Buccal Alveolar Bone changes and upper first molar displacement after maxillary expansion with RME, Ni-Ti leaf springs expander and Tooth-Bone-borne Expander. A CBCT based analysis

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Abstract

Aim To evaluate the buccal alveolar bone changes and the upper first molar displacement in subjects treated with conventional rapid maxillary expansion (RME), Ni-Ti leaf springs expander (Leaf Expander) and Tooth-Bone-borne Expander (Hybrid Expander) using CBCT scans.

Methods The sample consisted of 52 children treated with RME (n=18), Leaf Expander (n= 17) and Hybrid Expander (n= 17). CBCTs were taken before and after maxillary expansion and the Horos software was used for the analysis. Descriptive statistics and paired t-test were used to assess changes between the pre-treatment and post-treatment measurements. ANOVA test and Tukey's post hoc test with Bonferroni correction was used for between groups comparison.

Results The alveolar bone thickness at CEJ 3,5 and 10 decreased after expansion for all the three groups instead alveolar bone height had not significant variations. The ANOVA test showed a significant lower decrease of CJ3 and a greater amount of molar displacement concerning the DR variable in the Hybrid expander group. A significant buccal displacement of the first molars with increasing of DC and DR and decreasing of AI after the three expansion protocols was found.

Conclusions The Hybrid Expander during preadolescence showed few advantages over the use of tooth-anchored expanders. An expansion approach with mini-screws is not preferable during early mixed dentition to a conventional approach. The differences in dental tipping values were clinically insignificant and the reduction in cortical bone thickness remained less than 1 mm. When possible, the use of second primary molars as anchorage should be preferred.

KEYWORDS Malocclusion; Maxillary hypoplasia; Malocclusion; Leaf expander; Bone borne maxillary expander; RME; CBCT

Introduction

Over the years, different tooth- and bone-borne appliances have been tested for orthopedic maxillary expansion with different treatment protocols[Pereira et al., 2017; Krüsi, Eliades and Papageorgiou, 2019]. Among the tooth-supported expanders, rigid screw devices (Hyrax expander) or Nickel-Titanium activated-screw devices exist [Corbridge et al., 2011; Lanteri et al., 2020].

The most frequently used expansion protocols are rapid maxillary expansion (RME) and slow maxillary expansion (SME)[Maspero et al., 2020]. The former is associated with intermittent high-force systems while the latter is often associated with continuous low-force systems [Agarwal and Mathur, 2010; Corbridge et al., 2011].

In addition, hybrid expanders anchored with palatal mini-screws and upper molars bands have been deeply described [Gunyuz Toklu, Germec-Cakan and Tozlu, 2015; Garib et al., 2021].

Limited skeletal movement, dentoalveolar tipping, root resorption and buccal alveolar bone loss are possible side effects due to the use of rapid and slow maxillary expansion protocol[Baysal et al., 2012; Lin et al., 2015]. Although many treatment protocols with different expanders have been shown to be successful in achieving proper maxillary expansion, it is important for clinicians to assess their periodontal and bone thickness effects. Maxillary expanders supported by mini-screw seems to produce less side effects at the level of the periodontal tissue [Kapetanović et al., 2022].

The introduction of low-dose Cone-Beam Computerised Tomography (CBCT) analyses of skeletal, periodontal and dentoalveolar changes after orthopedic treatment[Timock et al., 2011; Gunyuz Toklu, Germec-Cakan and Tozlu, 2015] permitted us to quantitative assess the alveolar bone thickness [Timock et al., 2011].

Previous studies have investigated dentoalveolar variations after maxillary expansion with different devices and treatment protocols[Brunetto et al., 2013; Lanteri et al., 2020; Pasqua et al., 2022]. The objective of the present investigations was to evaluate three-dimensionally the potential dental and periodontal side effects produced by three different expansion protocol RME, Leaf expander and Hybrid expander by means of CBCT scans in a group of growing subjects.

Materials and methods

A longitudinal study was conducted on a sample of 52 consecutively treated patients (mean age 8.5 ± 2.5 years old) at the Department of Biomedical Surgical and Dental Sciences, University of Milan, between February 2018 and September 2021. The study protocol was approved by the Ethical Committee of the Fondazione IRCCS Ca'Granda, Ospedale Maggiore(protocol n.573/15). All procedures performed in this retrospective study involving human participants were in accordance with the ethical standards of the institutional and/or research committee and with the 1964 Helsinki declaration and its later amendments. Informed consent was obtained from all patients' parents or their guardians.

Subjects were selected with the following inclusion criteria: mixed dentition; mono/bilateral posterior cross-bite; transversal maxillary deficiency; no previous orthodontic treatment; informed consent forms signed by the patients' parents or guardians.

Exclusion criteria were: no alteration of bone metabolism or use of drugs altering the bone metabolism, lack of post-treatment records; poor radiographic quality; patients with previous orthodontic treatment; hypodontia in any quadrant excluding third molars; inadequate oral hygiene; craniofacial syndromes or cleft lip or palate; patients with obstructive sleep apnea syndrome (OSAS).

The power analysis calculation was computed using the G*Power free software (version 3.1.9.4, Franz Faul, Universitat Kiel, Kiel, Germany). The primary outcome was considered the buccal bone thickness, thus the mean values(δ) and standard deviations(σ) at 3 mm from the amelo-cement-junction (CEJ 3) after RME (δ = -0.88 σ = 0.28) and SME (δ = -1.36 σ =0.44) obtained by Brunetto et al.[2013] and a power ($1 - \beta$) of 0.80, an alpha of 0.05 were used to perform the sample size calculation.The analysis showed that 22 patients, at least 11 for each group, were needed to execute a statistically meaningful comparison.

On the basis of the aforementioned inclusion and exclusion criteria the sample included three groups:

- 18 subjects treated with Hyrax Expander, 8 mm-screw, anchored on the second upper deciduous molars (Group A), mean age 8.8 ± 2 years old.
- 17 subjects treated with Leaf Expander, 9 mm-screw, anchored on the second deciduous molars (Group B), mean age 9.0 ± 1.2 years old.
- 17 subjects treated with Hybrid expander (Forestadent GmbH, Pforzheim Germany), 10 mm-central screw, anchored on two mini-screws and supported on bands on maxillary first molars (Group C), mean age 9.2 ± 1.8 years old.

The reason behind the choice of the appliance were as follow: patients who could not show up for checkups frequently and considered less cooperative were treated with Leaf expander and assigned to the Group B as it requires no compliance from patients' parents, and it is less painful compared to conventional expanders[Lanteri et al., 2021a]. Otherwise, patients belonging to the Group C were treated with Hybrid expander as second primary molars were not available as anchorage due to different reasons such as destructive caries or previous extraction, thus mini-screws were used. The other patients were treated with conventional Hyrax expander.

The treatment protocol for group A and C was 2 activations per day (0.2mm each activation) for the first week, then the patients have been re-evaluated by the same operator who decided to continue or stop the activations considering the amount of expansion needed, while the Leaf Expander (group B) was activated following the protocol described by Lanteri et al.[Lanteri et al., 2021b].

The expansion was considered completed when the mesio-palatal cusp of the upper first permanent molars occluded on the edge of the lingual side of buccal cusps of the lower first permanent molars. All expanders were removed after 12 months.

Cortical Bone Thickness Measurements

CBCT scans were obtained before and after 12 months when the appliance was removed, using the same machine i-CAT Cone-Beam Tomography unit (Imaging Sciences International, Hatfield, PA, USA) and the same configuration with 0.25-mm volumetric reconstruction, isometric voxels, X-ray tube with 120-kV voltage, reduced field of view (FOV) 11x8-cm to decrease the radiation exposure, 3.8-mA current, and 20-second acquisition time. After acquisition, the images were saved in the Digital Imaging and Communication in Medicine (DICOM) format.

The Horos software v.3.3.6 (Horos Project, Annapolis, MA, USA), was used for analysis and measurements. This system allows multi-planar reconstructions to be obtained with the three sections corresponding to the sagittal, axial, and coronal planes.

A single operator (M.M.) made all measurements; he was unaware of the group to which each patient belonged. Axial-guided navigation (AGN) was used to locate landmarks as described by Maspero et al.[2019]. Analyses and measurements were conducted using the long axis of the mesio-buccal root of the first molar as a reference to reproduce the same axial position at T0 and T1.

According to the same method used by Brunetto et al. [2013] the standard image in the coronal section was used to determine variables related to the height of the buccal alveolar bone (NOVC and NOV variables) (Fig. 1). The buccal bone thickness was evaluated at 10, 5 and 3 mm from the amelo-cement-junction (CEJ) using as reference a line parallel to the tomographic vertical plane (Fig. 2).

Moreover, the inclination of the first molars (AI) and the amount of crown and root expansion (DC and DR) was measured at T0 and T1 to assess the maxillary first molars displacement (Fig. 3-4).

The primary outcome was the buccal bone thickness while alveolar bone height and tooth displacement and inclination were considered as secondary outcome. All parameters evaluated are summarised in table 1.

Statistical analysis

The data obtained were analysed by an expert clinician (A.U.), and descriptive statistics were performed using means and standard deviation. All statistical analyses were performed using IBM SPSS Statistics ver. 25.0 software (IBM Co., Armonk, NY, USA).

A normal distribution for the values of all parameters was checked and confirmed using the Shapiro-Wilk test.

A two-tailed paired t-test was used to compare the changes between the pre-treatment and post-treatment measurements and to compare the upper right and left permanent molars at T0.

To compare the difference between groups, the ANOVA test and Tukey's post hoc test with Bonferroni correction was used.

Data were collected by the principal investigator (M.M.) and checked by a second examiner (A.A.) to evaluate the reproducibility and reliability of the method. The observers were blinded to the patients' identity. Measurements and landmark locations were repeated (15 days after the first measurement) on 15 randomly selected CBCTs for all the variables. The Dahlberg's formula(Dhalberg, 1940) was performed, and intra-class correlation coefficients were calculated.

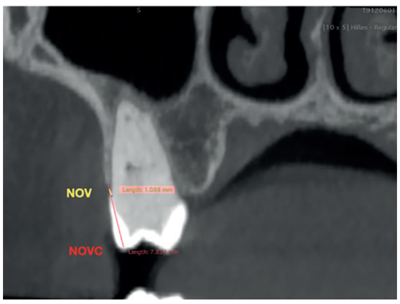

FIG. 1 Representation of the distance between the buccal CEJ and the most occlusal point of the buccal alveolar crest (NOV) and the distance between the buccal cusp tip and the most occlusal point of the buccal alveolar crest (NOVC)

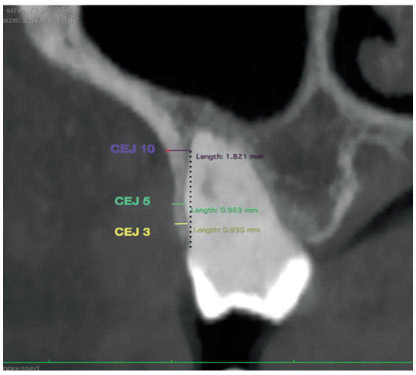

FIG. 2 The distance between the outer surface of the buccal alveolar plate and the outer alveolar bone thickness wall of the buccal root 3,5 and 10 mm above the CEJ perpendicular to the 10mm dotted line

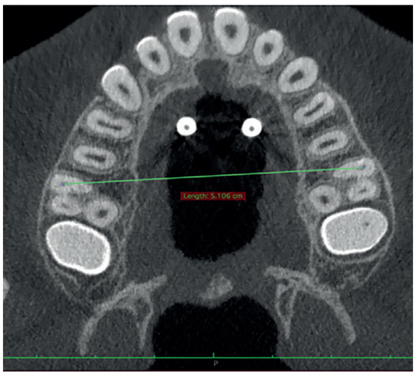

FIG. 3 DR values, measured as the distance between the most buccal points of the mesial buccal roots' canals of the first molars

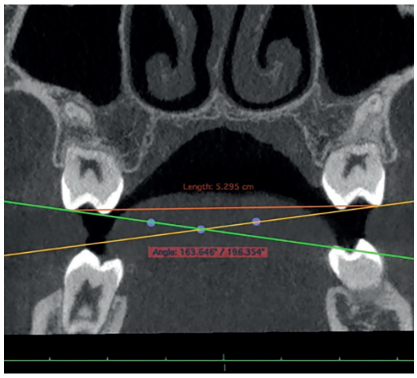

FIG. 4 The intersection of the lines passing through the mesial cusps of the maxillary upper first molars generate an angle whose value indicates the inclination of the first molars (AI), the orange line indicates DC measurement

Probabilities of less than 0.05 were accepted as significant in all statistical analyses except for the ANOVA test where it was at <0.017.

Results

The average intra-observer and inter-observer ICC (average ± SD, range) showed high results: 0.96 ±0.02, 0.91–0.99 and 0.97 ± 0.019 0.92–0.98 respectively. Dahlberg's formula showed that the random error for linear measurements was about 0.07 mm for the periodontal linear measurements and 0.3 for the linear measurements concerning tooth displacement.

Baseline comparison did not show any statistically significant difference (p>0.05) (Table 2). Paired t test demonstrated no significant difference between 16 and 26 in each group, thus data of 16 and 26 were grouped assuming that there were no significant differences between the two hemi-arches (Table 3).

The alveolar bone thickness at 3 mm from the CEJ, decreased after expansion for all three groups, more in group A (-077mm) rather than group C (-0.20 mm) and group B (-0.55mm), whereas CEJ5 did not statistically decrease after treatment. CEJ10 showed a statistically significant post-expansion alveolar bone reduction for the three considered groups. NOV and NOVC parameters, had not statistically significant variation(p>0.05) after maxillary expansion in the three groups (Table 4).Furthermore, the results demonstrated a significant buccal displacement of the first permanent molars with increasing of DC and DR in all three groups(p<0.05). AI statistically decreased after the three expansion protocols (Table 4). Between groups comparison with ANOVA test showed a significant difference for the values of CEJ3 and DR (Table 5). A significant lower decrease of CJ3 and a greater amount of molar displacement concerning the DR variable was found in the group C.

Discussion

It is well known that bone remodeling and changes in periodontal conditions are possible side effects of orthopedic-orthodontic treatments. In the present study, the possible dental and periodontal side effects post-palatal expansion with RME, Leaf Expander and Hybrid expander were investigated in growing patients with maxillary transverse discrepancy. The use of hybrid-type palatal expanders is considered a reliable and advantageous therapy for correcting transverse deficits by distributing forces to the palatal bones rather than the teeth. It is therefore assumed that this type of device causes fewer undesirable effects like cortical bone loss, as confirmed in literature[Celenk-Koca et al., 2018].

The results suggested that the cortical bone thickness at 3 and 10 mm from the CEJ showed to be reduced in a statistically significant way after RME, Leaf expander and Hybrid expander. Furthermore, the values of CEJ3 were found to be significantly more reduced in the RME and Lead Expander groups compared to the Hybrid group. Nevertheless, these differences were considered not clinically significant. The literature reported that the slight decrease of buccal bone thickness in the Hybrid expander group, less than with traditional RME, also occurred in case of purely palatal anchored palatal expanders without bands on dental elements[Garib et al., 2006].

Measure	Description	Aim
NOV (mm)	Distance between the end of the buccal alveolar bone ridge and the buccal CEJ.	Alveolar bone height
NOVC (mm)	Distance between the end of the alveolar buccal bony ridge and the vertex of the buccal cusp.	Alveolar bone height
CEJ3 (mm)	Distance between the outer buccal margin of the root and the outer buccal margin of the alveolar bone 3mm from the CEJ.	Alveolar bone thickness
CEJ5 (mm)	Distance between the external buccal margin of the root and the external buccal margin of the alveolar bone at 5mm from the CEJ.	Alveolar bone thickness
CEJ10 (mm)	Distance between the outer surface of the buccal alveolar plate and the outer wall of the buccal root 10mm above the CEJ.	Tooth inclination
DC (mm)	Distance between the mesial buccal cusp tips of the maxillary first permanent molars.	Tooth displacement and inclination
DR (mm)	Distance between the most buccal points of the root canals of the mesial buccal roots of the maxillary first permanent molars	Tooth displacement and inclination
AI (°)	Angle formed by the intersection of 2 lines traced toward the midline and tangent to both mesial cusp tips of each maxillary first permanent molar	Tooth inclination

TABLE 1 Definition of variables in tomographic analysis

T0.	Group A		Group B		Group C		ANOVA test
	Mean	SD	Mean	SD	Mean	SD	p value
CEJ3	2.46	0.71	2.33	0.57	2.18	0.42	NS
CEJ5	2.36	0.67	2.68	0.62	2.31	0.45	NS
CEJ10	4.50	1.10	4.37	1.04	4.16	1.85	NS
NOV	2.10	0.66	2.11	0.51	2.03	0.35	NS
NOVC	7.76	0.90	8.15	0.89	7.69	0.75	NS
DC	50.68	3.36	51.79	3.38	50.56	2.69	NS
DR	45.72	2.22	47.02	3.67	46.08	1.80	NS
AI	127.84	8.38	128.31	7.25	129.43	7.56	NS
**: statistically significant difference (p<0.017); NS: not significant							

TABLE 2 Mean, Standard deviation (SD) and statistical comparison at T0 between the three groups

Regarding the movement of the first permanent molar, values of DC an AI confirmed previous findings of displacement and buccal inclination of these teeth after rapid and slow maxillary expansion[Garib et al., 2006], but they did not show a significant difference between the three appliances confirming a less molar tipping on the uppers first molars when the appliance is bonded on the deciduous teeth [Cozzani et al., 2003; Ugolini et al., 2015] (Table 5). Conversely, the tooth displacement at the root level (DR) showed greater results for the Hybrid appliance corroborating that expansion on mini-screws causes more bodily movement of the permanent molars[Lin et al., 2015]. Moreover, it is possible to observe that even with the use of hybrid expander there is a reduction of the buccal bone thickness of the mesial vestibular roots of the upper first molars. In fact, considering the hybrid group, the values of CEJ3, CEJ5 and CEJ10 were reduced, with a greater decrease of CEJ10 (- 0.79 mm).

The differences in NOV and NOVC were not statistically significant, which confirmed that the use of deciduous teeth as anchorage or bone-borne appliance allowed the preservation of the vertical bone peak (Table 5). The findings obtained were superimposable with those proposed by Celenk-Koka et al.[2018], in which they showed that even in appliances supported by mini-screws there was a slight decrease in the buccal thickness of the first molars between T0 and T1 (-0.10mm).

Regarding the vertical bone height Lin et al.[2015]demonstrated a decrease of about 0.10 mm which is superimposable to our results, a difference that is neither statistically nor clinically relevant as it also resulted in the study performed by Pham and Lagravere[2017]

No dehiscence was detected in our sample, which are instead often reported in other studies on patients treated with RME 17.

Comparing the present findings with those of Digregorio et al.[2019] on patients treated with RME using both deciduous and permanent molars as anchorage, the authors can state that the reduction in bone thickness occurred in a statistically and clinically less significant way when the appliance is bonded on the second deciduous molar.

Regarding the change in molar angulation and the resulting coronal tipping, Martina et al. [2012] reported a 3°- 4° increase towards the buccal side, which is greater than the results obtained in the current study. In fact, the sharpening of the AI angle of the three investigated groups, and therefore the increase of the coronal tipping of the first molars, was not clinically significant, confirming a predominantly bodily movement of the teeth, greater in the hybrid expander, with less compensatory dental movement.

Considering also the most recent literature, our findings were comparable with those of Bazargani et al.[2021]. They reported, in their RCT, that in young preadolescents with constricted maxilla, conventional RME achieves the same clinical results of the tooth-bone-borne RME in terms of dental expansion, alveolar bending, and tipping of the upper first molars.

Among the limitations of the present research, the author can state the retrospective design of the study and the lack of long-term follow-up. In fact, retrieving multiple scans of a patients over time could allow us to better understand the possible three-dimensional longitudinal changes over time such as eventual alveolar bone damages. Further prospective CBCT studies, with long-term examinations are necessary to accurately evaluate the periodontal changes after LeafExpander, RME and Hybrid expander treatment.

Conclusions

In conclusion, data showed that from the point of view of the periodontal tissues, an expansion approach with mini-screws is not preferable during early mixed dentition to a conventional approach. The reduction in cortical bone thickness at 3,5 and 10 mm from the CEJ remained less than 1 mm. Furthermore, the vestibular alveolar ridge height has not undergone any clinically significant changes after the three expansion protocols. The single advantage was the less coronal molar tipping, which did not show a statistically significant difference. Therefore, when possible, the use of the second primary molar as anchorage should be preferred. The use of maxillary expanders supported by mini-screws in young preadolescent should be adopted wisely by the orthodontist keeping in mind the most appropriate clinical conditions.

Conflicts of Interest The authors declare no conflict of interest.
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Ethical approval The Ethical Committee of the Fondazione IRCCS Ca'Granda, Ospedale Maggiore, Milan - Italy (protocol n.573/15) which follows the World Medical Association Declaration of Helsinki, approved the research protocol. Signed informed consent for the

	Group A (16 vs 26)					Group B (16 vs 26)					Group C (16 vs 26)				
	Mean	SD	Mean	SD	p value	Mean	SD	Mean	SD	p value	Mean	SD	Mean	SD	p value
CEJ3	2.47	0.46	2.45	0.68	NS	2.31	0.62	2.33	0.53	NS	2.33	0.51	2.03	0.26	NS
CEJ5	2.37	0.58	2.35	0.72	NS	2.65	0.65	2.70	0.61	NS	2.29	0.40	2.31	0.52	NS
CEJ10	4.47	0.75	4.54	1.10	NS	4.34	1.16	4.39	1.12	NS	4.03	1.79	4.28	1.98	NS
NOV	2.13	0.50	2.07	0.69	NS	2.19	0.59	2.03	0.48	NS	2.11	0.66	1.96	0.49	NS
NOVC	7.70	0.91	7.82	0.89	NS	8.18	2.78	8.12	0.94	NS	7.77	0.54	7.59	0.93	NS
DC	50.56	1.54	50.81	1.56	NS	51.1	3.86	52.48	2.08	NS	50.69	2.52	50.42	3.13	NS
DR	45.84	1.47	45.61	2.18	NS	46.07	4.64	47.95	2.35	NS	45.30	1.60	46.84	1.80	NS
AI	128.16	9.31	127.52	8.46	NS	130.53	5.94	128.39	4.16	NS	130.05	7.06	128.81	8.82	NS
*: statistically significant difference (p<0.05); NS: not significant															

TABLE 3 Mean, Standard deviation (SD) and statistical comparison with Paired t test, of 16 and 26 in each group at T0

	Group A T0-T1		Group B T0-T1		Group C T0-T1	
	Mean	SD	Mean	SD	Mean	SD
CEJ3	-0.77*	0.60	-0.55*	0.49	-0.20*	0.29
CEJ5	-0.13 NS	0.65	-0.25NS	0.53	-0.32NS	0.54
CEJ10	-0.81*	1.14	-0.94*	0.64	-0.79*	0.78
NOV	0.15 NS	0.56	0.26 NS	0.37	-0.17 NS	0.35
NOVC	-0.51 NS	0.78	-0.72 NS	3.19	0.16 NS	0.40
DC	5.37*	1.93	4.75*	1.73	3.64*	2.20
DR	3.68*	2.11	3.81*	2.00	4.49*	1.95
Al	-5.42*	3.08	-5.78*	2.03	-4.59*	3.74
*: statistically significant difference (p<0.05); NS: not significant.						

TABLE 4 Mean, Standard deviation (SD) and statistical comparison with Paired T test for RME (Group A), Leaf Expander (Group B) and Hybrid expander (Group C) between T1-T0

	ANOVA test	Tukeys' post-oc with Bonferroni's correction		
		B vs C	B vs A	C vs A
CEJ3	0.00**	0.00**	0.20	0.00**
CEJ5	0.20 NS	0.24	0.31	0.33
CEJ10	0.69 NS	0.74	0.92	0.870
NOV	0.02 NS	0.486	0.05	0.028
NOVC	0.03 NS	0.162	0.034	0.06
DC	0.08	0.108	0.453	0.038
DR	0.015**	0.015**	0.306	0.003**
AI	0.11	0.347	0.720	0.535
**: statistically significant difference (p<0.017); NS: not significant.				

TABLE 5 ANOVA test comparing the net values of the three groups and the related pairwise comparisons(p<0.017) with Tukey post-hoc test with Bonferroni's correction

release of diagnostic records for research purposes was gained from parents of all patients included in the research.

Author Contributions Conceptualisation: A.C., M.M., A.A., V.L.; Methodology: A.C., A.U.; Investigation: M.M., F.G., V.L and A.A.; Validation: A.U.; Software, M.M; Formal Analysis: F.G. and A.A.; Data Curation: A.U., and A.A; Writing-Original Draft Preparation: M.M., A.A. and F.G ; Writing-Review And Editing: A.C., A.U., V.L. and A.A; Supervision: A.C., V.L. All authors have read and agreed to the published version of the manuscript.

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