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Assessment of Nasopharyngeal Changes Following MARPE and Self-ligating Appliance Treatments: A CBCT-based Study

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Authors' contributions

This work was carried out in collaboration among all authors. Author AMdRG managed the literature searches, managed the analysis of the study and wrote the first draft of the manuscript. Author TF wrote the first draft of the manuscript. Author CMMR, AO, DMT and JEPdS managed the acquisition of data and interpretation of data, Author FPV, PC and CRMP-V managed the literature searches, wrote the protocol of the study, managed interpretation of data. Author KMSF performed the statistical analysis, managed the acquisition and interpretation of data, wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Objective: The objective of this study was to compare the sagittal area, minimum axial area and volume of the nasopharynx after treatment with MARPE and self-ligating appliances.
Materials and Methods: The sample consisted of documentation and initial and final CT scans of 37 patients with Class I malocclusion treated without extraction, divided into 2 groups: Group 1 (Self-ligating): 21 patients, mean age of 19.55 years (s.d.=1.31), 11 men and 10 women, with moderate dental crowding, presence of maxillary atresia and treated with self-ligating fixed appliance Damon 3MX. Group 2 (MARPE): 16 patients, with a mean age of 24.92 years (s.d.=7.60), 11 women and 5 men, with the presence of maxillary atresia and posterior crossbite and treated with mini-implant anchored rapid maxillary expansion (MARPE). The Dolphin Imaging 3D software was used to assess nasopharyngeal changes using CBCT scans before and after treatment with MARPE and after leveling with self-ligating appliances. Intergroup comparison was performed using the independent t-test.
Results: The MARPE group showed a statistically greater increase in all nasopharyngeal measurements, ie, sagittal area, minimum axial area and volume, with treatment, than the self-ligating group.
Conclusion: Miniscrew-supported rapid maxillary expansion (MARPE) achieved better results with a greater increase in all nasopharyngeal measurements than self-ligating appliances.

Keywords: Orthodontic anchorage procedures; airway management; cone beam computed tomography; fixed orthodontic appliances.

1. INTRODUCTION

The miniscrew assisted rapid palatal expansion (MARPE) was developed to treat young adult patients with maxillary discrepancy, minimizing the need for surgically assisted rapid maxillary expansion. According to Lombardo et al. [1] “the expansion obtained with MARPE causes minimal damage to the teeth and periodontium, correcting transverse deficiencies. Furthermore, as mini-implants are anchored in bone, the force exerted by the device results in skeletal movement”.

In an attempt to correct maxillary atresia with compensatory orthodontics, self-ligating appliances are an accessible option for orthodontists. According to Lima et al. [2] “the Damon self-ligating system increases the dimensions of the maxillary arch, mandibular intercanine and interpremolar distances compared to conventional appliances”.

“Some authors claim that MARPE can improve airflow in the nasal cavity, leading to an improvement in respiratory function due to the increase in volume of the upper airways” [3-7]. With self-ligating appliances, there appears to be no significant increase in the upper airways [8,9].

According to Calil et al. [10] “MARPE produced more skeletal effects, and the self-ligating appliances more dental effects” [10]. Furthermore, MARPE is effective and efficient in increasing the airway dimensions, which increases the nasal cavity and nasopharyngeal volume [11]. Both skeletal and dental maxillary expansion efficiently increases airway volume [11].

Since there is no comparison between the changes of nasopharyngeal measurements after treatment with self-ligating appliances and the MARPE appliance, this study aimed to compare the sagittal area, minimum axial area and nasopharynx volume after treatment with MARPE and self-ligating appliances.

2. MATERIALS AND METHODS

2.1 Materials

The sample calculation was based on an alpha significance level of 5% and a beta of 20% to detect a minimum difference of 5500mm³ with a mean standard deviation of 5408.15mm³ for the nasopharynx volume [12]. Therefore, the sample calculation resulted in the need for at least 16 patients in each group.

This retrospective research comprised patients previously treated at the Instituto de Odontologia Avanzada, Assunción, Paraguay and Bauru Dental School, University of São Paulo, Bauru, Brazil.

The following inclusion criteria were used: patients with Class I malocclusion, no prior orthodontic treatment, presence of all erupted teeth up to first molars, healthy periodontium, and minimum age of 16 years.

The sample consisted of initial and final cone beam computed tomography (CBCT) scans of 37 patients divided into 2 groups:

Group 1 (Self-ligating): 21 patients (11 male; 10 female) with a mean age of 19.55 years (s.d.=1.31), with moderate dental crowding, presence of maxillary atresia requiring transverse maxillary increase and treated with self-ligating fixed appliance (Damon 3MX, Ormco, Orange, USA). This sample was obtained from the archives of the Bauru Dental School, University of São Paulo, Bauru, Brazil. The archwire sequence for alignment and leveling of teeth was followed: 0.014", 0.014"x0.025", and 0.016"x0.025" Copper NiTi (Ormco, Orange, USA). Finally, 0.019"x0.025" stainless steel archwires were installed. Alignment time was 6 months on average. Patients were evaluated at the beginning of treatment (T1) and the end of the alignment and leveling stage (T2), when the 0.019"x0.025" stainless steel archwires were in place for one month.

Group 2 (MARPE): 16 patients (5 male; 11 female), with a mean age of 24.92 years (s.d.=7.60), with maxillary atresia and posterior crossbite, treated with miniscrew assisted rapid palatal expansion (MARPE). This sample was obtained from the archives of the Instituto de Odontologia Avanzada, Assunción, Paraguay. The patients underwent maxillary disjunction with the MARPE device (PecLab, Belo Horizonte, Brazil), model SL, supported on four titanium mini-implants of 1.8mm diameter and 8mm length, with bands on the first molars. The activation protocol was ¼-turn in the morning and ¼-turn at night until a relationship was obtained in which the palatal cusps of the maxillary first molars touched the buccal cusps of the mandibular first molars. No other orthodontic treatment was performed. Suture rupture was confirmed clinically by evaluating the opening of the maxillary interincisor diastema. Only patients with success in opening the midpalatal suture were included. Three cases of failure in opening the midpalatal suture were not included in the MARPE sample. The device was maintained for 4 months after the end of expansion. Patients were evaluated at the beginning of treatment (T1) and right after the removal of the expander (T2).

2.2 Methods

To evaluate changes in the nasopharynx, CBCT scans were performed before treatment (T1) and after alignment and leveling in the self-ligating group and immediately after the removal of the expansion appliance in the MARPE group (T2).

In group 1, patients underwent CBCT scans with the i-Cat Cone Beam 3-D Dental Imaging System (USA), with the following image acquisition protocol: amperage of 36.12mA, 120kV, field of view (FOV) of 13cm (including the entire face), exposure time was 40 seconds, generating a voxel of 0.25x0.25x0.25mm.

In group 2, CBCT scans were performed using the Orthophos SL 2D/3D device (Sirona Dental Systems GmbH, Germany) with the following image acquisition protocol: FOV of 8cm Ø x 5.5cm height (maxilla) and voxel of 0.08mm.

The images were saved and imported in DICOM (Digital Imaging and Communications in Medicine) format and were measured using Dolphin Imaging 3D software (Chatsworth, USA), version 11.95 Premium.

Initially, the head position was standardized, using as a reference in the frontal view, the plane that passes through the lowest point of the infraorbital foramina, in the lateral view and also in the axial direction, the plane that passes through the Anterior Nasal Spine (ANS) and Posterior Nasal Spine (PNS) [10].

2.2.1 Analysis of the upper airway (nasopharynx)

Since the MARPE group's CBCT scans included only the maxilla, the oropharynx could not be evaluated.

The nasopharynx was measured using a tool from the Dolphin Imaging 11.95 Premium program (Chatsworth, USA) appropriate for evaluating the upper airways [9]. A plane transverse to the sagittal plane passing through in the PNS and the lower medial border of the

first cervical vertebra divides the pharyngeal airway into two segments: nasopharynx (upper) and oropharynx (lower) [9].

The limits of the nasopharynx, or upper airway, were 2 lines: the upper line was established by a point on the posterior edge of the nasal spine (PNS) and the midpoint of the curvature between the upper and lower surfaces of the basilar portion of the occipital bone (Ba). The lower line was established by a medial point in the anterior region of the first cervical vertebra (CV1m) to a point on the anterior wall of the nasopharynx, parallel to the nasal floor (Na) (Fig. 1).

“Once the portion of the airway of interest was defined, the Dolphin 3D airway analysis tool was used to measure the nasopharynx. This program allowed airway selection by defining a threshold range of computed tomography units that characterized the sectioned airspace. As the air space has a lower computed tomography value than the denser surrounding soft tissues, it was possible to delimit the same region to perform the measurements” [10]. Then, using the sinus/airway analysis option, points were marked in the selected region and the volume option was updated and the software shows the volume, sagittal area and minimum axial area of the nasopharynx (Fig. 1).

2.2.2 Error study

To calculate the error of the method, the initial and final CBCT scans of 12 patients were evaluated. The first and second measurements were performed with a month interval. Dahlberg's formula was used to evaluate the casual errors [13], and the systematic errors were evaluated by dependent t test [14].

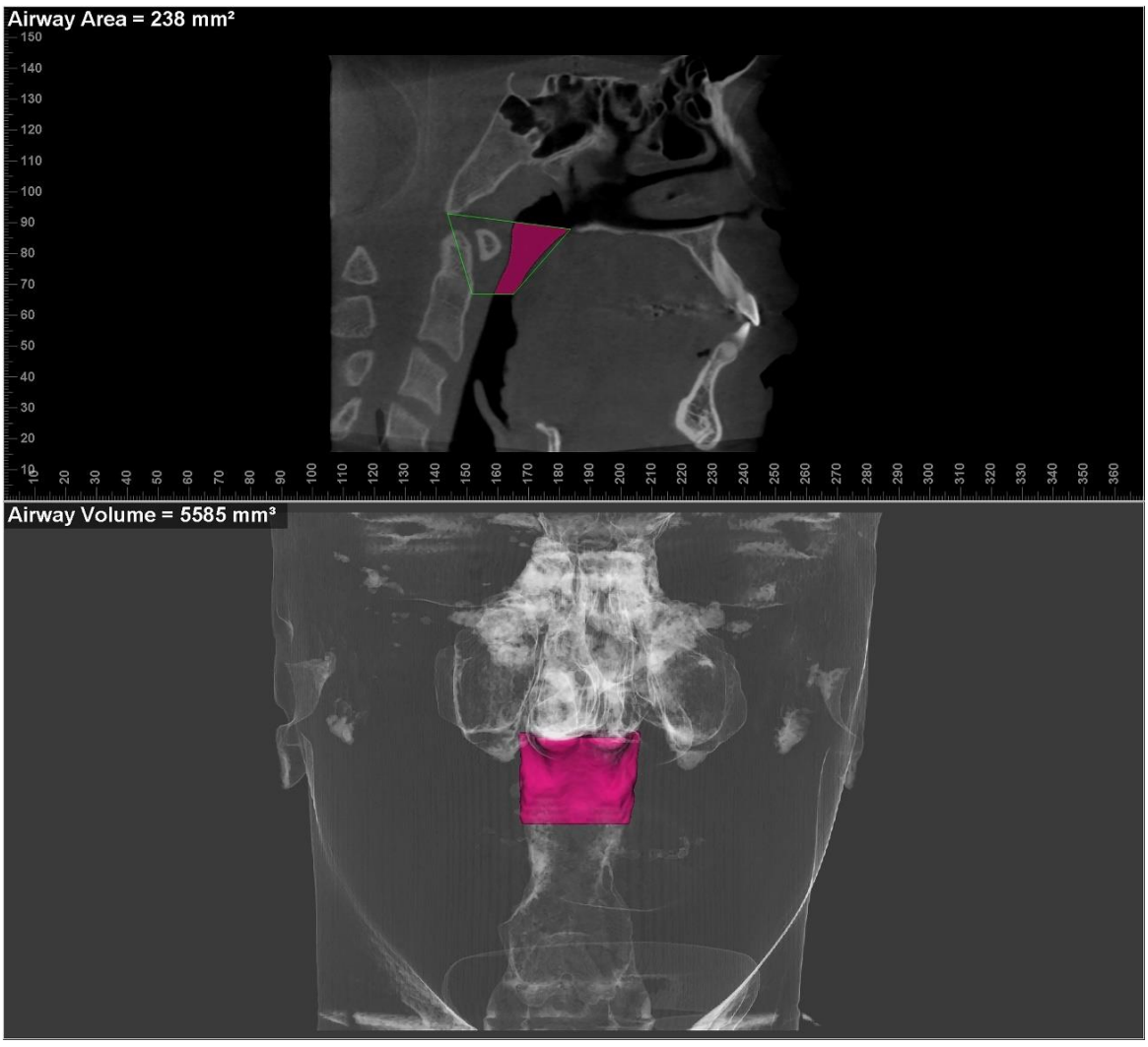

Fig. 1. Nasopharynx measurement

2.2.3 Statistical analysis

The normality of the data normality was confirmed by the Shapiro-Wilk test. Intragroup comparisons were performed using the dependent t test. Intergroup comparisons at T1 and T2 stages and changes with treatment were performed using the independent t test.

The tests were performed with Statistica software (version 12.0, Statsoft, Tulsa, USA). Data were considered significant at P <0.05.

3. RESULTS

There was no significant systematic error, and the largest casual error was 52.41 mm^3, considered within acceptable limits [15].

The self-ligating group was significantly younger than MARPE group (Table 1). The sex distribution was compatible between the groups (Table 1).

The comparison between the initial and final stages of the self-ligating group showed no significant changes in the measurements of the nasopharynx with the treatment performed (Table 2). The MARPE group showed a statistically significant increase in the sagittal area and nasopharyngeal volume with treatment (Table 2).

The groups were compatible in nasopharyngeal measurements in the initial stage, and the measurements were also similar between the groups in the final stage (Table 3). With treatment, the MARPE group showed a statistically significant increase in all nasopharyngeal measurements, i.e., sagittal area, minimum axial area and volume, compared to the self-ligating group (Table 3).

Table 1. Results of the intergroup compatibility of age and sex distribution

Variables	Self-ligating (N=21) Mean (s.d.)	MARPE (N=16) Mean (s.d.)	*P*
Age (years)	19.55 (1.31)	24.92 (7.60)	**0.003*** [T]
Sex			X^2 =1.65
Males	11	5	DF=1
Females	10	11	p=0.198 [α]

** Statistically significant for P <0.05*
[T] independent t test; [α] chi-square test

Table 2. Results of the intragroup comparison of the initial and final stages of nasopharyngeal measurements (dependent t-test)

Variables	Initial		Final		*P*
	Mean	**s.d.**	**Mean**	**s.d.**	
Self-ligating (n=21)					
Sagital area (mm^2)	233.13	111.45	270.02	106.82	0.140
Minimum axial area (mm^2)	78.21	62.13	83.22	71.65	0.405
Volume (mm^3)	6943.63	4789.23	7532.81	5489.17	0.356
MARPE (n=16)					
Sagital area (mm^2)	229.71	107.88	304.83	95.22	**0.045***
Minimum axial area (mm^2)	75.91	59.12	104.37	45.01	0.136
Volume (mm^3)	6723.15	4678.92	9995.61	4002.33	**0.042***

** Statistically significant for P<0.05*

Table 3. Results of intergroup comparison of the initial (T1) and final (T2) stages and treatment changes (T2-T1) of nasopharyngeal measurements (independent t-tests)

Variables	Self-ligating (N=21)		MARPE (N=16)		*P*
	Mean	**s.d.**	**Mean**	**s.d.**	
Initial stage (T1)					
Sagital area (mm^2)	233.13	111.45	229.71	107.88	0.926
Minimum axial area (mm^2)	78.21	62.13	75.91	59.12	0.910
Volume (mm^3)	6943.63	4789.23	6723.15	4678.92	0.889

Variables	Self-ligating (N=21)		MARPE (N=16)		*P*
	Mean	**s.d.**	**Mean**	**s.d.**	
Final stage (T2)					
Sagital area (mm^2)	270.02	106.82	304.83	95.22	0.311
Minimum axial area (mm^2)	83.22	71.65	104.37	45.01	0.308
Volume (mm^3)	7532.81	5489.17	9995.61	4002.33	0.139
Treatment changes (T2-T1)					
Sagital area (mm^2)	36.89	17.44	75.12	26.74	**0.000***
Minimum axial area (mm^2)	5.01	3.07	28.46	12.56	**0.000***
Volume (mm^3)	589.18	400.92	3272.46	2531.16	**0.000***

** Statistically significant for P<0.05*

4. DISCUSSION

In this study, the sagittal area, minimum axial area and volume of the nasopharynx were evaluated using CBCT scans. CBCT was chosen due to the high quality images, with little distortion and high resolution [16]. Therefore, it is important that groups are comparable to avoid the influence of other factors.

There was a statistically significant difference in the age of the groups, where the self-ligating group was younger than the MARPE group (Table 1); however, most patients were young adults. Lagravère et al. [17] reported that there is little bone growth in adulthood in the transverse dimension. Furthermore, the groups were evaluated for a short period of time: the self-ligating group was evaluated for 6 months and the MARPE group was evaluated immediately after expansion (average of 4 months). These differences in initial age and time between the first and second CBCT scans probably did not influence the results. In the self-ligating group, patients had a minimum age of 18 years and a maximum of 20 years and in the MARPE group, a minimum age of 17 years and a maximum of 32 years. And it was observed that there are no significant growth changes in maxillary width in women after 15 years of age and in men after 18 years [18,19]. Although the self-ligating group is statistically younger, which would tend to favor better results for this group, the results were statistically significantly higher for the MARPE group in relation to all nasopharyngeal measurements.

In the present study, patients who did not show opening of the midpalatal suture after treatment with MARPE were excluded [20]. The advanced degree of bone maturation of this suture can occur even in young adult patients, justifying the failure in some cases [21]. However, failure can also come from the zygomatic-maxillary complex and the circummaxillary sutures [22]. To avoid this, it is necessary to create a complete treatment plan with CBCT scans [19,20,23].

The groups performed the CBCT scans with different voxels (0.25mm and 0.08mm for self-ligating and MARPE, respectively), but this did not compromise the reliability of the results [24]. It is known that the smaller the voxel, the sharper the CBCT images, however, the 0.25mm voxel (self-ligating group) presented sufficient sharpness for measurements of the nasopharynx. According to a previous study, tomographic measurements had similar reproducibility, even with images of different voxel sizes [25].

The measurements were made only in the nasopharynx because the MARPE sample had CBCT scans only from the maxilla, which did not allow the measurement of the oropharynx.

There was no statistically significant increase in the nasopharynx after leveling with self-ligating appliances (Table 2), corroborating previous studies [8,12]. In the study by Vieira et al. [12], the Damon System produced a significant transverse increase in the posterior region of the maxillary and mandibular arches with differences in dental inclinations, however, there was no significant difference in the upper airways [12]. Besides, rapid maxillary expansion with Hyrax followed by fixed appliances produced more dimensional changes in the upper airway than the Damon system [8].

The results found show an increase in the nasopharynx and improvement in the upper airway with MARPE treatment, which may favor an increase in airflow [26-29], also enabling improvement in tongue posture and favorable pharyngeal adaptations, contributing to improvement in Obstructive Sleep Apnea Syndrome (OSAS) [30-32].

With the expansion of the MARPE group, there was a statistically significant increase in the

nasopharyngeal sagittal area and volume (Table 2), corroborating previous studies [3,33,34].

Abdalla et al. [16] reported that, at pretreatment, patients with younger skeletal age had a greater prediction of airway changes during treatment and had a greater increase in airway volume [4,5,35,36].

Furthermore, the nasopharynx volume measured in the MARPE group was from 6,723.15 mm³ to 9,995.61 mm³ (Table 3). Yi et al. [36] reported a statistically significant increase in nasopharyngeal volume of 8.48% in the MARPE group. Kim et al. [4] noted a statistically significant increase in the volume of the nasal cavities and the volume of the nasopharynx after MARPE [4,36].

Therefore, treatment with MARPE resulted in a greater increase in the nasopharynx than leveling and alignment with self-ligating brackets. No known studies have compared these treatment modalities. However, several studies show an increase in the upper airway after MARPE [4,5,11,36] and some studies have shown no significant changes in the upper airway with self-ligating appliances [8,12].

Both self-ligating and MARPE appliances have transverse expansive effects [10]. However, since MARPE promotes a greater skeletal effect than treatment with self-ligating appliances [10], a greater increase in airways was already expected with MARPE compared to the self-ligating appliance, as demonstrated by the results of the present study.

The limitations of the study are the small and retrospectively obtained sample and the fact that the oropharynx could not be evaluated.

5. CONCLUSION

MARPE treatment obtained better results with a greater increase in all nasopharyngeal measurements than self-ligating appliances.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

CONSENT

It is not applicable.

ETHICAL APPROVAL

This study was approved by the Human Research Ethics Committee of Ingá University Center UNINGÁ (protocol n. 51486321. 4.0000.5220).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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