental Casts) using D800, 3Shape, Copenhagen, Denmark	-	3-Shape Software for designing of Removable space maintainers.	Polymethyl methacrylate (PMMA)	Comparison was done with conventional removable space maintainer	Not mentioned	Fit was the outcome that was evaluated. The spacing between tissue surface of RSM and the cast was measured and compared.	Digital was better as it had less spacing.
16	**Pawar 2019** (16)	Case report.	7 years	Band and Loop Fixed Space maintainer.	Indirect scanning was performed (The cast was scanned using a 3D digital dental scanner (Medit T500, Medit Corp., Seongbuk-gu, South Korea)	Not mentioned	Dental CAD 2.2 Valletta (Exo-CAD GmbH, Darmstadt, Germany)	3D printing using Metal laser sintering of titanium	No comparison	Not mentioned	-	Follow up was done after 3 months.
17	**Ierado et al 2017** (17)	Case report of 3 cases.	8-10 years	Lingual arch, band and loop and one Removable space maintainer.	Indirect scanning was performed (Scanning of Dental Casts) (D810, 3Shape, Denmark).	Not mentioned	3Shape Dental Design software	Roland DWX-50 features 5-axis-milling of PEEK (poly ethyl ether ketone) Block	No comparison	Not mentioned	-	-
18	**Harleen Kaur Soni 2016**(18)	Case report	6 years	Fixed Esthetic Band and Loop	Indirect Scanning	No information	No information	Milling of Bruxzir Zirconia	No comparison	The gingival one-third of the distal surface of canine and gingival one-third of the mesial surface of the primary second molar etched with phosphoric acid for 15 seconds. After water rinse and drying, the hybridization was achieved by using two steps etch and rinse adhesive system (Adper Single Bond 2, 3M/ ESPE). The adhesive layer was polymerized during 15 seconds. The inner surface of the space maintainer was cemented with the help of resin luting cement (RelyX ARC – self adhering flowable composite, 3M/ESPE)	Survival	Reported follow up of 6 months

DISCUSSION

Types of 3D space maintainers

Fixed/Removable; Esthetic/Non-esthetic; Functional/ Non-Functional type of 3D space maintainers were reported in literature pertaining to pediatric dentistry. Removable esthetic 3D space maintainers were described in the study by Guo et al 2020.[30] Multiple studies reported the use of 3D Fixed space maintainers.

Esthetic 3D fixed space maintainers: Esthetic 3D fixed space maintainers can be inherently esthetic (PEEK, Zirconia) or masked (metal masked with opacifier).

Esthetic 3D fixed space maintainers: PEEK material based- 3D posterior fixed space maintainers were reported in the studies by Abdelshahed et al 2023,[40] Aboulazam et al 2022,[37] Essawy et al 2021,[31] PEEK material based- 3D Lingual arch has been reported in the study by Ierado et al 2017.[28] PEEK material based- 3D anterior fixed space maintainers are reported in the study by Beretta et al 2022.[38] Zirconia based milled 3D fixed space maintainers were reported in the studies by Harleen Kaur Soni 2016,[27] Lee 2021.[32] Metal fused opacifier added masked 3D fixed band and loop was reported in the study by Rathi et al 2023.[43]

Non-Esthetic 3D fixed space maintainers: Metal based non esthetic 3D fixed space maintainers were reported in the studies by Cengiz and Karayilmaz 2024 ,[44] Yangdol et al 2023,[42] Khanna et al 2021,[33] Pawar 2019.[29]

Method of Scanning

Two types of scanning are performed in relation to fabrication of 3D space maintainers**.** *Direct scanning* and Indirect scanning. Direct scanning involves the use of intra-oral scanners to scan directly in the patient. Indirect scanning utilizes lab scanners to scan a cast that is made after taking impression from the patient.

Direct scanning is utilized in the studies by Cengiz and Karayilmaz 2024,[44] Rathi et al 2023,[43] Beretta et al 2022,[38] Aboulazam et al 2022,[37] Rodrigues et al 2022,[36] Gupta et al 2022,[34] Lee 2021.[32]

3Shape TRIOS, Medit T500, CEREC Omniscan, Primescan Dentsply were the most commonly used commercial intra-oral scanners available for direct scanning Cengiz and Karayilmaz 2024,[44] Rathi et al 2023,[43] Beretta et al 2022,[38] Aboulazam et al 2022,[37] Rodrigues et al 2022,[36] Gupta et al 2022,[34] Lee 2021.[32] Indirect scanning was utilized in the studies by Harleen Kaur Soni 2016,[27] Ierado et al 2017,[28] Pawar 2019,[29] Guo et al 2020,[30] Essawy et al 2021,[31] Khanna et al 2021,[33] Abdelshahed et al 2023,[40] Yangdol et al 2023.[42] 3Shape E2 Series, D800, D810, InEos X5 DentSply Sirona were the lab scanners used for indirect scanning of casts after impression in the included studies.

Computer Assisted Design for 3D space maintainers:

After the scanning is achieved (Direct or Indirect) the scan is further processed in STL format to be uploaded in designing software. 3 Shape, ExoCAD, were the software's that was utilized for designing the space maintainers in the all the included studies.

Materials used for 3D space maintainer fabrication

PEEK, PMMA, Zirconia, Titanium alloy powder, Cobalt-Chromium alloy powder. 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.

Processing techniques used for 3D space maintainer fabrication

The digital 3D space maintainers can be fabricated using additive or subtraction technology.

Additive technolo*gy*: Additive technology includes different types of techniques such as; Stereolithography, Digital Light Processing, Fused Filament Fabrication/Fused Deposition Modelling, Selective Laser Sintering/Melting and Electron Beam Melting, Digital Light Processing. Stereolithography (SLA) is a 3D printing process that uses a UV laser and liquid resin to create parts layer by layer. The resin is light-reactive and thermosets, meaning that when exposed to certain wavelengths of light, the resin's short molecular chains join together to create rigid or flexible geometries. The UV light cures the resin layer by layer until the final object is complete. Digital light processing (DLP) is a 3D printing technology that uses a digital projector to cure a layer of photopolymer resin at once, eliminating the need for path-planning procedures. DLP is a type of stereolithography (SLA), but uses a more conventional light source, such as an arc lamp, rather than a UV light. Fused Filament Fabrication/Fused Deposition Modelling. Fused deposition modeling (FDM), also known as fused filament fabrication (FFF), is a 3D printing technique that uses a continuous filament of thermoplastic material to create a 3D object. The filament is fed through a moving extruder head and deposited onto a substrate in layers, where it solidifies to form the object. FDM is a filament-based technique that uses thermoplastic materials, mainly polymer and its composites.

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Selective laser sintering (SLS) is a 3D printing technology that uses a laser to fuse powdered material into a solid structure. The laser automatically targets points in space defined by a 3D model, binding the material together to create a solid structure. SLS is a powder-based technology that uses an even layer of powder, which is then sintered, and the process is repeated until the part is complete. *Subtraction technology:* Subtraction technology involves process such as Computer aided milling (CAM) of solid blocks of materials such as PMMA, PEEK and Zirconia, Metal blocks. 3D printing was utilized in the study by Beretta et al 2022.[38] Milling was utilized in the studies by Harleen Kaur Soni 2016,[27] Ierado et al 2017,[28] Essawy et al 2021,[31] Lee 2021,[32] Rodrigues et al 2022,[36] Aboulazam et al 2022,[37] Abdelshahed et al 2023.[40] SLS was utilized in the studies by Yangdol et al 2023 and Cengiz and Karayilmaz 2024.[42,44] DLP was utilized in the study by Tamburrino et al 2023.[39]

Tooth preparation for 3D space maintainer

Most of the included studies did not mention any tooth preparation for receiving of space maintainer. Few studies mentioned minimal tooth preparation before the intraoral scanning step.[32]

Methods to obtain retention of 3D space maintainers

Methods such as surface roughening using sandblasting air abrasion is employed in few studies to improve the bond strength of the fabricated 3D space maintainer Lee 2021,[32] Aboulazam et al 2022,[37] Abdelshahed et al 2023.[40] Other measures such as etching the enamel surface of abutment tooth is carried out in the studies by Barakat et al 2023,[41] Beretta et al 2022,[38] Lee 2021,[32] Essawy et al 2021.[31] Cementation of metal powder sintered 3D space maintainers was accomplished using glass ionomer luting cement Cengiz and Karayilmaz 2024,[44] Rathi et al 2023,[43] Khanna et al 2021,[33] Pawar 2019.[29] PEEK, Zirconia, PMMA based space maintainers were cemented using composite resin based luting cements such as Transbond Plus, 3M, Rely-X, Multilink R Speed (Ivoclar Vivadent AG), Panavia F 2.0; Kuraray Noritake Dental, Viso-link adhesive system. Harleen Kaur Soni 2016,[27] Essawy et al 2021,[31] Aboulazam et al 2022,[37] Beretta et al 2022,[38] Abdelshahed et al 2023.[40]

In-Vitro studies

In-vitro studies evaluated different parameters related to 3D printed space maintainers. The study by Barakat et al 2023,[41] 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. The study by Tocuk and Yilmaz 2022, [35] 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. The study by Guo et al 2020, [30] evaluated the fit. The spacing between tissue surface of space maintainer and the cast was measured and compared. The authors reported that 3D space maintainers were better as it had less spacing. 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.[39]

Conventional versus 3D Space maintainers Clinical Studies

Only few studies were clinical trials comparing conventional space maintainers with 3D Space maintainers. Most of the studies reported better patient satisfaction ad better survival rate in 3D space maintainers. Aboulazam et al 2022,[37] Essawy et al 2021,[31] Abdelshahed et al 2023.[40] Except the study by Cengiz and Karayilmaz 2024,[44] which reported higher failure rates in 3D space maintainers.

Limitations and Directions for Future Research: Most of the studies reported in the literature are isolated case reports, without a proper follow-up, a well-planned randomized control trial can be planned comparing parameters such as clinical survival between 3D space maintainer and conventional space maintainers in clinical scenarios with a minimum follow up of 24 months.

CONCLUSION

3D printed space maintainers have both advantages and disadvantages and certain limitations. Advantages include ease of fabrication, improved customization, chair side fabrication and delivery, reduced discomfort due to decrease in the number of steps, possibility of customization with various materials disadvantages include increased bulk, and difficulty in tight interproximal contact situations. More Randomized controlled trials are required to evaluate the clinical success rate of 3D space maintainers in comparison to conventional space maintainers.

DECLARATIONS

Ethics approval and consent to participate

Not Applicable

Consent for publication

Not Applicable.

Competing interests

The authors declare no conflict of interest.

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Authors' contributions

Conceptualization ST, LA, GM; methodology SS, GM; software, MMM; validation, MC, GM, MMM; Formal analysis, MMM, ST; Writing—original draft preparation, GM, MMM; Writing—review and editing, GM, MDB, GC; Visualization, GC, MMM; supervision, GM, GC; project administration, MDB. All authors have read and agreed to the published version of the manuscript.

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REFERENCES

1. Petersen PE. The World Oral Health Report 2003: continuous improvement of oral health in the 21st century – the approach of the WHO Global Oral Health Programme. Community Dent Oral Epidemiol. 2003;31(s1):3–24.
2. Lavorgna L, Cervino G, Fiorillo L, et al. Reliability of a Virtual Prosthodontic Project Realized through a 2D and 3D Photographic Acquisition: An Experimental Study on the Accuracy of Different Digital Systems. Int J Environ Res Public Health. 2019;16(24):5139.
3. Rajamanickam K, Teja KV, Ramesh S, Choudhari S, Cernera M, Armogida NG, et al. Evaluation of Root Canal Cleanliness on Using a Novel Irrigation Device with an Ultrasonic Activation Technique: An Ex Vivo Study. Appl Sci 2023;13:796-8.
4. Minervini G, Marrapodi MM, Tirupathi S, Afnan L, Di Blasio M, Cervino G, et al. Comparative anti-plaque and anti-gingivitis efficiency of Triphala versus chlorhexidine mouthwashes in children: a systematic review and meta-analysis. J Clin Pediatr Dent. 2024;48(5):51–9.
5. Tirupathi SP, Afnan L. Effectiveness of 'video-based interventions' of toothbrushing over other interventions on improvement of oral hygiene in children with Autism Spectrum Disorders (ASD): a systematic review and meta-analysis. Evid Based Dent. 2025;431-6.
6. B PK, N RK. Loss of space and changes in the dental arch after premature loss of the lower primary molar: A longitudinal study. J Indian Soc Pedod Prev Dent. 2006;24(2):90.
7. Rathi N, Tirupathi S, Sawarkar S. Three-dimensional Printed Esthetic Innovative Space Maintainer for Children with ADHD: Short Communication. Int J Clin Pediatr Dent. 2023;16(6):908–10.
8. Di Stasio D, Lauritano D, Minervini G, et al. Management of denture stomatitis: a narrative review. J Biol Regul Homeost Agents. 2018;32(2 Suppl. 1):113-6.
9. Del Giudice C, Rengo C, Maglitto M, Armogida NG, Iaculli F, Rengo S, et al. Cytotoxicity effects and differentiation potential of ormocer-based and nanohybrid composite resins on human dental pulp stem cells. Dental Materials 2024;40:984–92.
10. Khanna S, Rao Di, Panwar S, Pawar BA, Ameen S. 3D Printed Band and Loop Space Maintainer: A Digital Game Changer in Preventive Orthodontics. J Clin Pediatr Dent. 2021;45(3):147–51.
11. Fereño-Cáceres A, Vélez-Astudillo R, Bravo-Torres W, Astudillo-Rubio D, Alvarado-Cordero J. Primary stability with osseodensification drilling of dental implants in the posterior maxilla region in humans: A systematic review. Dent Med Probl. 2024;61(4):605–12.
12. Suresh B, Jeevanandan G, Ravindran V. Assessment of Knowledge and Utilization of Prefabricated Band and Loop Space Maintainers in Primary Dentition Among Dentists: A Cross-Sectional Questionnaire Study. Cureus. 2024;324-7
13. Contaldo M, della Vella F, Raimondo E, et al. Early Childhood Oral Health Impact Scale (ECOHIS): Literature review and Italian validation.

Int J Dent Hyg. 2020;18(4):396-402.
14. Inchingolo AD, Patano A, Coloccia G, Ceci S, Inchingolo AM, Marinelli G, et al. Treatment of Class III Malocclusion and Anterior Crossbite with Aligners: A Case Report. Medicina (Kaunas). 2022;58(5).
15. Inchingolo F, Tatullo M, Marrelli M, Inchingolo AM, Tarullo A, Inchingolo AD, et al. Combined occlusal and pharmacological therapy in the treatment of temporo-mandibular disorders. Eur Rev Med Pharmacol Sci. 2011;15(11):1296–300.
16. Afritha NA, Sharanya, Moses J. 3-D Printed space maintainers - A review. Int J Pedod Rehabil.2022;7(2):19–24.
17. Nery JC, Manarte-Monteiro P, Aragão L, da Silva LP, Brandão GSP, Lemos BF. Clinical Effects of Interproximal Contact Loss between Teeth and Implant-Supported Prostheses: Systematic Review and Meta-Analysis. Prosthesis. 2024;6(4):825–40.
18. Alshahrani FA, AlGhamdi M, Alghamdi D, Alshammary H, Akhtar S, Khan SQ, et al. Nanocomposite Provisional Resin: Effect of Nanoparticles Addition on the Physical Properties and Antimicrobial Activities In Vitro. Prosthesis. 2024;6(4):952–69.
19. Scribante A, Gallo S, Pascadopoli M. Oral Implantology: Current Aspects and Future Perspectives. Prosthesis. 2024;6(1):89–92.
20. Zarean P, Zarean P, Sendi P, Neuhaus KW. Advances in the Manufacturing Process of Space Maintainers in Pediatric Dentistry: A Systematic Review from Traditional Methods to 3D-Printing. 2023;13, Appl Sci (Switzerland). MDPI
21. Germano F, Bramanti E, Arcuri C, Cecchetti F, Cicciù M. Atomic force microscopy of bacteria from periodontal subgingival biofilm: Preliminary study results. Eur J Dent. 2013;07(02):152-158.
22. Bramanti E, Matacena G, Cecchetti F, Arcuri C, Cicciù M. Oral health-related quality of life in partially edentulous patients before and after implant therapy: a 2-year longitudinal study. Oral Implantol (Rome). 2013;6(2):37-42.
23. Mehta D, Sarfaraz H, lampl S, Gurunathan D, Singh MV. Comparative Analysis of Marginal Fit and Fracture Resistance in CAD-CAM Lithium Disilicate and Pre-processed Composite Endocrowns: An In Vitro Study. J Contemp Dent Pract. 2024; 26;25(8):732–9.
24. Yangdol P, Kalra N, Tyagi R, Khatri A, Sabherwal P, Goyal T. Three-dimensional printing technology: Patient-friendly and time-saving approach for space management in an autistic child in covid-19 times. Int J Clin Pediatr Dent. 2023;16(S3):321–6.
25. Lo Russo L, Guida L, Mariani P, Ronsivalle V, Gallo C, Cicciù M, et al. Effect of Fabrication Technology on the Accuracy of Surgical Guides for Dental-Implant Surgery. Bioengineering. 2023;10(7):875.
26. Leonardi R, Ronsivalle V, Barbato E, Lagravère M, Flores-Mir C, Lo Giudice A. External root resorption (ERR) and rapid maxillary expansion (RME) at post-retention stage: a comparison between tooth-borne and bone-borne RME. Prog Orthod. 2022;23(1):45.
27. Soni HK. Application of CAD-CAM for Fabrication of Metal-Free Band and Loop Space Maintainer. J Clin Diagn Res. 2017;11(2):14-16.
28. Ierardo G, Luzzi V, Lesti M, Vozza I, Brugnoletti O, Polimeni A, et al. Peek polymer in orthodontics: A pilot study on children. J Clin Exp Dent. 2017;e1271–5.
29. Pawar B. Maintenance of space by innovative three-dimensional-printed band and loop space maintainer. J Indian Soc Pedod Prev Dent. 2019;37(2):205.
30. Guo H, Wang Y, Zhao Y, Liu H. Computer-aided design of polyetheretherketone for application to removable pediatric space maintainers. BMC Oral Health. 2020;20(1):201.
31. Essawy kareem, Gomaa Y, Ali Khattab N. Clinical Performance of CAD /CAM Fixed Functional Space
Maintainer Made of Poly Ether Ether Ketone (PEEK). Minia J Med Res. 2021;32(4):7–12.
32. Lee J. Fully digital workflow for the fabrication of a tooth-colored space maintainer for a young patient. Journal of Esthetic and Restorative Dentistry. 2023;35(4):561–6.
33. Khanna S, Rao D, Panwar S, Pawar BA, Ameen S. 3D Printed Band and Loop Space Maintainer: A Digital Game Changer in Preventive Orthodontics. J Clin Pediatric Dent. 2021;45(3):147–51.
34. Gupta G, Gupta DK, Gupta P, Rana KS, Shah P, Sankhla D. Digital impression and CAD/CAM system applications in pediatric dentistry: Case series. IP Indian Journal of Conservative and Endodontics. 2023;7(4):197–201.
35. Tokuc M, Yilmaz H. Comparison of fit accuracy between conventional and CAD/CAM-fabricated

band–loop space maintainers. Int J Paediatr Dent. 2022;32(5):764–71.

36. Rodrigues LP, Dourado PHN, de Araújo CAR, No-Cortes J, Pinhata-Baptista OH. Digital workflow to produce esthetic space maintainers for growing patients. J Prosthet Dent. 2022;341-345

37. AboulAzm N, Sharaf A, Dowidar K, AbdelHakim A. Effectiveness of CAD/CAM Peek Fabricated Space Maintainer in Children: A Randomized Controlled Clinical Trial. Alexandria Dent J.2023;48(2):203–10.

38. Beretta M, Federici Canova F, Gianolio A, Zaffarano L. Fully digital fixed orthodontic prosthesis: use of PEEK technopolymer in cases of early loss of primary incisors. Eur J Paediatr Dent. 2022;23(1):51–3.

39. Tamburrino F, Chiocca A, Aruanno B, Paoli A, Lardani L, Carli E, et al. A Novel Digitized Method for the Design and Additive Manufacturing of Orthodontic Space Maintainers. Appl Sci. 2023;13(14):8320.

40. Peter Samir Abdelshahed, Ibrahim Hassan Ellkalla, Hossam Elsherbiny Hammouda. Clinical Evaluation of Band and loop Versus PEEK Space Maintainers. Int J Dent Med Sci Res 2023;5(4):390–5.

41. Farah Ahmed Barakat, Islam Tarek Hassan, Gehan Gaber Allam. Evaluation of Bond Strength Of 3D Printed Space Maintainer and Conventional Band and Loop Space Maintainer: An In Vitro Study. IOSR J Dent Med Sci. 2023;22(7):04–7.

42. Tyagi R, Khatri A, Sabherwal P, Goyal T, Yangdol P, Kalra N. Three-dimensional Printing Technology:Patient-friendly and Time-saving Approach for Space Management in an Autistic Child in COVID-19 Times. Int J Clin Pediatr Dent. 2024 Jan 11;16(S3):321–326.

43. Tirupathi S, Rathi N, Sawarkar S. Three-dimensional Printed Esthetic Innovative Space Maintainer for Children with ADHD: Short Communication. Int J Clin Pediatr Dent. 2024;16(6):908–10.

44. Cengiz A, Karayilmaz H. Comparative evaluation of the clinical success of 3D-printed space maintainers and band–loop space maintainers. Int J Paediatr Dent. 2024;34(5):584-592.

Sunnypriyatham Tirupathi, Lamea Afnan, Sejal Shah, et al. 3D space maintainers in pediatric dentistry:Scope review. Bulletin of Stomatology and Maxillofacial Surgery. 2025;21(3). 141-152. doi:10.58240/1829006X-2025.3-141