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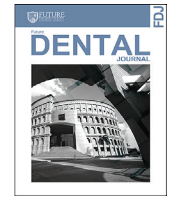

Evaluation of Anchorage Loss Following Anterior Segment Retraction Using Friction Versus Frictionless Mechanics: A Randomized Clinical Trial

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ABSTRACT

Objective: Evaluation of anchorage loss following anterior segment retraction (ASR) using friction versus frictionless mechanics when mini-screws are directly and indirectly loaded using Cone beam computed tomography (CBCT). ***Material and methods:*** Thirty females with bimaxillary protrusion were randomly allocated into two groups, friction and frictionless. In friction group, a hook was crimped on 0.017- by 0.025-inch stainless steel wire distal to the lateral incisor and elastomeric chain rendering 160 g/side extending between the hook and mini-screw implant to complete the ASR. In the frictionless group, canines were ligated to the mini-screws for indirect anchorage then ASR was done using closing T-loops fabricated from 0.017- by 0.025-inch titanium molybdenum alloy (TMA) wire rendering comparable retraction force. Analysis of first molar anchorage loss in terms of bodily and angular movement were assessed using cone beam computed tomographic (CBCT) images. ***Results:*** The use of mini-screws prevented significant anchorage loss in both groups and ASR was accomplished successfully. Anchorage loss in the form of angular tipping was of no statistical significance between friction and frictionless group. ***Conclusion:*** No advantage of either mechanics over the other regarding anchorage loading on the first permanent molars. Mini-screws are efficient devices to control the anchorage. Both direct and indirect mini-screw anchorage prevented first permanent molar mesial tipping and can be use alternatively.

1. INTRODUCTION

Extraction therapy is inevitable treatment option in many cases in orthodontics. A wide diversity of cases necessitate extraction, among which are cases of bimaxillary dentoalveolar protrusion. Premolars extraction followed by anterior segment retraction is a fundamental phase to help reducing anterior teeth proclination and lip procumbency in these patients [1].

The needed movement for retraction can be achieved by friction or frictionless mechanics. In friction (sliding) mechanics, driving force is generated by coil spring or power chain, while in frictionless (segmental) mechanics, two segments are connected with an active loop. It has been stated that retraction using friction mechanics is an indeterminant system due to lack of force control because of friction [2]. On the other hand, segmental mechanics is desired to avoid the friction and apply more precise loading [3]. Additionally, loop fabrication is technique sensitive where minor errors may result in undesirable tooth movement along with that the loop may cause pain and soreness for the patients which may make the frictionless mechanic less desirable [4].

After extraction decision is made, anchorage plan is necessary to minimize movement of the molar into the extraction space that is intended for ASR especially in cases that necessitate maximum anchorage. With the introduction of mini-screws [5],[6] as anchorage devices, it has become possible to achieve absolute anchorage whether the mini-screws are directly loaded (direct anchorage) or used indirectly to stabilize a dental anchorage unit (indirect anchorage) [7-9].

There is a paucity of data concerning the superiority of one mechanics over the other as regards to their anchorage load when mini-screws are utilized. Several studies focused on comparing different anchorage methods, mini-screws vs conventional methods [10],[11]. While others evaluated anchorage loss during en masse retraction by comparing it with two-step retraction mechanics without using mini-screws [12]. Monga et al. [13] evaluated anchorage loss during en-masse retraction with indirectly loaded mini-screws. yet all previously mentioned studies assessed their outcomes through lateral cephalometric radiographs with the shortcoming of superimposition of the left and right sides [14].

The current study aimed at evaluation of anchorage loss of first permanent molars following ASR using friction versus frictionless mechanics using CBCT. The null hypothesis assumed that there would be no difference in the anchorage loss using both methods for retraction.

2. MATERIAL AND METHODS TRIAL DESIGN

This study was a randomized clinical trial with two arms parallel group, single-blind, 1:1 allocation ratio and approved from the Institutional Review Board of Faculty of Dentistry, Future University in Egypt (11102018). All participant/ guardian was asked to sign an informed consent on the overall treatment that was ensued. The CONSORT statement reporting guidelines were followed throughout the study.

Participants, Eligibility Criteria, and Settings

Forty Potential patients were identified during their initial visits to the departmental clinic in accordance with inclusion and extrusion criteria (table 1). The treatment plan for all patients in both groups involved bonding upper and lower arches with 0.022- by 0.022-inch slot conventional Roth prescription brackets (American Orthodontics, Sheboygan, Wis.). Levelling and alignment was done using nickel titanium arch wires until 0.017- by 0.025-inch stainless steel (SS) wire was reached. Self-drilling mini-screws (1.6- by 8-mm, bracket head design; Dual Top Anchor System, Jeil Medical Corporation, Seoul, Korea) were used. After administration of local anaesthesia, they were inserted between the second premolars and first molars bilaterally in each quadrant at the level of the mucogingival junction in the interradicular region and checked for primary stability. The screws were re-checked every visit for stability and replaced if necessary. Then, canine retraction was initiated after extraction of permanent first premolars and after canine retraction was completed, the canine brackets were ligated to the mini-screws using 0.010-inch ligature wire.

Table 1.

Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Bimaxillary protrusion requiring extraction of four first premolars and maximum anchorage (aged between 13-25 years.)	Craniofacial syndromes or systemic disease.
Female patients.	Congenitally missing teeth (other than third molars) or badly decayed teeth.
Good oral health and full set of permanent dentition (except 3rd molars)	Previous orthodontics therapy
Class I molar relation (Angle's classification)	Abnormal occlusal habits

Interventions and measurements

In the friction group, elastomeric chains were used to perform ASR. Elastomeric chains extending between the mini-screw head and a hook of 8mm (variable cimpable hook, Dentos, Korea) crimped distal to the lateral incisors on 0.017- by 0.025-inch SS wire, rendering a retraction force of 160g/ side. Correx tension gauge was used to reactivate and calibrate the elastomeric chains every four weeks (figure 1).

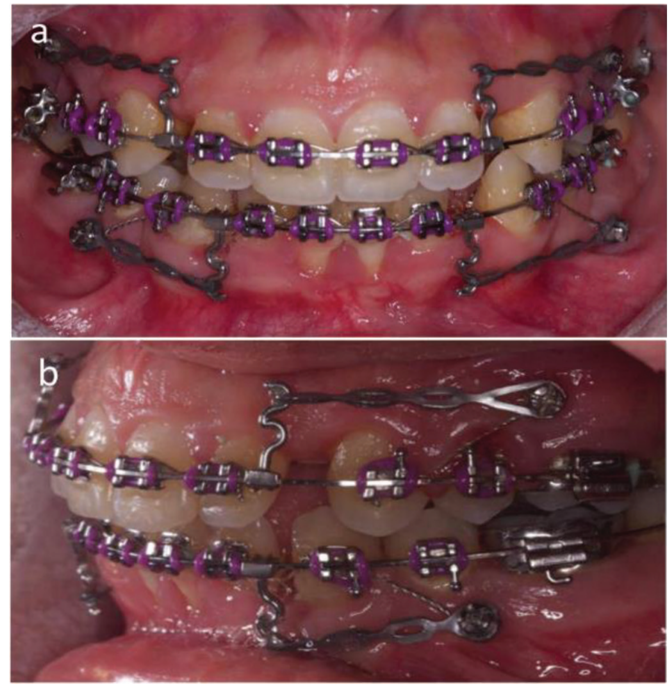

Figure (1) — Friction mechanics appliance setup. (a), Frontal view; (b), lateral view.

In the frictionless group, consolidation of the posterior segments was done using 0.017- by 0.025-inch SS wire segments and anchored indirectly to mini-screw using 0.010-inch ligature wire. T-loops were fabricated using 0.017- by 0.025-inch TMA wire according to Burstone et al [15]. Distal activation of 4mm were arranged to render around 160g/side [15]. In every 4 weeks, reactivation and calibration were performed every 2–3mm of T-loop closure to maintain a comparable force delivery (figure 2).

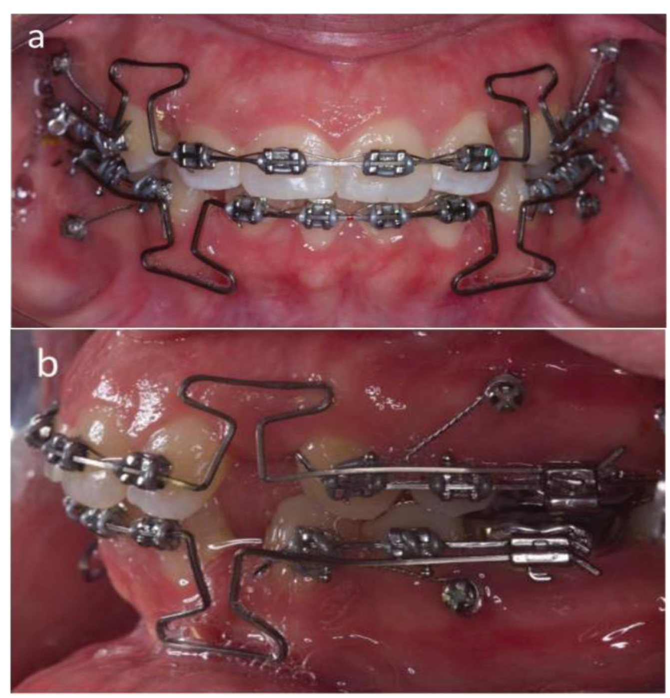

Figure (2) — Frictionless mechanics appliance setup. (a), Frontal view; (b), lateral view

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Immediately before allocation of the patients into groups, pre-intervention cone beam computed tomography (CBCT) scans were obtained with a (Planmeca ProMax, 3D Mid, Helsinki, Finland). ALARA (as low as reasonably achievable) guidelines were considered [16] therefore, a medium CBCT field of view was used. The post-intervention CBCT scans were obtained after ASR was completed and normal overjet obtained using the same machine and specification.

The analysis and the 3D images construction were done using Invivo Anatomage version 5.2 (Anatomage, San Jose, Calif) and saved as digital imaging and communications in medicine (DICOM) files. The measurements were performed using the landmarks, planes presented in (tables 2 and 3) and (figures 3 and 4). One of the co-authors did the measurements twice (DB) and then it was repeated by another co-author (HD) at different time points.

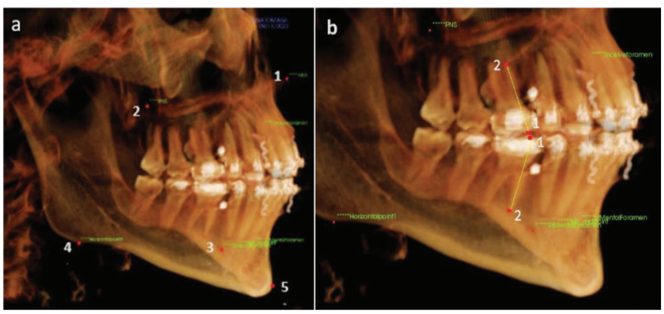

Figure (3) — (a) Skeletal landmarks: 1, ANS; 2, PNS; 3, Mental foramen; 4, Horizontal point; 5, Pogonion. (b) Dental landmarks: 1, Molar cusp; 2, Molar apex.

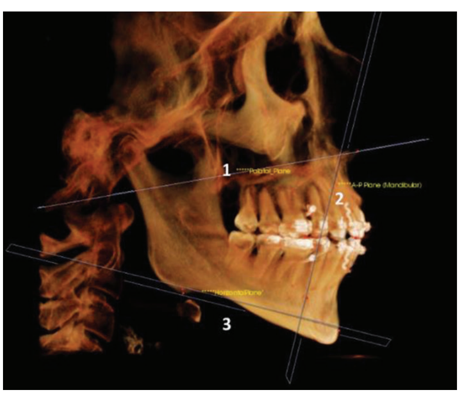

Figure (4) — Reference planes on CBCT. 1, Palatal plane; 2, Antero-posterior plane; 3, Horizontal plane.

Table 2.

CBCT Landmarks, lines and reference planes and their definitions.

Landmarks	Definition
Anterior nasal spine (ANS)	The most anterior point on the tip of anterior nasal spine
Posterior nasal spine (PNS)	The most posterior point on the hard palate at the tip of posterior nasal spine
Mental foramen	The lowest point in the outer border of the right/left mental foramen
Horizontal point	The lowest most convex point in the inferior border of the mandible at the gonial area (right/left)
Pogonion	The most convex point anteriorly on the mandible
Molar cusp	The mesio-buccal cusp tip of permanent first molar
Molar apex	The mesio-buccal root apex tip of the permanent first molar
Reference Lines	**Definition**
Mental foramina line	Line joining right mental foramen and left mental foramen
First molar long axis	Line connecting mesio-buccal cusp tip and mesio-buccal root apex
Reference Planes	**Definition**
Horizontal plane	Plane passing by: right horizontal point, left horizontal point and Pogonion
Antero-Posterior Plane (Mandible)	Plane passing right and left mental foramina and perpendicular to horizontal plane
Palatal plane	Plane formed between ANS, PNS and perpendicular to Mid sagittal plane

Table 3.

CBCT measurements used and their definitions.

Measurements	Definition
Anchorage loss of Maxillary first permanent molar	**Maxillary arch:** Angular measurement of molar tipping assessed by: angle between Upper first molars long axis and palatal plane.
Anchorage loss of Mandibular first permanent molar	**Mandibular arch:** Angular measurement of molar tipping assessed by: angle between lower first molars long axis and horizontal Plane.
	Linear measurement of lower 1st molar: 1. Distance Between lower first molars' mesio-buccal cusp tip and antero-posterior plane. 2. Distance Between first molars' mesiobuccal root apex and antero-posterior plane.

Random Sequence Generation and Blinding

Randomization list was computer-generated using Microsoft Office Excel 2013 sheet. Allocation concealment was performed by co-author (HD) using opaque sealed envelopes. All patients picked envelopes on their intervention day then assigned by the co-author (HD) into one of the two groups according to the excel sheet. Only the assessors were blinded, due to the nature of the study.

Sample size calculation

Sample size calculations recommended twenty subjects (ten per group) using Minitab software with an alpha value of .05 and a power of 80% based on the study by Dincer et al. [1] Sample attrition was considered and ten additional patients were included.

Statistical Analysis

SPSS (Statistical Package for the Social Science; IBM Corp, NY, USA) for Windows was used to perform the analysis. Quantitative variables were tested for normality using Kolmogorov Smirnov test. Normal distribution was found for the variables in most part, allowing the use of parametric tests. Comparison between the study groups for independent samples was done using student t test. And comparisons within groups was done using paired t test. Two-sided p values less than 0.05 was considered statistically significant. Terms of mean ± standard deviation (± SD) were used to statistically describe the data.

3. RESULTS

The Baseline characteristics were similar for both groups, with no significant differences (table 3). Thirty subjects recruited at the beginning of the trial; two patients discontinued the trial due to causes explained in (figure 5). twenty-eight subjects were measured and analysed.

Table 3.

Baseline characteristics in each of the study groups.

	Friction		Frictionless		Difference	P-value
	Mean	**SD**	**Mean**	**SD**		
Age (years)	15.6	2.1	16.0	1.9	0.40	0.160
U1/Mx (degree)	117.51	2.29	118.16	1.94	0.644	0.545
L1/Md (degree)	103.77	3.03	104.34	3.02	0.57	0.597
U1/L1 (degree)	110.09	4.37	109.39	3.83	0.695	0.705
ANB (degree)	2.89	1.03	3.23	0.97	0.342	0.140
SN/Mx plane (degree)	9.12	1.10	10.01	1.38	0.894	0.174
SN/Md plane (degree)	34.21	3.00	34.87	2.63	0.655	0.520
Mx/Md plane (degree)	28.98	2.20	30.13	1.67	1.15	0.257

Significance level $P \leq 0.05$. *Data presented in mean (M) and standard deviation (SD).*
The ASR mean time was 4.8±0.74 months for the friction group and 4.3±0.78 months for the frictionless group.

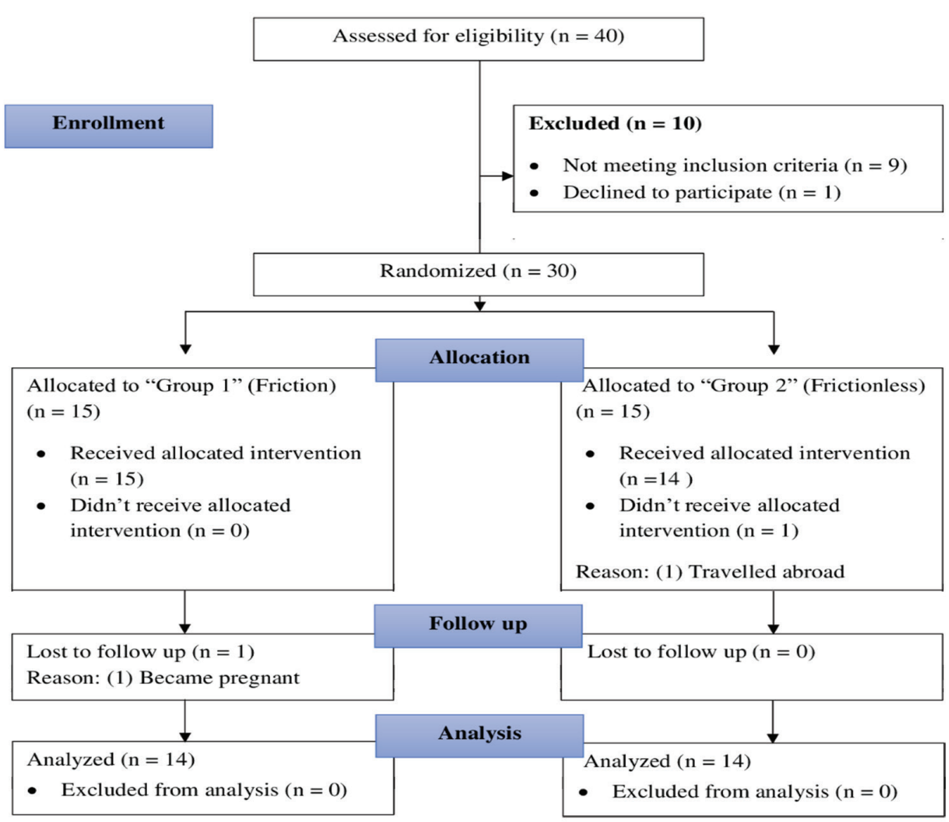

Figure (1) — CONSORT flow diagram showing patients' flow and dropouts during the trial.

Anchorage loss in the form of angular tipping of the upper first permanent molar was of 0. 59º and 1.09º in friction and frictionless group, respectively. These angular changes and the difference between them were statistically insignificant (Table 4).

Anchorage loss in the form of angular tipping of lower first permanent molar was of 0.532º and -0.061 º in friction and frictionless group, respectively. Also, these angular changes and the difference between them were statistically insignificant (Table 4).

In the lower arch linear anchorage loss was also measured at the level of mesio-buccal cusp tip and root apex of the lower first permanent molar. Both linear movements were found to be of no statistical significance with no difference between groups (Table 4).

Both angular and linear CBCT measurements were tested for intra- and interobserver agreement and it was found to be 0.99 (intraclass correlation coefficient).

Table 4.

Showing the mean values and SD for the for the anchorage loss.

	Friction				Frictionless				Diff	p value
	Pre	Post	Diff	p value	Pre	Post	Diff	p value		
U6 MB angular Tipping (º)	85.20±1.92	85.79±2.75	0.593	0.356	83.06±3.07	84.15±3.43	1.095	0.087	- 0.502	0.555
L6 angular Tipping (º)	84.02±4.05	84.55±3.80	0.532	0.799	83.99±3.15	83.92±4.30	-0.061	0.964	0.592	0.809
L6- MB cusp distance (mm)	7.71±2.46	7.44±2.49	- 0.274	0.140	8.39±2.91	7.90±3.06	-0.492	0.049	0.218	0.438
L6- MB apex distance (mm)	7.50±2.15	7.23±2.19	- 0.271	0.300	8.38±2.11	7.71±2.07	- 0.668	0.051	0.398	0.317

*Significance level $P \leq 0.05$. *Statistically significant. (º) in degrees. (mm) in millimetre. Data presented in mean (M) and standard deviation (SD).*

4. DISCUSSION

Anchorage preservation is a key factor in treating bimaxillary protrusion patients because the movement of the molar into the extraction space that is intended for anterior segment retraction is something to be avoided specially in cases that necessitate maximum anchorage. Skeletal anchorage by mini-screws was implemented because it provided less anchorage loss as described by Thiruvenkatachari et al. [17], Antoszewska et al. [18] and Becker et al. [19].

Although much research has been done on comparing conventional anchorage devices with mini-screws [10],[11], the literature is still sparse on anchorage control when the different retraction mechanics are implemented.

Initially, to assess the effect of different retraction mechanics on anchorage loss, force systems were standardized regarding constancy, magnitude, duration, and direction of force. Both friction and frictionless mechanics offered intermittent manner of force application [20] rendering comparable magnitude and duration. Other studies used two different force systems of force application without using mini-screw as an anchorage device [1],[21],[22]. While others, only used mini- screws with en masse retraction cases compared to conventional anchorage devices for the two-step retraction. [10],[11].

In this study, a retraction force of 160 g/side was planned similar to previous studies [1],[10], [22]. To implement such a force in friction group, Correx tension gauge was used to reactivate and calibrate the elastomeric chains every four weeks. In frictionless group, 4 mm of distal activation using 0.017- by 0.025-inch TMA wire was recommended by Burstone et al. [15]. On the other hand, retraction force of 100g/side was reported by Heo et al. [22] and 150g/side by Dincer et al. [1] when 1 mm of distal activation was performed on 0.019- by 0.025-inch and 0.018- by 0.025-inch SS wires, respectively. Gjessing [2] and Schneider et al. [21] used retraction force of 100g/side for incisors retraction while greater forces were only reported for en masse retraction [20].

Angular tipping of the upper and lower first permanent molars was assessed in reference to the palatal plane and horizontal plane, respectively. While linear movement of lower permanent first molar was assessed in reference to a plane passing through the mental foramen and perpendicular to the horizontal plane.

The mesial crown tipping of all first molars as well as the linear movement of lower first molars was insignificant (P≤0.05). These findings are concurrent with the systematic review conducted by Pithon et al. [23], that mini-screws provide absolute anchorage during the retraction of maxillary anterior teeth. Similarly, Mango et al. [13], reported that angular change in position of first permanent molars was -2.43±3.12 º (UM/PP) for the maxillary first molar and -0.03±4.28 º for the mandibular first molar (LM/MP), indicating a net distal tipping that was not significant. Conversely, Upadhyay et al [11], reported 0.78±1.35mm and Al-Sibaie et al. [10], 0.89±0.74 mm of anchorage gain. On the other hand, due to absence of skeletal anchorage, Dincer et al. [1], revealed significant anchorage loss in the friction group with 2.66±2.99º mesial molar tipping and 1±0.85mm linear mesial movement.

In comparison between direct and indirect skeletal anchorage in friction and frictionless mechanics, respectively. Both prevented anchorage loss similarly with no significant anchorage loss. Comparable to that, Holberg et al [24] conducted a study using computer-aided design/computer-aided manufacturing (CAD-CAM)- models to evaluate direct and indirect loading of minis-crews. Direct loading was found to be greater for the compact bone in the proximity of the mini-screw in comparison to indirect anchorage. Therefore, indirect mini-screw anchorage is a reliable option to reduce the peri-implant loading of the bone and to reduce the risk of losing the mini-screw. Similarly, Mango et al. [13], concluded that indirect mini- screw anchorage can be a viable alternative to direct anchorage.

Limitations and Generalizability

This study was conducted in a single center and by a single operator; however, all attempts to reduce bias were considered. Blinding of the main investigator to the interventions was difficult, yet the outcome assessor was blinded to the intervention and assessed anonymous CBCTs. The upper first molar linear movement weren't assessed because no stable landmark was found to construct a frontal plane on CBCT. Also, the gender restriction to females aid in validation of the comparison but limited the results generalizability.

5. CONCLUSION

- There was no superiority of the frictionless over the friction mechanics with regards to anchorage loss.
- Both direct and indirect mini-screw anchorage were efficient methods to control the anchorage.

List of abbreviations:

ASR	anterior segment retraction
TMA	titanium molybdenum alloy
SS	stainless steel
CBCT	Cone beam computed tomography
ALARA	as low as reasonably achievable

Ethics approval: This retrospective study was performed after obtaining approval from the Institutional Review Board of Faculty of Dentistry, Future University in Egypt, (11102018).

Consent for publication: participation consent forms were signed by the patients' parents or their legally authorized representatives.

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: DMB was responsible for study design as well as data collection, analysis and interpretation. FAS and HMD were responsible for study design and critically revised the manuscript. YAM conceived the study. All authors read and approved the final manuscript.

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