

Comparative evaluation of efficacy and efficiency of 3D Printed Space Maintainers with that of Conventional Band n Loop and Fibre-reinforced (Ribbond) Space Maintainers- An in vivo study

Abstract:

Background: Traditional space maintainers, like band and loop, face issues such as short lifespan and gum health concerns. Fibre-reinforced space maintainers offer benefits like improved aesthetics and comfort but are time consuming and have less longevity. 3D printing technology offers potential for more customized, effective space maintainers with biodegradable materials.

Aim: To compare and evaluate the efficacy and efficiency of 3D Printed space maintainers with that of conventional band n loop space maintainers and fibre-reinforced (ribbond) space maintainers.

Materials and Methodology: 30 children, according to pre-determined inclusion and exclusion criteria, who required space maintainers were included in the study and were equally divided into 3 groups. Group-1- conventional band n loop space maintainers, group-2- Fibre-reinforced (ribbond) space maintainers, group-3- 3D Printed space maintainers. The longevity of the appliance was evaluated by determining the retention, breakage and dislodgement of the appliance. Plaque accumulation was determined by using Silness and Loe index. Chairside time was evaluated using a digital stopwatch.

Results: Based on the longevity, the highest retention 70% and least breakage 0% with only 30% dislodgement cases, was reported in the 3D printed space maintainers (Group 3). The least plaque accumulation was reported in the 3D printed space maintainers. The least mean chair side time was seen in the 3D printed space maintainers 7.50 ± 2.17 .

Conclusion: 3D Printed Space Maintainers were found to be child-friendly and thus, more acceptable.

Key-words: space maintainers, 3D Printing, Intra-oral scanner, 3D Printed space maintainer, CAD-CAM.

Introduction:

The premature loss of primary teeth can significantly disrupt the development of a child's permanent teeth.[1] Primary teeth play a crucial role in guiding the eruption of permanent teeth into their proper positions within the jaw, effectively acting as placeholders. If these teeth are lost early, whether due to extraction, injury, or decay, it can interfere with the eruption of the permanent teeth, potentially leading to alignment issues and other dental complications. One of the major consequences of early tooth loss is dental crowding. This occurs when there isn't enough space for the permanent teeth to erupt properly, often causing them to overlap or become misaligned. Such malocclusion can impact both the aesthetics and function of the bite. In more severe cases, the teeth may

rotate, tilt, or drift, and permanent teeth may even become impacted. These issues can lead to more complicated treatments later on, such as braces or extractions, to correct the misalignment.[2]

In orthodontics, both preventive and interceptive approaches are vital to preserving the alignment and occlusion of

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permanent teeth after the early loss of primary teeth. A key element in managing this process is the use of space maintainers. These devices are specifically designed to keep the necessary space open for the permanent teeth to erupt properly, preventing shifts in the bite and the development of harmful parafunctional habits. Space maintainers can also have psychological benefits for children, as they help maintain the function and appearance of their teeth, minimizing distress caused by early tooth loss. Additionally, space maintainers prevent any alterations in the dental arch length, contributing to better long-term dental health.[3]

In pediatric dentistry, there are different types of space maintainers available. Fixed space maintainers, such as the band and loop, crown and loop, lingual arch, and distal shoe, are cemented to adjacent teeth to ensure stability and maintain space until the permanent tooth erupts.[4] On the other hand, removable space maintainers like partial dentures, flippers, and Hawley appliances offer greater convenience and require less maintenance. For example, flippers are removable acrylic prosthetics primarily used for cosmetic purposes, while partial dentures are supported by surrounding teeth and contain artificial teeth. Hawley appliances, which feature adjustable clasps and a palatal wire, help maintain space and facilitate the eruption of permanent teeth. The choice of space maintainer depends on the child's specific needs and the dentist's professional judgment.[5-7]

Traditional space maintainers, particularly the band and loop variety, have some drawbacks that have prompted research into alternatives. Studies comparing conventional band and loop space maintainers (BLSMs) with other designs have revealed that conventional Band n Loop maintainers tend to have a shorter lifespan and a higher failure rate, mainly due to issues with documentation.[8] These traditional devices can also negatively affect gum health, require laboratory fabrication, and are often uncomfortable or aesthetically unappealing. Furthermore, they do not prevent adjacent teeth from tilting or rotating, and they are prone to cement loss and dislodgement.[9] These shortcomings have led to the exploration of alternative materials, like fiber-reinforced (ribbond) material, which offer improved aesthetics, better patient acceptability, and easier fabrication.[10]

The main issues with conventional Band n Loop Space Maintainers, such as wire bending and cement loss, are also present with fibre-reinforced space maintainers (ribbond), but these alternatives show promise due to their enhanced comfort and overall design.[11] Unfortunately, conventional Band n Loop Space Maintainers can also cause discomfort, including pain, mucosal overgrowth, ulceration, and gingival

hypertrophy, often due to the plaque retention around the band.[12] Thus, ongoing innovation is necessary to address these limitations and improve the effectiveness of space maintainers in pediatric dentistry.

The rise of 3D printing technology has revolutionized the field of dentistry, allowing for the creation of highly customized, three-dimensional objects from digital models. This technology enables the precise fabrication of space maintainers, improving both comfort and performance while enhancing patient compliance.[13-14] With 3D printing, complex designs can be created efficiently, and the use of new materials, including biodegradable and biocompatible options, shows promise. These materials could potentially break down once the permanent teeth have erupted, offering a more sustainable solution.[15]

Researchers, such as Pawar[16] and Khanna et al.[17], have provided strong evidence of the effectiveness of 3D-printed space maintainers. However, to date, clinical trials have yet to confirm the long-term benefits of these devices. Based on the current understanding and potential advantages of 3D printing, this study was designed to evaluate and compare the efficacy and effectiveness of 3D printed space maintainers with that of conventional band n loop space maintainers and fibre-reinforced (ribbond) space maintainers.

Materials and Methodology:

The study was approved by the Research and Ethical Committee of the D.J college of dental sciences and research, Modinagar (DJC/IEC/46/2024). Written informed consent was obtained from the parents of all participants after complete research procedures were explained. No vulnerable populations were involved. This randomized controlled investigation adopted the Consolidated Standards of Reporting Trials (CONSORT) standards to guarantee clear and comprehensive reporting. Clinical cases done in this study were performed after intraoral and radiographic examination, children who had lost their first or second primary molar teeth early due to various reasons, with the need for space maintainers were selected. 30 children of age group 6 to 9 years old were included in this study and were equally divided into 3 groups based on the inclusion and exclusion criteria. Not a single patient failed to follow-up.

Inclusion Criteria:

1. Abutment tooth showing no signs of root resorption.
2. Presence of a succedaneous (permanent) tooth.
3. Presence of a bony crypt covering the succedaneous tooth germ.

4. Absence of any pathological conditions.
5. Patient exhibits a normal occlusion.

Exclusion Criteria:

1. Presence of root resorption in the abutment tooth.
2. Absence of a succedaneous (permanent) tooth.
3. Lack of a bony crypt over the succedaneous tooth germ.
4. Presence of pathological conditions.
5. Abnormal occlusal relationships.

Sample size estimation:

Based on the 90% power of the study and 5% type I error and effect size of 0.75 (large effect size), SD=1, the minimum sample size came out to 30 samples which can be divided into groups and subgroups.

Group-1- conventional band n loop space maintainers:

In Group-1, conventional band n loop space maintainers were given. After intra-oral examination, pre-operative radiograph was taken. Any caries in the adjacent tooth was evaluated and treated. Fabrication of a band in the adjacent tooth was done and alginate impressions were taken for the fabrication of the appliances. The patients were recalled for the next visit and the appliance was delivered and evaluated at 6 months interval. Oral hygiene instructions were given to the patients and their parents. (Fig-1)

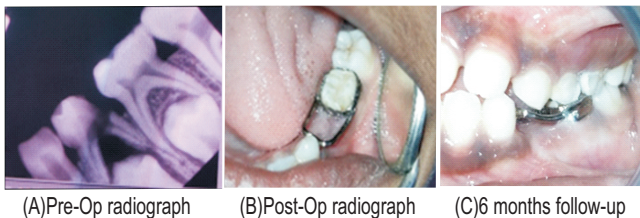


Fig-1- Group-1- Conventional Band n Loop space maintainer

Group-2- Fibre-reinforced (Ribbond) space maintainers:

In Group-2, Ribbond space maintainers were given. After pre-operative radiographic evaluation, the space to be maintained was measured intraorally, and two strips of non-impregnated Ribbond®-THM bondable reinforcement ribbon were cut to the appropriate length. The surfaces of the prepared teeth were first cleaned with pumice, then etched using Ultra-etch® 35% phosphoric acid gel. After rinsing and lightly drying, PQ1® bonding agent was applied twice, followed by light drying and curing. A thin layer of Permaflo® flowable composite was then applied to the buccal surfaces of the adjacent teeth. The wetted Ribbond® ribbon was carefully

positioned using a rounded instrument to ensure tight contact during the curing process. This procedure was repeated on the lingual side. Additional flowable composite was applied to cover the exposed ribbons, and the entire structure was light-cured for 40 seconds. Once, the curing process was complete, final finishing and polishing were carried out. Occlusion was checked, and any excess composite was removed. Oral hygiene instructions were provided to the children and their parents, emphasizing the importance of reporting any loosening or dislodging of the appliance. Follow-up appointments were scheduled, with the children being recalled for examinations at 6months. (Fig-2)

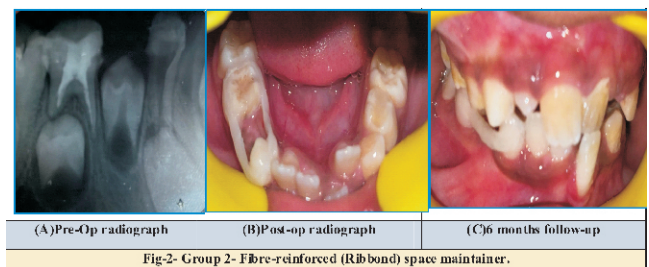


Fig-2- Group 2- Fibre-reinforced (Ribbond) space maintainer.

Group-3- 3D Printed space maintainers :

In Group-3, 3D Printed space maintainers were given. After obtaining pre-operative radiograph, the digital impression was made with the help of an intra-oral scanner (Fig-3). The scanned file was saved in standard tessellation language (STL) format and were sent to the laboratory. The scanned file was used to make a 3D model (Fig-4) and with the help of CAD-CAM, the appliance was designed and generated using a 3D printer by stereolithography technique. In the next appointment the appliance was delivered (Fig-5) and the parents and children were instructed to maintain the oral hygiene. 6 months follow up was done for all the patients (Fig-6).



Fig-3- Recording digital impression with the help of intra-oral scanner



Fig-4- 3D model

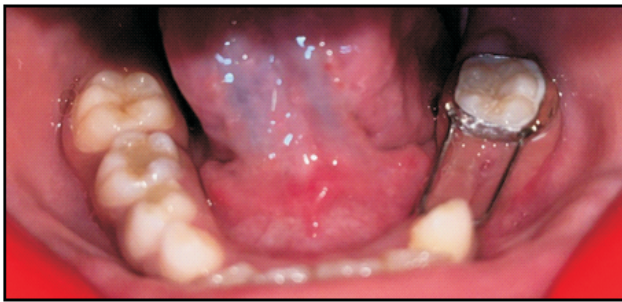


Fig-5- 3D Printed space maintainer



Fig-6- 6 months follow-up of 3D Printed space maintainer.

For all the groups, the following criteria were used to assess the efficacy and efficiency of all the space maintainers.

1. Longevity of the appliance by evaluating dislodgements, breakage and retention of the space maintainers
2. Plaque accumulation by using Silness-Loe plaque index.[18]
3. Chair-side time for impression making and fabrication of the appliance using digital stopwatch.

Statistical Analysis

The data for the current study was entered into Microsoft Excel 2007 and analysed using SPSS statistical software 23.0 Version. The descriptive statistics such as frequency, percentage mean and standard deviation were used. The significance level of 5% was established for the current study.

The intergroup comparison of the ordinal variable like score of plaque and longevity analysis was done compared using Chi Square test. The intragroup comparison of continuous variables was done using the One-Way ANOVA test followed by post hoc analysis.

Groups	Retentive Appliance	Dislodged Appliance	Broken Appliance	Group 1- Group 2	Group 1- Group 3	Group 2 -Group 3
Conventional band n loop (Group 1)	4	3	3	0.768 (Non-Sig)	0.045 (Sig)	0.012 (Sig)
	40.0%	30.0%	30.0%			
Ribbond space maintainer (Group 2)	4	1	5			
	40.0%	10.0%	50.0%			
3D printed space maintainers (Group 3)	7	3	0			
	70.0%	30.0%	0%			

Table-1-intergroup Compariosn of Longevity Between The Group

Groups	Score 0	Score 1	Score 2	Group 1- Group 2	Group 1- Group 3	Group 2 -Group 3
Conventional band n loop (Group-1)	0	5	5	0.951 (Non-Sig)	0.013 (Sig)	0.024 (Sig)
	10.0%	50.0%	50.0%			
Ribbond space maintainer (Group-2)	1	4	5			
	10.0%	40.0%	50.0%			
3D printed space maintainers (Group-3)	2	8	0			
	20.0%	80.0%	0.0%			

Table-2- Intergroup Compariosn of Plaque Scores Between The Groups

	Mean	Std. Deviation	Std. Error	Group 1- Group 2	Group 1- Group 3	Group 2 -Group 3
Conventional band n loop	27.60	3.777	1.194	0.001 (Sig)	0.001 (Sig)	0.001 (Sig)
Ribbond space maintainer	44.30	5.396	1.706			
3D printed space maintainers	7.50	2.173	0.687			

Table-3- Intergroup Compariosn Of Chairside Time Between The Groups

Results:

In terms of longevity, the 3D printed space maintainers (Group 3) demonstrated the highest retention rate at 70%, along with no recorded instances of breakage. Fibre-reinforced (Ribbond) space maintainers (Group 2) showed the lowest rate of dislodgement at 10%, though they experienced the highest rate of breakage at 50%. Retention levels were similar between the conventional space maintainers (Group 1) and the Ribbond group. Statistically, the performance of the 3D printed maintainers was significantly different from the other two groups, whereas no significant difference was found between Groups 1 and 2 based on the Chi-square test. (Table-1)

The highest plaque scores were reported in the Conventional and Ribbond space maintainers and least plaque accumulation was reported in the 3D printed space maintainers. The difference of 3D printed space maintainers with other two groups were statistically significant but the difference between Group 1 and Group 2 was statistically non-significant (Chi Square test). (Table-2)

The mean chair side time in the Conventional band n loop space maintainers was 27.60±3.77 in the Ribbond space maintainer was 44.30±5.39 and least in the 3D printed space maintainers 7.50±2.17. The difference between all three groups was statistically significant when analyzed using One way ANOVA followed by post hoc analysis. (Table-3)

Discussion:

This study significantly appreciates highest longevity in the 3D printed space maintainers (Group 3) as compared to both conventional band n loop space maintainers (Group-2) and fibre-reinforced (ribbond) space maintainers (Group-3) due to the fact that it is a single unit appliance with no solder joint and hence it does not break. Bhaggyashri A. Pawar^[16] (2019) and Vivek Rana et al¹⁹ (2022), in their case reports, discussed that 3D printed space maintainers are quick and precise. Whereas conventional band n loop breaks at the solder joint and often dislodge and fibre-reinforced space maintainers offer weak strength and breaks or dislodges easily. It tends to de-cement often leading to failure.^[20]

In terms of plaque scores, 3D printed space maintainers (Group 3) showed statistically least plaque accumulation as compared to both conventional band n loop space maintainers (Group-2) and fibre-reinforced (ribbond) space maintainers (Group-3) as 3D printed space maintainers are made digitally with precision, which leads to no spaces for plaque accumulation in the appliance and moreover no solder joint is present leading to less plaque accumulation in that area. This is in accordance with the case reports done by Suhani Khanna et al (2021)¹⁷ and Naman Pahuja et al (2023)²¹, as they concluded that less plaque accumulation is noted in patients with 3D Printed space maintainers. Whereas conventional band n loop space maintainers, due to ill-fittings and a solder joint, accumulates plaque and also fibre-reinforced (ribbond) space maintainers leads to adherence of plaque at their unfinished composite-ribbond interface.^[20]

Chair side time was found to be statistically least with 3D printed space maintainers (Group 3) as compared to both Conventional band n loop space maintainers (Group-2) and Fibre-reinforced (ribbond) space maintainers (Group-3) as the impression is made digitally with the help of digital scanner which hardly takes 5 mins to scan the area and requires less cooperation from the child patient. It is in accordance with the review of literature done by Afritha and Moses in 2022²². Whereas for conventional band n loop space maintainers, impressions are made with alginate or putty and requires lot of patient's co-operation and takes time and fibre-reinforced space maintainers is made at the chair side and thus requires lot of patient's co-operation and is also a technique sensitive procedure requiring lot of time.

Conclusion:

3D-printed space maintainers proved to be more effective and efficient than both conventional band-and-loop and Ribbond space maintainers. Their child-friendly design contributes to improved treatment outcomes and higher levels of patient satisfaction in pediatric dentistry.

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