Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Digital Versus Conventional Nance-Based Space Maintainers for Preservation of Maxillary Arch Dimensions in Children: A Randomized Controlled Clinical Trial

Nehal Salman
Pharos University in Alexandria
Hani AlSwafeeri
hani.alswafiri@pua.edu.eg

Pharos University in Alexandria

Research Article

Keywords: Space Analysis, Space Management, Preventive Orthodontics, Digital Analysis, 3D printed appliances

Posted Date: November 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11446420/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Digital Versus Conventional Nance-Based Space Maintainers for Preservation of Maxillary Arch Dimensions in Children: A Randomized Controlled Clinical Trial

Nehal Raid Salman[1], Hani AlSwafeeri[2*]

[1] Lecturer of Pediatric Dentistry, Department of Pediatric Dentistry, Faculty of Dentistry, Pharos University in Alexandria, Alexandria, Egypt.

[2] Lecturer of Orthodontics, Department of Orthodontics, Faculty of Dentistry, Pharos University in Alexandria, Alexandria, Egypt.

*Corresponding author name and email address: Hani AlSwafeeri - hani.alswafiri@pua.edu.eg

Abstract

Background: Early extraction of deciduous molars can conduct to space loss and mesial rotation of the maxillary first permanent molars. Though Digital workflows and 3D-printed appliances were introduced in an attempt to enhance the precision of space maintainers (SM), but the combined Nance-transpalatal arch (Nance-TPA) design has rarely been studied. This study compared digitally fabricated and conventional Nance and Nance-TPA SMs in preserving maxillary dental arch dimensions after bilateral early loss of primary molars.

Methods: This single-blinded, parallel-group randomized controlled trial followed the CONSORT statement. A total of 128 healthy children aged 8 to 9 years with bilateral prematurely extracted maxillary primary molars were randomly allocated 1:1:1:1 (n = 32 per group) to digital Nance, digital Nance-TPA, conventional Nance, or conventional Nance-TPA. Digital appliances were designed from intraoral scans and fabricated from cobalt-chromium by direct metal laser sintering. Digital arch scans were recruited at baseline and at 3, 6, and 12 months. Arch perimeter, palatal vault depth, maxillary and anterior segment width and length, and molar rotation were measured using 3D Slicer Software. Findings were assayed using a three-factor mixed repeated-measures ANOVA with Bonferroni-adjusted comparisons ($p < 0.05$).

Results: Eight patients were lost to follow-up (attrition 6.25%), mainly due to appliance breakage, and 120 patients (30 per group) were analyzed. All measured parameters changed significantly over time ($p < 0.001$). Digital fabrication was allied with a significantly greater arch perimeter at 3, 6, and 12 months ($p = 0.029$, $p = 0.001$, and $p<0.001$, respectively), whilst conventional appliances showed greater palatal vault depth ($p < 0.001$). Digital groups differed significantly from conventional groups in maxillary width from 3 months onward. The digital Nance-TPA group showed the least molar rotation and the most stable anterior segment width. The conventional Nance-TPA group showed the most stable arch perimeter and maxillary width. No single appliance-fabrication combination was superior across all dimensions.

Conclusions: Digital and conventional Nance-based appliances both showed measurable changes in arch dimensions over 12 months, and the effect of fabrication method and appliance design depended on the parameter measured. Digital fabrication was favorable for arch perimeter and palatal vault depth, and adding a TPA helped limit molar rotation and preserve few arch dimensions. Appliance selection should therefore be individualized to the arch dimension of greatest clinical concern.

This randomized controlled clinical trial was registered with the ClinicalTrials.gov Protocol Registration and Results System (PRS) under registration number NCT07179146.

Keywords: Space Analysis, Space Management, Preventive Orthodontics, Digital Analysis, 3D printed appliances.

1. Background

A critical problem in oral health is dental caries. This often leads to premature tooth loss or extraction of the decayed teeth(1). Early tooth loss interprets to space loss and disruption to the normal eruption process of permanent dentition thus causing arch length variation and malocclusion(2). To prevent consequences of space deficiency of premature extraction of deciduous teeth, space maintainers (SM) are required to prevent against midline shift, over-eruption, crowding, ectopic eruption and impaction(3). In accord with the American Academy of Pediatric Dentistry (AAPD), for the avoidance of space deficiency, maintaining the space is vital in order to prevent deficit of arch parameters(4). Space maintenance was first defined by JC Brauer as the space being preserved after extraction of primary teeth(5). Furthermore, these are dental appliances inserted in the oral cavity to give room for the successor's teeth(6). Space maintainers can be divided into; fixed or removable, unilateral or bilateral, and functional or non-functional. Conventional SMs also present with restraints as it necessitates multiple visits for the patient(7). Impression taking process might be challenging for uncooperative patients and those having a gag reflex. The precise band placement before cast pouring is one of the drawbacks of the conventional impression process(8). In 1980, digital workflow was being fostered and been used since then. The usage of CAD-CAM innovation in pediatric dentistry and orthodontics has shown enormous attainment in recent years. Benefits are compliance and patient acceptance of treatments(9). Digital SMs is a term that uses 3D printing invention with new and biologically compatible substances(10). Other forms of 3D printing are layered construction, solid freeform manufacturing and additive industry(11). The idea of this innovation is the use of a 3D item designed by a layer-by-layer design for any appliance or restoration(12). Pawar was the one who took the first leed to construct digital 3D printing SMs(10).

A space maintainer is utilized to preserve the space formed by the extraction of primary tooth/teeth till the successor eruption. Depending on the number of teeth missing, the jaw involved, dental age, and the child's compliance, many types of appliances can be utilized to maintain the space(13). The most commonly used SMs in the maxillary arch are the Nance and transpalatal arch or bar (TPA) appliances(14).

Nance SM is indicated for both unilateral and two-sided extraction of upper deciduous molars. The appliance maintains space by receiving anchorage from the palatal vault, which resists mesial migration of the banded (first permanent molar) FPMs, and hence is better suited for patients with a deeper palatal vault(15).

However, a limitation of the Nance appliance is that in order to perform its function correctly, it must be constructed so that it touches the palatal mucosa. Additionally, excessive anchoring stresses on the appliance may cause it to become embedded in the palatal mucosa, making it unsanitary and difficult to remove(16). To avoid this drawback, the acrylic button could be constructed with a minimal space from the palatal mucosa. As a result, no matter how small the gap is, it can allow for some space loss to occur(17).

Furthermore, despite its ability to oppose mesial migration of the banded molars, the Nance appliance lacks a design element that prevents the FPM from rotating around their palatal roots(18).

The TPA resists mesial migration of maxillary FPMs barely in subjects of unilateral early extraction of primary molars. By delivering the FPMs' roots in connection with cortical bone, the TPA mainly prevents them from rotating around the palatal root. However, when the appliance is used in cases with bilateral premature extraction, mesial migration and rotation of the FPMs could occur(19, 20).

Both the Nance and the TPA appliances have therefore few limitations regarding their design. To overcome these limitations and to benefit from both their advantages, the merged Nance/Transpalatal arch (N-TPA) appliance has previously been introduced as an anchorage device by orthodontists during orthodontic treatment of Class II malocclusion patients. They concluded that this combined design was an effective method of anchorage during distalization of the anterior segment(21, 22). Nevertheless, this appliance has not been frequently tested as a SM in the mixed dentition of pediatric patients. Therefore, this study aims to assess the use of N-TPA appliance as a SM in children with mixed dentition, and to evaluate its effectiveness compared to the conventional Nance SM in maintaining the arch dimensions after bilateral premature extraction of primary molars.

In general, dental measurements are of great importance in dentistry and in particular deliberation in orthodontic planning and suitable treatment. Digital diagnostic aids are beneficial in the visualization of teeth site and form in the both dental arches, aside from offering a 3D patient occlusion copy(23). One of the fastest and most accurate modern approaches in orthodontics involves using specialized software to measure dental arch parameters digitally from scanned dental casts (24-26). The new digital approach in dental field is acceptable and exciting for patients as it is collaborated with less irritation due to their accuracy.

Angle sketched the upper first molars as the pivot of the occlusion, accentuating their continual orientation in an ordinary spot and their anatomic arrangement enclosed by the upper arch comparative to the cranial base(27). Later, Andrews acquainted his categorization system, ‘‘The Six Keys to Normal Occlusion’’, spotlighting the significance of these molar, involving their rotational adjustment in establishing optimum occlusal relationships(28).

Accurate positioning and derotation of the maxillary first molars play a crucial role in reducing anteroposterior interarch discrepancies and achieving optimal orthodontic treatment outcomes (29, 30). One of the most orthodontic abnormalities is the maxillary transverse skeletal deficiency (MTSD) fundamentally jeopardizing the unity of the dentoalveolar structures and hindering proper facial development. Rotational malposition of the permanent maxillary first molars (PMMRs) is another common finding in orthodontic patients, often associated with the premature loss of deciduous second molars or proximal caries, and may be influenced by tooth-size and arch-length discrepancies (31). Therefore, evaluation of PMMRs is fundamental for precise orthodontic diagnosis and treatment anticipation.

The aim of the current research is to evaluate the effect of the digital versus conventional Nance appliance and combined Nance/transpalatal arch (N-TPA) appliance in maintaining the arch dimensions

after premature extraction of maxillary primary molars regarding interpremolar width, intermolar width, first permanent molar rotation, and arch depth. The null hypothesis of the study is that there is no difference in maintaining the arch dimensions between the 3D printed and conventional Nance and combined Nance/transpalatal arch appliances.

2. Materials and Methods

2.1 Study design and sample size calculation

The present study was a single blinded, randomized parallel controlled clinical trial, executed based on the Consolidated Standards of R eporting Trials (CONSORT) statement. Sample size estimation was implemented at a 95% confidence level (alpha = 0.05) with 80% statistical power. In light of the data of Martín-Vacas et al.(32), the mean space loss was 1.336±1.817 mm for the TPA group and 0.695±1.377 mm for the Nance appliance group, with a mean difference of 0.64 mm [95% CI: −0.38 to 1.66]. Based on these estimates, the required calculated sample size was estimated to be 28 cases per group. This number was increased to 30 cases per group to compensate for possible dropouts. Accordingly, the overall sample size was tallied as follows: total sample size = sample size per group × number of groups = 30 × 4 = 120 cases. The sample size was founded on Rosner's method(33) and was reckoned using MedCalc Statistical Software version 22.017 (MedCalc Software bvba, Ostend, Belgium; https://www.medcalc.org; 2022).(34)

2.2 Inclusion and exclusion criteria

Inclusion criteria

The study incorporated cooperative, healthy children aged 8 to 9 years who were classified as ASA I (American Society of Anesthesiologists) with no systemic disease or special health care needs. Only children exhibiting positive behavior, corresponding to scores of 3 or 4 on the Frankl Behavior Rating Scale, were enrolled. All participants had bilateral, prematurely extracted maxillary primary molars, with the extraction having occurred within a period not exceeding one month prior to enrollment. Eligible children presented with absolute erupted maxillary permanent first molars and Angle's Class I molar occlusion. Additionally, all participants demonstrated adequate space for premolar eruption, as confirmed by Moyers' mixed dentition arch length analysis. Hand written informed consent was penned from the caregivers or legal guardians of all participants former to inclusion in the study.

Exclusion criteria

Children were excluded if their maxillary first permanent molars were badly destroyed or non-restorable, as evidenced by abnormal tooth mobility, gingival swelling, fistulous tract formation, or non-vital pulps. Radiographic signs of pathology, including a thickened or interrupted periodontal ligament space, internal root resorption, or periapical or furcal radiolucency, were also grounds for exclusion. Additional exclusion criteria included inherent missing permanent successors, successors

not yet coated by bone, and successors exhibiting two-thirds or more of root formation. Children with a history of allergy to metals or dental materials, those with intellectual, severe emotional, or behavioral problems, and those presenting with parafunctional habits such as clenching or bruxism were also excluded from the study.

2.3 Oral hygiene instructions

Before the beginning of the study, the participating children and their parents received aacomprehensive oral hygiene instruction demonstration using a displayed video and on a study model(35). Parents were educated on the signs of plaque buildup and gum inflammation, if present.

2.4 Randomization, allocation concealment and blinding

This randomized, parallel-group controlled trial employed a 1:1:1:1 allocation ratio across four study arms. An automated block randomization series (block size = 4) was arranged by an independent clinician blinded to treatment allocation. Group assignments were recorded on identical slips, sealed in opaque, name-labeled envelopes, shuffled, and stored in a container to ensure allocation concealment. Envelope storage and opening were managed by personnel independent of the trial team. At the intervention visit, the parent selected an envelope, which was opened by the assistant nurse to reveal the assigned appliance. Due to the constitution of the intervention, the treating clinician could not be blinded; however, participants, and the statistician remained blinded to group allocation throughout data collection and analysis, classifying this as a single-blinded trial.

2.5 Grouping

The present study included 128 children distributed equally between the digital (n=64) and conventional (n=64) space maintainer groups, with each further subdivided into Nance (n=32) and Nance–TPA (n=32) appliance subgroups.

Group D-N:(n=32) assigned to a digital 3-D printed Nance space maintainer.

Group D-N-TPA:(n=32) assigned to a digital 3-D printed Nance-Transpalatal space maintainer.

Group C-N:(n=32) assigned to a conventional Nance space maintainer.

Group C-N-TPA:(n=32) assigned to a conventional modified Nance-Transpalatal arch space maintainer.

2.6 Clinical procedures

Digital Appliance fabrication

All clinical procedures were implemented in the outpatient clinic in the Pediatric Department at the Faculty of Dentistry, Pharos University in Alexandria, by a single clinician to maintain consistency in appliance preparation. The procedures were performed in the following steps: Tell-Show- Do technique was explained to the patient that we would take a photo of his upper and lower teeth using a camera as a means of distraction and motivation of the child. The three universal maneuvers in the digital appliance strategy were implemented: (1) Scanning the arch configuration to acquire digital record; (2) Digital data guidance with a software application to frame the appliance

reproduction; and (3) Development technology to convert the framework into a SM. Digital impressions were obtained using a third-generation optical engine intraoral scanner (Medit i900; Medit Corp, Seoul, South Korea) featuring a 10-bit imaging camera technology. The device utilizes an LED light source with 3D in-motion video technology including a full-color streaming capture with a small sized-autoclavable tip. The scan was singly executed in a constant direction. The scans were started from the distal side of one maxillary molar towards the contralateral side, passing over the occluding surfaces, succeeded by the palatal and then the facial tooth surfaces. All scans were illustrated on display as a virtual model, if any missed area was noticed, re-scanning was done. The scanned cast was exported as STL files.

The files were transferred to the lab for 3-D digital design of the Nance or Nance-TPA SM using OnyxCeph³™ orthodontic software (Version 3.1.54; Image Instruments GmbH, Chemnitz, Germany). To visualize the cast in a 3D view, swiveling icons, magnifying and rotation tools were used. This advancement has the creditability of adjusting different options in the appliance such as: thickness and material of choice, cement space and visualizing undercuts.

Construction was accomplished via direct metal laser sintering SLM additive technology by means of a cobalt-chromium (Co-Cr) base alloy (0.5 mm thickness for the band and 0.9 mm for the wire), preferred for its cost-efficiency collated to titanium alloys. Shinning 3D DMLS printer (Hangzhou, China: Shining 3D) was utilized.

Conventional appliance fabrication

Bands for the maxillary FPMs (First permanent molar) were selected using the Ormco™ standard high-retention first molar band kit (Ormco™; California, USA). The selected bands were the smallest tight-fitting bands with the occlusal end just below the proximal ridges and the gingival end 1mm below the gingival margin.

The Tell-Show-Do technique was used to explain to the child that clay or Play-Doh was applied inside the mouth to take a print of his teeth. The proper tray size was selected according to the size of the jaw, either size 1, 2, or 3. An alginate impression was taken for the upper dental arches in the following steps: the dental tray was placed in the mouth by retracting the person's lips on one flange with a mouth mirror/gloved finger, then rotation of the tray to the contralateral side. After centralizing the tray in position, the impression was held in place with slight pressure. All the soft tissues flanges were handled throughout the alginate impression taking to produce all the details. Once set, the bands were removed by band removal, and the impression had to be quickly and firmly snapped. During the removal of the impression, care was taken not to twist or distort. The stone model was poured immediately to avoid any shrinkage and to ensure accurate measurements.

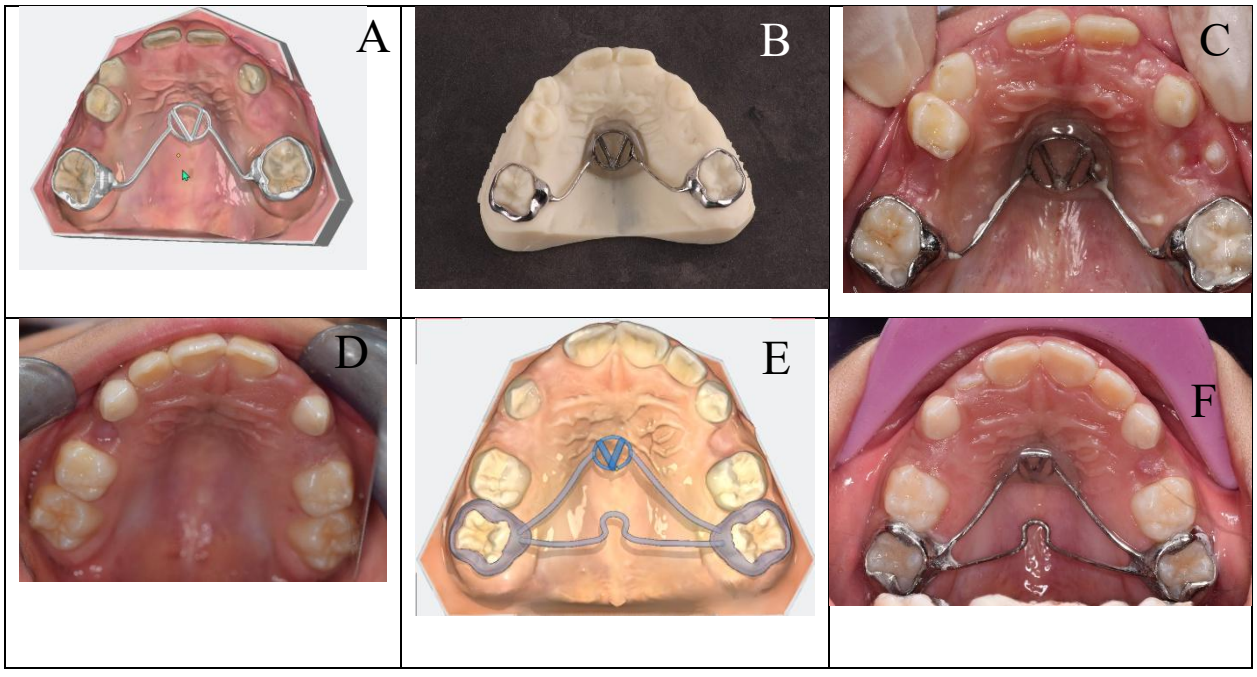
Nance SM was designed using 0.9 mm wire. In the design, the wire was welded palatally to the posterior molar bands and extends anteriorly to the acrylic button on the rugae area.

The combined Nance/transpalatal arch appliance was crafted the same as Nance SM, and another wire was welded to the posterior molar bands and spanned horizontally across the posterior hard palate with an omega loop midway across its length. The omega loop faced mesially.

Appliance insertion and cementation

Participants returned for appliance insertion within 2-3 days from the intervention visit. Tell-Show-Do was used to introduce the appliance to the child. The appliances were first tried on to ensure proper fit. As previously stated, the bands were correctly seated in position, the wire was checked not to irritate the palatal mucosa with no blanching around the acrylic button, which was passively resting on the rugae.

Prior to cementation, the finishing and polishing for all the appliances groups was done and the interior surfaces of the bands were sandblasted with 50-µm aluminum oxide (Al_2O_3) corpuscles. The appliance was inserted intraorally for try-in and cemented using Ultra Band-Lok (regular fluoridated) cement (Reliance Orthodontic Products, Inc., USA), according to the user guide. Oral hygiene instructions for the appliances were given to the participants and post-operative mandate involved eschewing solid food for half an hour, Figure (1).



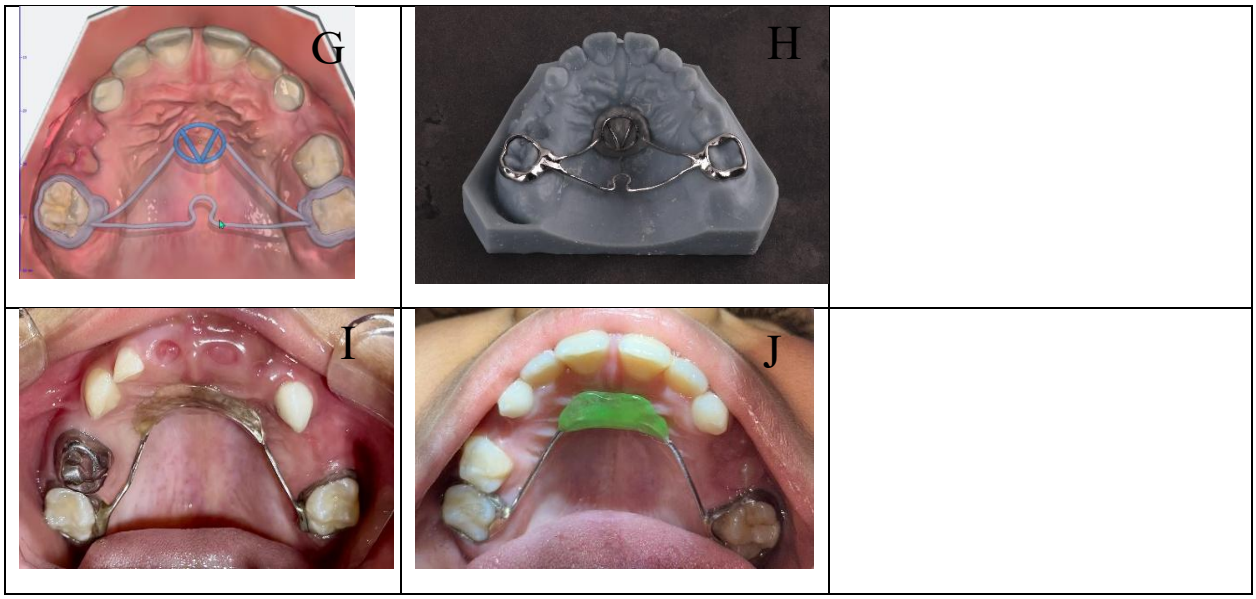


Figure 1: showing the workflow of the Conventional and Digital Appliances. A,B,C: Digital Nance space maintainer. D,E,F,G,H: Digital Nance-TPA space maintainer. I,J: Conventional Nance Space Maintainer.

Baseline dental arch measurements: T0 were performed for all participants by a digital scan to the upper arch. The digital images were implied to a free, source available 3D Slicer Software, (3D Slicer, Version 5.12, Surgical Planning Laboratory, Brigham and Women's Hospital, Boston, MA, USA; available at: 3D Slicer Official Website)(36-38), used for dental image computing and visualization. The marked landmarks were identified in the software with a cursor. After identifying the points, measurements were dragged spontaneously by the program.

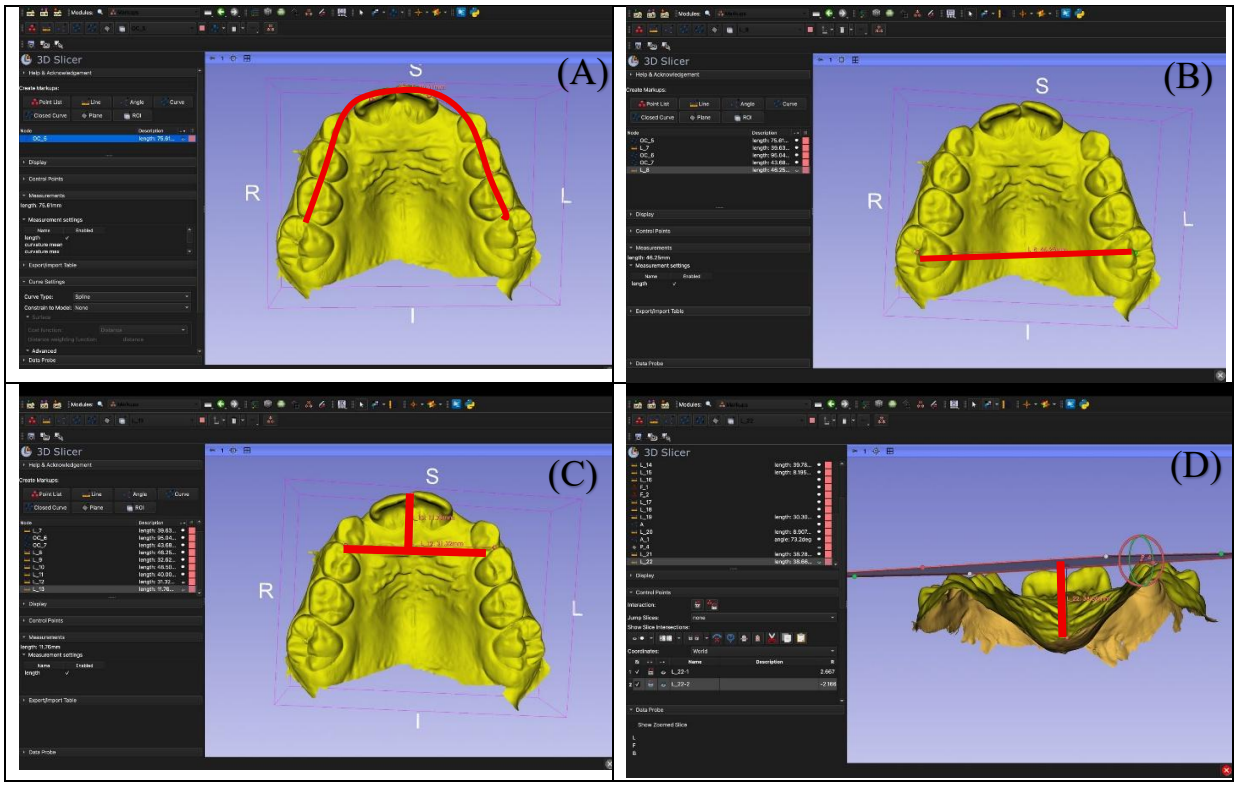
All participants were followed up after 3, 6 and 12 months. The appliances were removed using a band remover (Leone S.p.A; Florence, Italy), digital scans and measurements were repeated after each follow-up visit T3 months, T6 months, T12 months.

2.7 Dental arch measurements (39)

- Arch perimeter(circumference): The magnitude was achieved from a spot located in the mid of the distal surface of the first molar. Based on the data, from the first and last labels and three extra marks-two located in the center portion of the primary molar and one set at the contact points in between the central incisors.
- The anterior section perimeter: from the distal side of the canine to the distal side of the opposing canine, six teeth quantified with the program; if the canines were missing, dimensions were seized from the medial surface of the deciduous molars.
- The maxillary width (intermolar width): width of maxilla in the zone of the molars.

- The anterior segment width (canine to canine perimeter/width): a linear merging point in the center of the medial side of the deciduous molars.
- The anterior segment length: assessed from a spot on the facial surface central incisors to a line linking marks centralized at the medial interface of the primary molar.
- The right and the left molar rotation angle: remarkable points on the molar teeth were referenced subsequent to the account of the ‘‘Ricketts Molar-Cusp Reference Line’’ delineated as the line joining the mesio-palatal and disto-buccal cusps of the molars(40). To reach this, firstly a transversal plane was launched at right angle to the midsagittal plane. This was fulfilled by acquainting the model in which the midsagittal plane was viewed perpendicularly intersecting the transverse plane posteriorly. The Ricketts Molar-Cusp Reference Line was parallelly oriented to the transverse plane, guaranteeing precise and regular angle values between this line and the midsagittal reference plane in 3D space.
- Arch depth (palatal vault depth) displaying the midsagittal plane (red vertical line) bisecting the transverse plane perpendicular from a posterior view,

The aforementioned steps were carefully carried out for all groups, respectively as illustrated in Figure 2.



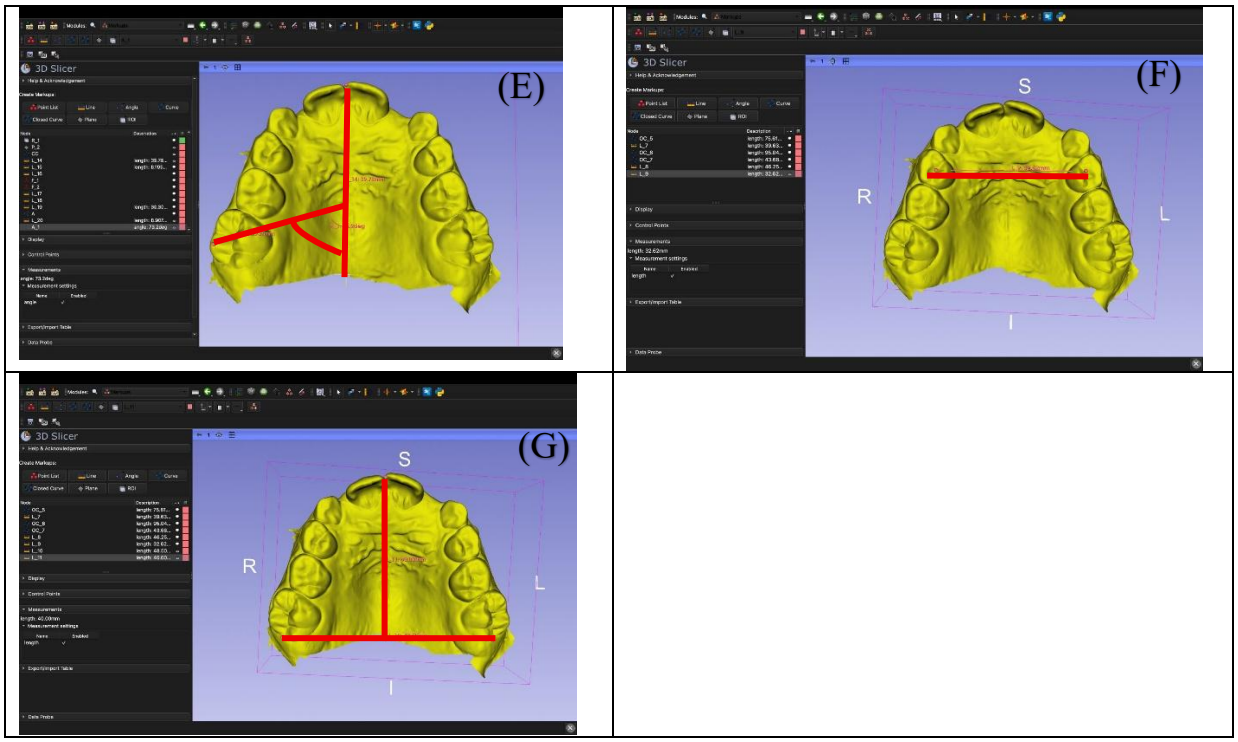


Figure 2: Screenshots of 3D Slicer Software showing digital measurements of arch perimeter **(A)**, width of maxilla in area of molars **(B)**, length of anterior segment of dental arch **(C)**, arch depth **(D)**, degree of molar rotation **(E)**, width of maxilla in area of premolars **(F)**, and length of maxillary dental arch **(G)**.

2.8 Reliability test

Inter examiner reliability was assessed by having two independent examiners perform measurements on the same set of dental casts/models, and agreement between examiners was appraised using the intraclass correlation coefficient (ICC) with a two-way random-effects model for absolute agreement. ICC values ranged from 0.887 to 0.971, these findings indicate that all measured variables showed good to excellent agreement between examiners, supporting the reliability and reproducibility of the measurement protocol employed in this study.

2.9 Statistical analysis

Data normality was guided using the Shapiro-Wilk test and Q-Q plots. Mauchly's test revealed a violation of the sphericity assumption; thus, the Greenhouse-Geisser correction was applied to the repeated-measures effects. A three-factor mixed repeated-measures ANOVA was conducted, with fabrication technique (Digital vs Conventional) and space maintainer type (Nance vs Nance-TPA) as between-subject factors and follow-up interval (T0, T3, T6, and T12) as the within-subject factor. Main effects and two- and three-way interactions were assessed. Significant effects were further examined using Bonferroni-adjusted pairwise comparisons. Results were reported as F values, p values, and partial eta squared (ηp^2) as a measure of effect size. Statistical significance was adjusted

at p<0.05. Data were analyzed through IBM SPSS version 23.0 for Windows, commercially available software program (Statistical Package for Scientific Studies, SPSS, Inc., Chicago, IL, USA).

3. Results

A total of 128 patients were randomly allocated equally (n = 32) to the four study groups: digital Nance, digital Nance-TPA, conventional Nance, and conventional Nance-TPA. All allocated participants received the assigned intervention. During follow-up, appliance failure occurred in four patients in each digital group. All of these appliances were welded and recemented; two participants in each group resumed follow-up and completed the study, whereas two patients in each group were lost to follow-up because they did not attend subsequent visits. In the conventional Nance group, four appliances failed. Two were soldered and recemented, and these patients completed the study, while the other two patients discontinued follow-up after appliance breakage. In the conventional Nance-TPA group, three appliances were soldered and recemented. Two of these patients continued in the study, and one was lost to follow-up due to travel. In addition, one patient in this group did not return after appliance breakage. Consequently, two patients were lost to follow-up in each group, and 30 patients per group (n = 120 in total) were included in the final analysis. As illustrated in Figure 3, arch perimeter decreased significantly over time in the Digital Nance, Digital Nance-TPA, and Conventional Nance groups. In the Conventional Nance-TPA group, a significant reduction was observed only between T3 and T6 (p=0.020).

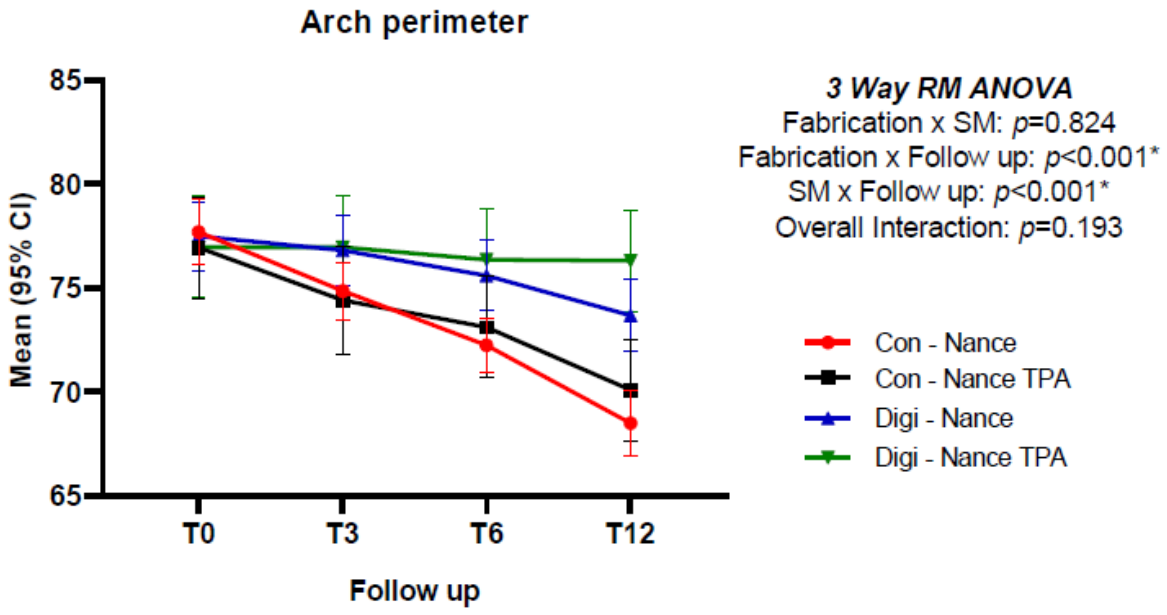


Figure 3: Line graph showing change in arch perimeter at baseline (T0), after 3 months (T3), after 6 months (T6) and after 12 months (T12).

There was no significant difference between Digital and Conventional fabrication at T0 (p=0.933). Digital fabrication showed a significantly greater arch perimeter at T3 (p=0.029), T6 (p=0.001), and T12 (p<0.001). No significant differences were found between Nance and Nance-TPA at T0, T3, or T6; a significant difference was observed at T12 (p=0.040).

Significant effects were found for fabrication technique (p=0.006) and follow-up (p<0.001), but not for space maintainer type (p=0.592). Significant fabrication × follow-up and space maintainer × follow-up interactions were observed (both p<0.001), while the fabrication × space maintainer interaction (p=0.824) and three-way interaction (p=0.193) were not significant.

As illustrated in Figure 4, palatal vault depth increased significantly over time in the Digital Nance, Conventional Nance, and Conventional Nance-TPA groups (p<0.001). In the Digital Nance-TPA group, no significant change was observed between T0 and T3 (p=1.00), while all subsequent comparisons were significant (p<0.001).

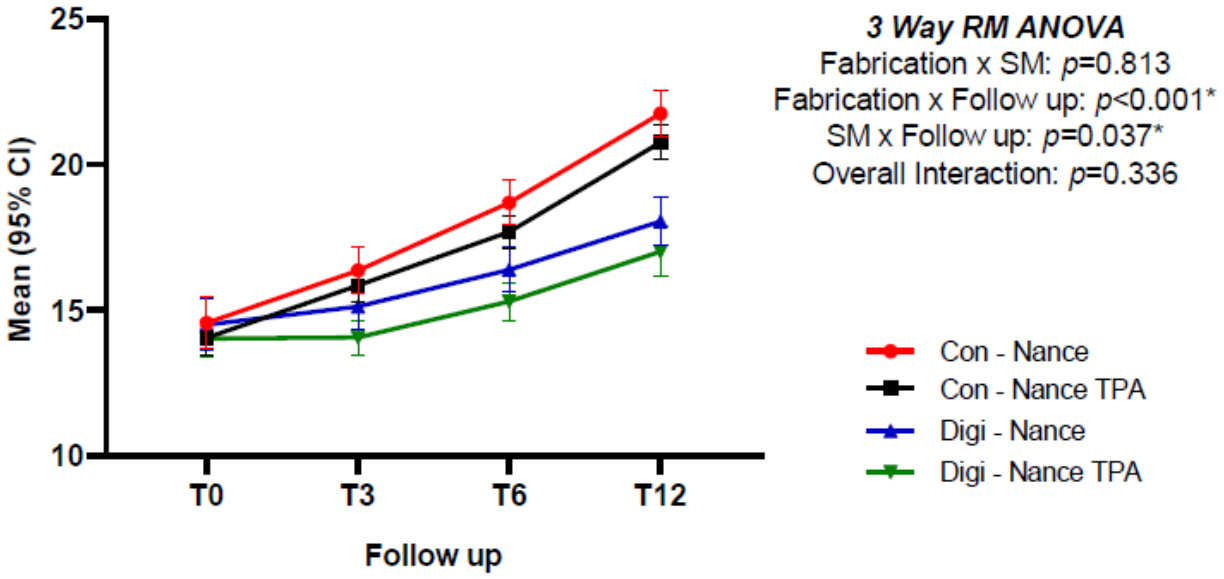


Figure 4: Line graph showing change in arch depth at baseline (T0), after 3 months (T3), after 6 months (T6) and after 12 months (T12).

There was no significant difference between Digital and Conventional fabrication at baseline (p=0.907). Conventional fabrication showed significantly greater palatal vault depth than Digital fabrication at T3, T6, and T12 (p<0.001). Nance and Nance-TPA did not differ significantly at T0 (p=0.186), but Nance showed greater palatal vault depth at T3 (p=0.024), T6 (p=0.003), and T12 (p=0.008).

Significant effects were noticed for fabrication technique (p<0.001), space maintainer type (p=0.016), and follow-up (p<0.001). Significant fabrication × follow-up (p<0.001) and space

maintainer × follow-up (p=0.037) interactions were also found. The fabrication × space maintainer interaction (p=0.813) and three-way interaction (p=0.336) were not significant.

As illustrated in Figure 5, maxillary width and length decreased over follow-up in all groups. For maxillary width, significant reductions were observed across follow-up intervals in the Digital groups and the Conventional Nance group, while the Conventional Nance-TPA group showed no significant differences between T0-T3 or T6-T12. For maxillary length, significant reductions were observed in all digital groups and the Conventional Nance-TPA group, while the Conventional Nance group showed no significant changes between T0-T3, T0-T12, or T6-T12.

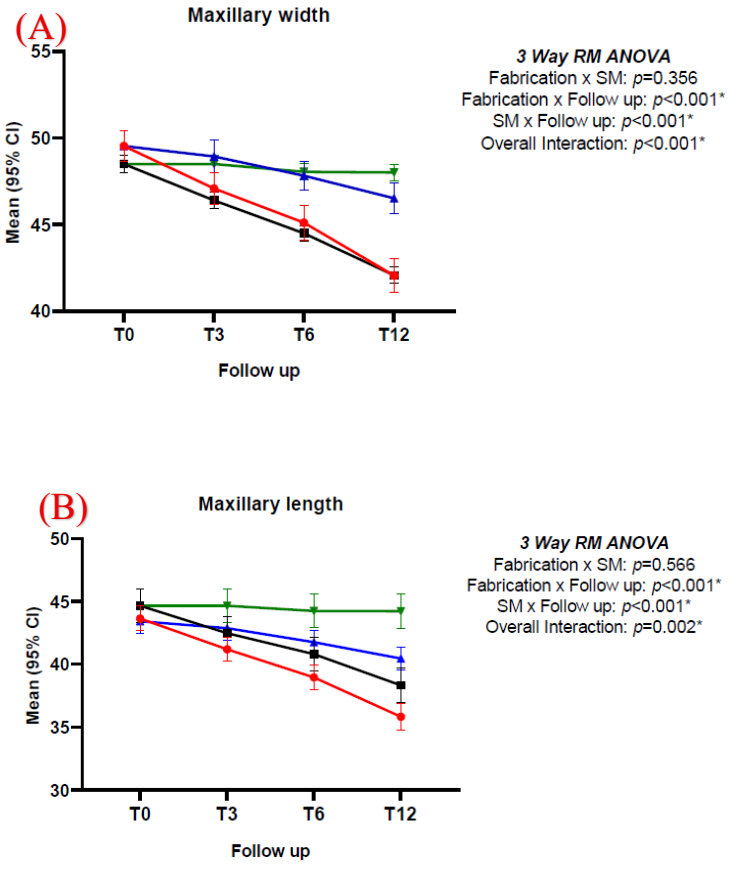


Figure 5: Line graph showing change in maxillary arch width **(A)** and maxillary arch length **(B)** at baseline (T0), after 3 months (T3), after 6 months (T6) and after 12 months (T12).

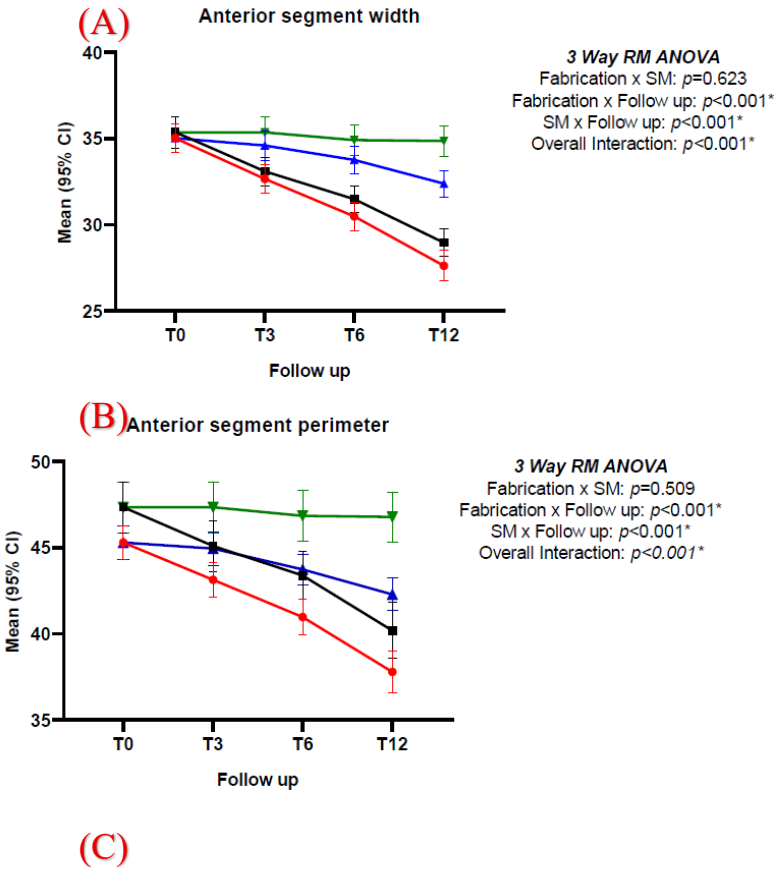
For maxillary width, significant effects were found for fabrication technique and follow-up (both p<0.001), with significant fabrication × follow-up, space maintainer × follow-up, and three-way interactions (p<0.001). For maxillary length, fabrication technique, space maintainer type, and

follow-up were significant (p<0.001, p=0.001, and p<0.001, respectively), with significant interactions involving follow-up and a significant three-way interaction (p=0.002).

For maxillary width, Digital Nance differed significantly from both Conventional groups at T3, T6, and T12, while Digital Nance-TPA differed from both Conventional groups at the same intervals. Digital Nance and Digital Nance-TPA differed only at T12 (p=0.025), and the two Conventional groups did not differ.

For maxillary length, Digital Nance-TPA differed from both Conventional groups at T3, T6, and T12. Digital Nance differed from Digital Nance-TPA at T6 and T12 and from Conventional Nance at T6 and T12. The two Conventional groups differed only at T12 (p=0.015).

As illustrated in Figure 6, anterior segment perimeter decreased over time in the Digital Nance, Digital Nance-TPA, and Conventional Nance groups (p<0.001). In the Conventional Nance-TPA group, no significant differences were noticed between T0-T3 (p=1.00), T0-T12 (p=0.217), or T6-T12 (p=1.00). Between-group differences became apparent from T3 onward, with the Conventional Nance group showing lower values than the Digital groups.



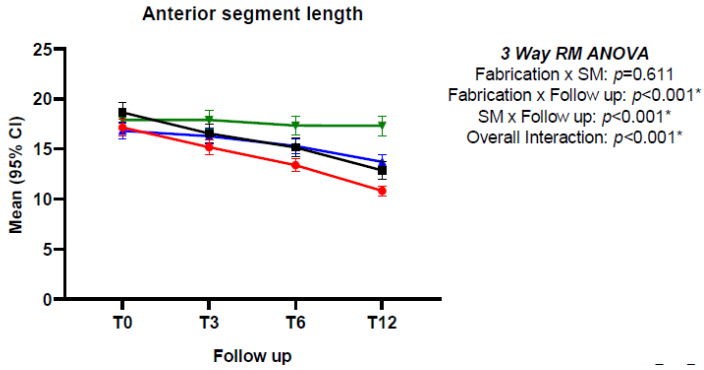


Figure 6: Line graph showing change in anterior segment width **(A)**, perimeter **(B)** and length **(C)** at baseline (T0), after 3 months (T3), after 6 months (T6) and after 12 months (T12).

Significant effects were observed for fabrication technique, space maintainer type, and follow-up ($p<0.001$). Significant fabrication × follow-up, space maintainer × follow-up, and three-way interactions were also observed ($p<0.001$). The fabrication × space maintainer interaction was not significant ($p=0.509$).

At T3, Digital Nance differed from Digital Nance-TPA ($p=0.041$) and Conventional Nance-TPA ($p<0.001$), while Digital Nance-TPA differed from Conventional Nance ($p<0.001$). At T6, Digital Nance differed from all other groups ($p\leq0.009$), while Digital Nance-TPA differed from both Conventional groups ($p<0.001$). At T12, Digital Nance differed from Digital Nance-TPA and Conventional Nance (both $p<0.001$), and Digital Nance-TPA differed from both Conventional groups (both $p<0.001$). The two Conventional groups did not vary significantly at either follow-up interval.

Anterior segment width and length decreased over follow-up in all groups. For width, significant reductions were observed across all intervals in the Digital Nance and both Conventional groups, while the Digital Nance-TPA group showed no significant change between T0-T3 or T6-T12. For length, significant reductions were observed in the Digital Nance and both Conventional groups; the Digital Nance-TPA group also showed significant reductions across all intervals.

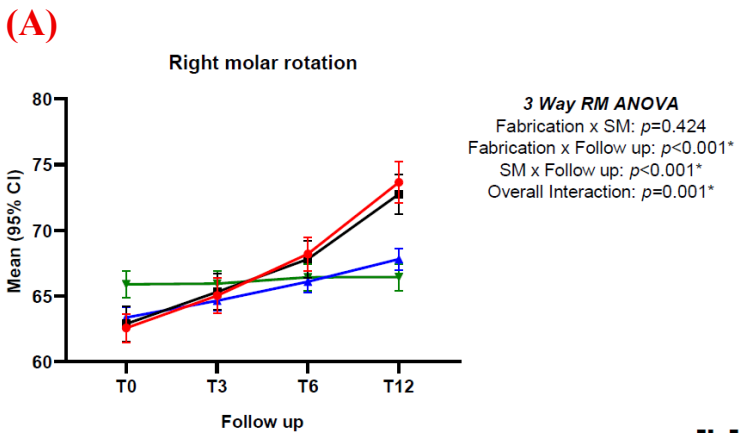
For anterior segment width, significant effects were found for fabrication technique, space maintainer type, and follow-up ($p<0.05$), with significant fabrication × follow-up, space maintainer × follow-up, and three-way interactions ($p<0.001$). For anterior segment length, fabrication technique, space maintainer type, and follow-up were significant ($p<0.001$), with significant interactions involving follow-up and a significant three-way interaction ($p<0.001$). The fabrication × space maintainer interaction was not significant for either outcome.

For anterior segment width, Digital Nance differed from Conventional Nance at T3, T6, and T12, and from Conventional Nance-TPA at T6 and T12. Digital Nance-TPA differed from both Conventional groups at T3, T6, and T12. The two Conventional groups did not differ significantly.

For anterior segment length, Digital Nance differed from Digital Nance-TPA at T6 and T12 and from Conventional Nance at T6 and T12. Digital Nance-TPA differed from both Conventional groups

at all follow-up intervals, except for Conventional Nance–TPA at T3. The two Conventional groups differed at T6 and T12.

As illustrated in Figure 7, right and left molar rotation increase over follow-up in all groups. For right molar rotation, significant increases were observed across all intervals in the Digital Nance, Conventional Nance, and Conventional Nance-TPA groups, while the Digital Nance-TPA group showed no significant differences between T0-T3 or T6-T12. For left molar rotation, significant increases were observed across all intervals in the Digital Nance and Conventional Nance-TPA groups, whereas the Conventional Nance group showed significant changes only from T3 onward.



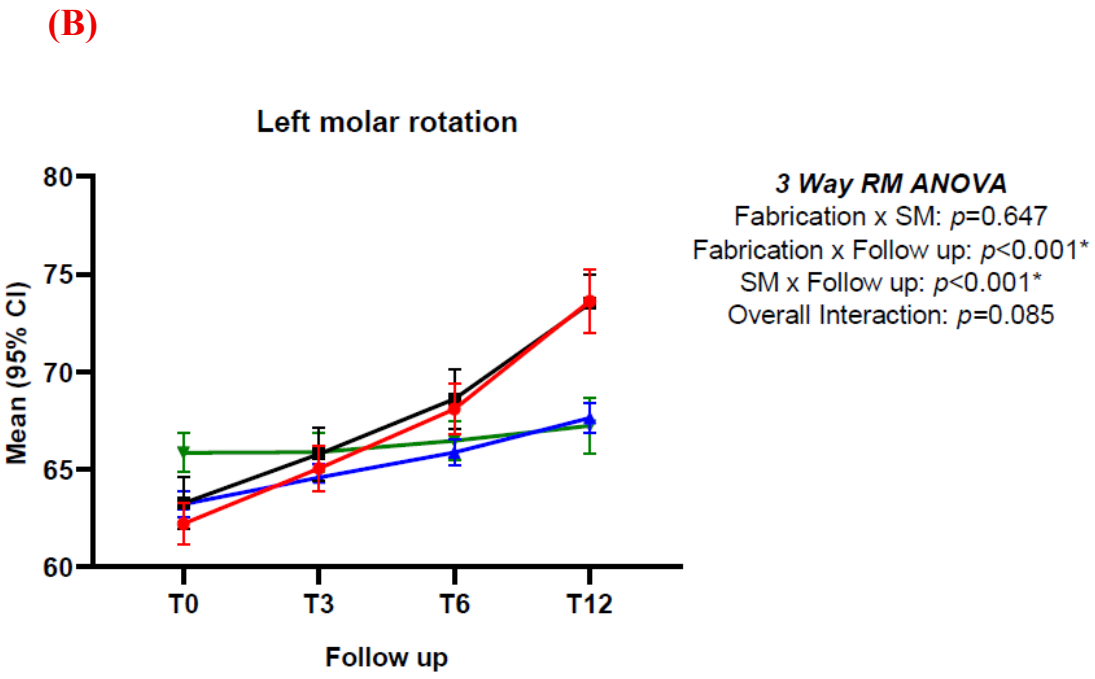


Figure 7: Line graph showing degree of rotation right molar (A) and left molar (B) at baseline (T0), after 3 months (T3), after 6 months (T6) and after 12 months (T12).

For right molar rotation, significant effects were found for fabrication technique ($p=0.004$), space maintainer type ($p=0.001$), and follow-up ($p<0.001$), with significant fabrication × follow-up, space maintainer × follow-up, and three-way interactions. For left molar rotation, fabrication technique, space maintainer type, and follow-up were significant ($p<0.001$), with significant interactions involving follow-up; the three-way interaction was not significant ($p=0.093$). The fabrication × space maintainer interaction was not significant for either side.

For right molar rotation, significant differences were observed mainly at baseline and T3, particularly between Digital Nance-TPA and the other groups. Most between-group differences were no longer significant at T12. For left molar rotation, Digital Nance differed significantly from Digital Nance-TPA at all follow-up intervals, while Digital Nance–TPA differed significantly from both Conventional groups at all intervals. The Conventional Nance and Conventional Nance-TPA groups also differed significantly at T0, T3, T6, and T12.

4. Discussion

Preterm extraction of deciduous molars is ordinarily prompted by extraction ahead of time owing to decay and/or unsuccessful pulp treatment, which may necessitates orthodontic correction before space loss, crowding and impaction or dislocation of the permanent teeth(41, 42). Space maintenance is contemplated to assert the cohesion of the dental arch after premature molar extraction(43). Choonara(44) recounted that in early mixed dentition, orthodontic cases involving space problems could be hindered if pediatric dentist maintained space available. Emerging technologies, such as 3D printing have broached a customized, precisely-planned apparatus that abate the in-office duration and boost treatment resultants. Likewise, the inclusion of digital workflow in treatment planning portrays a reassuring and green pediatric dentistry. This research delves into the classical and innovational digital perspectives of space maintainers in advancing space management strategies. The digital appliance is work saving and a better equivalent to conventional ones. Moreover, digital appliances provide various assets, for instance the eradication to assembly steps such as impression taking, band relocation, and laboratory soldering. Therefore, this study is the first to address the use of N-TPA appliance as a SM in children with mixed dentition, and to evaluate its effectiveness compared to the conventional Nance SM in preserving the arch parameters after bilateral early extraction of primary molars.

The digital groups exhibited significantly had increased arch perimeter values than the conventional groups at T3, T6, and T12. Conversely, there are scarce studies on the concealed reason which was not yet scouted. We assign that this diversity might be owing to alterations in the

transversal malocclusions displayed in the children, as diverse kinds of transverse discrepancies could escort to unsteady occlusal forces and unsymmetrical molar rotations. These findings were not in agreement with Elsayed et al. (45)although the resultant were not statistically significant, this increase can be contributed to the normal growth of the arches that takes place in this period of growth spurt and the outcome of Rajbhoj et al.(46) and Bishara et al.(47), both observed a significant increase in intermolar width and arch circumference during normal occlusal development at the age of eight.

This finding suggests that the digital fabrication workflow may provide more accurate reproduction of the planned appliance geometry and/or more consistent adaptation to the dental arch, potentially contributing to better preservation of arch perimeter over time. Regarding appliance design, no significant differences were noted between the Nance and Nance-TPA groups at T0, T3, or T6, while a significant difference emerged at T12. These Conventional Nance group findings were consistent with Shpack et al.(48) that reported that there was limited efficacy of Nance appliance in providing absolute anchorage. This delayed difference may indicate that the influence of the TPA on arch perimeter becomes more apparent over an extended period of appliance use. The TPA component may provide additional transverse and anteroposterior stabilization of the maxillary first permanent molars, thereby reduce unwanted tooth movement and contribute to improved maintenance of arch dimensions. A systematic review concluded that if the tooth absence persists beyond 6 months, reduction of the space will occur dramatically(49). Nevertheless, Padma and Retnakumari(50) observed the greatest space loss in the first 4 months after premature extraction, but space loss subsequently increased gradually and became stable over 6–24 months. Furthermore, Gandhi and Gurunathan noted that space closure takes place within the first six months after premature primary molar extraction (51).The lack of significant differences at the earlier follow-up intervals suggests that the effect of appliance design may be relatively modest during the initial months of treatment.

Collectively, these findings suggest that the digital workflow may offer an advantage in maintaining arch perimeter over time, whereas the specific Nance appliance design appears to have a comparatively limited overall effect. Digital workflows may allow improved standardization, reproducibility, and precision of appliance fabrication, which could contribute to more consistent clinical outcomes. However, the observable changes should be inferred within normal growth and dental development, and longer-term clinical studies are warranted to determine whether the differences in arch perimeter observed with digital fabrication translate into meaningful advantages in space preservation and subsequent occlusal development.

As for the palatal vault depth, conventional appliances showed significantly greater vault depth at T3, T6, and T12 this finding supports that conventional appliance (impression-based, potentially less precise adaptation) may allow or promote greater vault deepening over time compared to digitally printed appliances. While, the transpalatal arch component constrains vault deepening, plausibly through cross-arch rigidity limiting transverse/vertical tissue displacement that the acrylic button alone doesn't restrict. A statistically significant increase in arch depth was found within the conventional N-TPA group in Elsayed et. al(45). This was consistent with the results found by Ross-

Powell and Harris(52) who found a substantial increase in arch depth as the permanent incisors emerged. In another study by Thilander B(53) an escalation was noticed up to 13 years of age in both arches, mainly between 7 and 13 years, attributable to the proclination eruption of the permanent incisors.

As for the maxillary width the digital groups and conventional groups all showed significant width reduction across essentially all follow-up intervals, whereas the conventional Nance-TPA group was notably stable between T0-T3 and T6-T12. This suggests that the combination of conventional fabrication with a transpalatal arch produced the most dimensionally stable outcome for maxillary width, likely because the added rigidity of the TPA combined with the bulkier, less precisely adapted conventional appliance provides greater resistance to transverse collapse in the early and late intervals. Digital Nance and Digital Nance-TPA each differed significantly from both Conventional groups from T3 onward, indicating that digital fabrication regardless of appliance type is associated with a distinct transverse trajectory compared to conventional fabrication. On the other hand, this was in reverse with Bishara et al.(47) observed a significant increase in intermolar width during normal occlusal development at the age of eight.

However, for the maxillary length, the Conventional Nance group had no significant change across time intervals, while all Digital groups and the Conventional Nance-TPA group showed significant reductions. This implies that for the sagittal dimension, it was the absence of a TPA combined with conventional fabrication that is most resistant to change, essentially the opposite combination from what stabilized width. This was confirmed by Alexander et al.(54), the study deducted that maxillary space collapse was in account of the medial movement by the distal teeth in all participants.

The stability of Conventional Nance-TPA was a clinically meaningful finding, it suggests that when a transpalatal arch is added to a conventionally fabricated Nance appliance, the resulting construct provides the greatest resistance to anterior segment collapse of any combination tested. Mechanically, this is plausible the TPA cross-arch rigidity, combined with a conventional appliance typically bulkier acrylic coverage and broader tissue contact, may together offer more effective anchorage against mesial migration of posterior segments.

Digital Nance-TPA was the only group to show a stable, non-significant pattern of change specifically between T0-T3 and T6-T12, while Digital Nance and both Conventional groups showed significant reductions across essentially all intervals. This identifies Digital Nance-TPA as the most protective combination for anterior segment width, a finding that is notable because it is the opposite pairing from what emerged as most protective for anterior perimeter (Conventional Nance-TPA) and for maxillary width (which also favored the Conventional Nance-TPA combination).

It suggests that the TPA component consistently confers a stabilizing benefit across appliance types, but which fabrication method pairs most effectively with that TPA benefit appears to differ depending on which specific arch dimension is being measured digital fabrication for anterior segment width, conventional fabrication for anterior perimeter and maxillary width. Therefore, the

best appliance combination is parameter-dependent, and no single fabrication appliance pairing is uniformly superior across every dimension of arch form.

All groups showed significant anterior segment length reductions across the follow-up intervals for length. This indicates that while a TPA combined with digital fabrication may help preserve transverse anterior dimension, it does not confer the same protection against anteroposterior/sagittal anterior contraction. This asymmetry between width and length stability within the same appliance group (Digital Nance-TPA) is a noteworthy finding in itself and suggests that the biomechanical forces governing transverse versus sagittal anterior segment change are at least partially distinct, likely relating to differences in how mesial drift of posterior teeth manifests along different vectors, and how appliance rigidity resists each vector differently. Kobylńska et al.(55) retrieved that the space loss was owing to primary canine distal migration and secong primary molar mesialization on the two jaws. In the maxillary arch, the space discrepancies involved generally of the primary canine distal drift, but there was no reflection of mesial drifting of permanent molars or slanting of the primary molars(56, 57).

Digital Nance-TPA appears most effective for preserving anterior segment width, while offering no particular advantage for anterior segment length; Conventional Nance-TPA appeared most effective for anterior perimeter and maxillary width; and Conventional Nance alone appeared most stable for maxillary length. No single appliance–fabrication combination emerged as universally superior across all dimensions of arch form measured in this study.

This strongly supports an individualized, parameter-specific approach to appliance selection, where clinicians weigh which dimension of arch preservation (transverse anterior width, sagittal anterior length, total perimeter, or posterior/palatal dimensions) is of greatest concern for a given patient's malocclusion and treatment objectives, rather than a preferred fabrication method or appliance design.

Across both sides, molar rotation angle increased significantly over time in the Digital-Nance, Conventional Nance, and Conventional Nance-TPA subgroups, indicating progressive rotation of the first permanent molar mesial during the observation period. The Digital Nance-TPA subgroup showed the least significant molar rotation over the 12 months, suggesting that the addition of a TPA to the digitally fabricated appliance was most effective at limiting molar rotation over time. These results were consistent with significant findings stated by Naushad et al.(58), Maharjan et al.(59), and Shaheen et al.(60) in assessing the molar rotation angles between the right and left sides in malocclusion cases. Stivaros et al.(61) compared molar movements between the Goshgarian and Nance palatal arch groups in a randomized clinical trial. There were no statistically significant differences between the palatal arches with respect to prevention of mesial drift or distal tipping. There was a statistically significant difference in the degree of molar rotation between the arch types, with both expressing some disto-palatal rotation inspite of they were not generated for this motion. It is therefore necessary to insert a SM in the maxillary arch capable of preventing both mesial drift and

mesio-palatal rotation of FPMs as soon as possible consecutive to the premature loss of maxillary primary molars(62, 63).

Digital appliances have reduced deformation, breakage and decementation(64-66). Reduced number of sessions henceforth upgraded compliance of children. In other words, a solitary appliance means a high strength of the device therefore averting disruption and diminishing the failure rate. This could be due to the polished surfaced digital appliances are cleansable readily and lesser plaque buildup resulting in improved periodontal health. On the contrary, the conventional type had band pinching required and gingival lacerations.

Our study exploits 3D dimensions of maxillary parameters and molar rotation angles, proposing a more accurate and circumstantial inspection that refines the precision of dimensional assessments and amends treatment planning. By incorporating geometric measurement manner, this study not only conquers the hindrances of classical modes but surprisingly submits an innovative outlook to the articles, evolving the awareness of the convoluted importance of space maintainers.

Future research is recommended to resolve the space maintainers lifespan and impact on gingival health. Furthermore, evaluating child/parent behavior and acceptance of digitally constructed SMs. Added to that, supplemental clinical and comparative research is postulated involving more appliances concentrating on low-cost materials or other types of material other than CO-Cr, in case of allergic reaction. Incorporation of AI-founded automated identification and measurement tools for maxillary parameters measurements could be further studied. Last but not least, 3D printing in pediatric dentistry still needed to be sufficiently scrutinized.

5. Conclusion

Within the limitations of this study, both digital and conventional Nance-based space maintainers were associated with changes in arch dimensions over 12 months, and no single fabrication method or appliance design was superior across all parameters. Digital fabrication was associated with better preservation of arch perimeter, whereas the addition of a transpalatal arch helped limit first permanent molar mesial rotation and preserve certain arch dimensions, particularly in the digital Nance-TPA group. The digital workflow can therefore be considered a viable alternative to conventional fabrication, and the choice of appliance should be individualized according to the arch dimension of greatest clinical concern. Longer-term research are desired to verify these findings.

Study Limitation

The overall drop-out was 6.25%, and the reasons for discontinuation were appliance breakage with subsequent non-attendance and relocation or travel. Some of the observed group differences may partly reflect uncontrolled variability in growth pattern or timing of primary tooth loss between subjects, rather than appliance design alone.

Acknowledgment

The authors wish to express their sincere gratitude to Mohamed Elkanani for his cooperation during analytical procedures and measurements.

Authors' contributions

NR contributed to the design and analysis and formulated the draft. HA participated to the idea, design, data gathering, data examination, and data clarification. All authors scientifically modified the manuscript, gave final agreement and approved to be amenable for all elements of the project.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability

The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

6. Declarations

Ethics approval and consent to participate

The Unit of Research Ethics Approval Committee (UREAC) at Pharos University in Alexandria certified this study; serial no. 407 – 1/09/2025 and prospectively recorded on clinicaltrial.gov PRS (ID number NCT07179146). Firstly, informed consent to engage in the study was collected from every child's parents. The study entangled subjects who adhered with the ethical principles entitled in the Declaration of Helsinki, 1964, and its subsequent revisions and updates. All clinical diagnosis of this research were implemented in the dental outpatient clinics, Faculty of Dentistry, Pharos University in Alexandria, Alexandria, Egypt. This randomized controlled clinical trial is reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

Consent for publication

Not Applicable

Conflict of interest statement

All authors proclaimed that there is no conflict of interest in either research, authorship, or publication of this article.

7. References

1. Pitts NB, Zero DT, Marsh PD, Ekstrand K, Weintraub JA, Ramos-Gomez F, et al. Dental caries. Nature reviews Disease primers. 2017;3(1):17030.

2. Rao A, Sarkar S. Changes in the arch length following premature loss of deciduous molars. Journal of Indian Society of Pedodontics and Preventive Dentistry. 1999;17(1):29-32.
3. Abdulhafedh MA. Premature loss of primary molars: College of Dentistry, University of Baghdad; 2022.
4. American Academy of Pediatric Dentistry. Management of the developing dentition and occlusion in pediatric dentistry. The reference manual of pediatric dentistry. Chicago, Ill: American Academy of Pediatric Dentistry; 2020. pp. 393–409.
5. Barbería E, Lucavechi T, Cárdenas D, Maroto M. Free-end space maintainers: design, utilization and advantages. Journal of Clinical Pediatric Dentistry. 2007;31(1):5-8.
6. Reddy MR, Chandra HS, Thankachan C. Space Management. Illustrated Pediatric Dentistry-Part 2: Bentham Science Publishers; 2023. p. 154-93.
7. Dhanotra KG, Bhatia R. Digitainers—Digital space maintainers: A review. International journal of clinical pediatric dentistry. 2021;14(Suppl 1):S69.
8. Ghoneim AM, Dowidar KM, Talaat DM. Effectiveness of Digital Versus Conventional Impression on Discomfort and Dental Anxiety in Preschool Children (Randomised Controlled Clinical Trial). International Journal of Paediatric Dentistry. 2026;36(4):540-8.
9. Dadoo A, Jain S, Mowar A, Bansal V, Trivedi A. 3D printing using CAD technology or 3D scanners, a paradigm shift in dentistry—a review. Int J Med Dent Res. 2021;1(2):35-40.
10. Pawar BA. Maintenance of space by innovative three-dimensional-printed band and loop space maintainer. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2019;37(2):205-8.
11. 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.
12. Jandyal A, Chaturvedi I, Wazir I, Raina A, Haq MIU. 3D printing–A review of processes, materials and applications in industry 4.0. Sustainable Operations and Computers. 2022;3:33-42.
13. Koaban A, Alotaibi SS, Nakha KMA, Huraib SB, Alhassan MH, Rubayan AR, et al. Orthodontic space management in pediatric dentistry: a clinical review. Cureus. 2024;16(12).
14. Alrehaili R, Alhujaili A, Almanjhi W, Alnami H, Alsaiyari S, Alqahtani H, et al. How effective are the Nance appliance and transpalatal arch at reinforcing anchorage in extraction cases? Cureus. 2024;16(5).
15. Gupta A, Mohapatra A, Dutta B, Dhull KS. Functional space maintainer with bilateral early loss of primary maxillary first molars: NAFC. International Journal of Clinical Pediatric Dentistry. 2024;17(5):612.
16. Adeloye AY, Egbunah UP, Utomi IL. Iatrogenic fibrotic encapsulation of NANCE palatal arch appliance in the hard palate and its surgical management: a case report. Journal of Surgical Case Reports. 2023;2023(3):rjad120.
17. ARACKAL B, BHAT S. CHAIRSIDE NANCE BUTTON-A NOVEL TECHNIQUE OF FABRICATION OF THE NANCE PALATAL BUTTON. JOURNAL OF CONTEMPORARY ORTHODONTICS Учредители: IP Innovative Publication Pvt Ltd. 2024;8(4):552-4.
18. Green J. Mind the gap: Overview of space maintaining appliances. Dental Nursing. 2015;11(1):24-7.
19. WANG X, TIAN Y, BAI D. Research progress on the application of the transpalatal arch in orthodontic clinics and its mechanical mechanism. Journal of Prevention and Treatment for Stomatological Diseases. 2023;31(1):63-7.
20. Diar-Bakirly S, Feres MFN, Saltaji H, Flores-Mir C, El-Bialy T. Effectiveness of the transpalatal arch in controlling orthodontic anchorage in maxillary premolar extraction cases: A systematic review and meta-analysis. The Angle Orthodontist. 2017;87(1):147-58.
21. Ubilla-Mazzini W, Mazzini-Torres F, Moreira-Campuzano T. Orthodontic management of dentofacial discrepancies in skeletal Class II patients. Contemporary Clinical Dentistry. 2018;9(3):474.
22. Ubilla-Mazzini W, Moreira-Campuzano T, Mazzini-Torres F. Efficacy of Maximun Anchoring Using Transpalanance and Double ATP in Cases Requiring First Superior Premolar Extractions: A Comparative Analysis. Odovtos International Journal of Dental Sciences. 2019;21(3):119-26.
23. Lobo S, Argolinha I, Machado V, Botelho J, Rua J, Li J, et al. Advances in digital technologies in dental medicine: enhancing precision in virtual articulators. Journal of clinical medicine. 2025;14(5):1495.

24. Kostov I. The digitalization of dental services and their management. KNOWLEDGE-International Journal. 2023;61(1):173-9.
25. Yordanova G, Gurgurova G. Perception and feedback toward digital models and plaster casts in orthodontic patients. World Journal of Dentistry. 2021;12(3):173-7.
26. Rafiei E, Haerian A, Fadaei Tehrani P, Shokrollahi M. Agreement of in vitro orthodontic measurements on dental plaster casts and digital models using Maestro 3D ortho studio software. Clinical and Experimental Dental Research. 2022;8(5):1149-57.
27. Angle EH. Classification of malocclusion. 1899.
28. Andrews LF. The six keys to normal occlusion. Am J orthod. 1972;62(3):296-309.
29. Warren JJ, Bishara SE, Yonezu T. Tooth size-arch length relationships in the deciduous dentition: a comparison between contemporary and historical samples. American journal of orthodontics and dentofacial orthopedics. 2003;123(6):614-9.
30. Zablocki HL, McNamara Jr JA, Franchi L, Baccetti T. Effect of the transpalatal arch during extraction treatment. American journal of orthodontics and dentofacial orthopedics. 2008;133(6):852-60.
31. Volchansky A, Evans B, Cleaton-Jones P. Position and orientation of the maxillary first permanent molar and localized attachment loss. World Journal of Orthodontics. 2004;5(2):141.
32. Martín-Vacas A, Caleya AM, Gallardo NE. Comparative analysis of space maintenance using transpalatal arch and Nance button. Journal of Clinical Pediatric Dentistry. 2021;45(2):129-34.
33. Rosner B. Fundamentals of biostatistics: Nelson education. Nelson Education. 2015.
34. https://www.medcalc.org/en/calc/sample-size-ci-difference-between-means.php.
35. Dean JA, Hughes CV. Mechanical and chemotherapeutic home oral hygiene. McDonald and Avery Dentistry for the Child and Adolescent: Elsevier; 2011. p. 205-22.
36. https://www.slicer.org/
37. Fedorov A, Beichel R, Kalpathy-Cramer J, Finet J, Fillion-Robin J-C, Pujol S, et al. 3D Slicer as an image computing platform for the Quantitative Imaging Network. Magnetic resonance imaging. 2012;30(9):1323-41.
38. Kikinis R, Pieper SD, Vosburgh KG. 3D Slicer: a platform for subject-specific image analysis, visualization, and clinical support. Intraoperative imaging and image-guided therapy: Springer; 2013. p. 277-89.
39. Bogdanov V, Yordanova G, Gurgurova G. Change in dental arch parameters—perimeter, width and length after treatment with a printed RME appliance. Applied Sciences. 2024;14(10):3959.
40. Ricketts RM. Occlusion—the medium of dentistry. The Journal of prosthetic dentistry. 1969;21(1):39-60.
41. Northway WM, Wainright RL, Demirjian A. Effects of premature loss of deciduous molars. The Angle Orthodontist. 1984;54(4):295-329.
42. Posen A. The effect of premature loss of deciduous molars on premolar eruption. The Angle Orthodontist. 1965;35(3):249-52.
43. Bijoor RR, Kohli K. Contemporary space maintenance for the pediatric patient. New York State Dental Journal. 2005;71(2):32.
44. Choonara S. Orthodontic space maintenance--a review of current concepts and methods. SADJ: journal of the South African Dental Association= tydskrif van die Suid-Afrikaanse Tandheelkundige Vereniging. 2005;60(3):113, 5-7.
45. Elsayed S, Abdelrahman A, ElHabashy LM. Effectiveness of combined design nance/transpalatal arch appliance in maintaining arch dimensions after premature extraction of primary molars (A randomized controlled clinical trial). Alexandria Dental Journal. 2024;49(3):155-64.
46. Rajbhoj AA, Parchake P, Begnoni G, Willems G, de Llano-Pérula MC. Dental changes in humans with untreated normal occlusion throughout lifetime: a systematic scoping review. American Journal of Orthodontics and Dentofacial Orthopedics. 2021;160(3):340-62. e3.
47. Bishara SE, Jakobsen JR, Treder J, Nowak A. Arch length changes from 6 weeks to 45 years. The Angle Orthodontist. 1998;68(1):69-74.

48. Shpack N, Davidovitch M, Sarne O, Panayi N, Vardimon AD. Duration and anchorage management of canine retraction with bodily versus tipping mechanics. The Angle Orthodontist. 2008;78(1):95-100.
49. Zhao J, Jin H, Li X, Qin X. Dental arch spatial changes after premature loss of first primary molars: a systematic review and meta-analysis of split-mouth studies. BMC Oral Health. 2023;23(1):430.
50. Kumari BP, Kumari NR. Loss of space and changes in the dental arch after premature loss of the lower primary molar: a longitudinal study. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2006;24(2):90-6.
51. Gandhi JM, Gurunathan D. Short-and long-term dental arch spatial changes following premature loss of primary molars: a systematic review. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2022;40(3):239-45.
52. Ross-Powell RE, Harris EF. Growth of the anterior dental arch in black American children: a longitudinal study from 3 to 18 years of age. American Journal of Orthodontics and Dentofacial Orthopedics. 2000;118(6):649-57.
53. Thilander B. Dentoalveolar development in subjects with normal occlusion. A longitudinal study between the ages of 5 and 31 years. The European Journal of Orthodontics. 2009;31(2):109-20.
54. Alexander SA, Askari M, Lewis P. The premature loss of primary first molars: space loss to molar occlusal relationships and facial patterns. The Angle Orthodontist. 2015;85(2):218-23.
55. Kobylińska A, Piekoszewska-Ziętek P, Gozdowski D, Turska-Szybka A, Olczak-Kowalczyk D. Spatial changes in the dental arch after premature extraction of the first primary molar–a 12-month observational study. New Med. 2019;23(3):96-104.
56. LIN YT, LIN WH, LIN YTJ. Twelve-month space changes after premature loss of a primary maxillary first molar. International Journal of Paediatric Dentistry. 2011;21(3):161-6.
57. Lin Y-T, Lin W-H, Lin Y-TJ. Immediate and six-month space changes after premature loss of a primary maxillary first molar. The Journal of the American Dental Association. 2007;138(3):362-8.
58. Naushad H, Shaheed S, Zahra S, Bano S. Maxillary first molar rotation and its relationship with skeletal and occlusal discrepancies. Pakistan Orthodontic Journal. 2014;6(2):43-7.
59. Maharjan S, Rajbhandari A, Pradhan R, Bajracharya M, Pant BD. Assessment of maxillary first molars rotation in class II malocclusion cases: A cross sectional study. Orthodontic Journal of Nepal. 2022;12(2):15-8.
60. Shaheen A, Momina AU, Shahnawaz A, Amin U, Farooq A, Ibrar A. Comparison of maxillary first molar rotation in hyper and hypo divergent patients. Pakistan Orthodontic Journal. 2020;12(1):31-5.
61. Stivaros N, Lowe C, Dandy N, Doherty B, Mandall N. A randomized clinical trial to compare the Goshgarian and Nance palatal arch. The European Journal of Orthodontics. 2010;32(2):171-6.
62. Chauhan SP, Sharma DS, Jain M. Initial stresses induced in permanent maxillary first molar in mixed dentition under normal masticatory forces: a finite element study. Journal of Clinical Pediatric Dentistry. 2016;40(4):334-40.
63. Gibas-Stanek M, Loster BW. The effect of premature extraction of primary molars on spatial conditions and formation of malocclusion–a systematic review. Journal of Stomatology. 2018;71(5):420-31.
64. Aktaş N, Atabek D. Fracture resistance of space maintainers produced using 3D printable materials. European Journal of Paediatric Dentistry. 2024;25(4):266-70.
65. Thakur B, Bhardwaj A, Luke AM, Wahjuningrum DA. Effectiveness of traditional band and loop space maintainer vs 3D-printed space maintainer following the loss of primary teeth: a randomized clinical trial. Scientific Reports. 2024;14(1):14081.
66. Nedeljkovic A, Milosavljevic M, Mladenovic K, Janjic V, Schimmel M, Mladenovic R. Clinical outcomes of novel CAD/CAM-designed functional space maintainers produced via additive and subtractive methods: A randomized controlled trial. Journal of Dentistry. 2025;155:105608.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFileTables.docx
- Consort20251.docx