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Case Studies

Effects of maxillary skeletal expansion on respiratory function and sport performance in a para-athlete – A case report

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ABSTRACT

The aim of this case report was to demonstrate the effects of the Maxillary Skeletal Expander (MSE) used to orthopedically correct a maxillary constriction, on the respiratory functions and swimming performance of a Para-athlete. Cone-beam computed tomography (CBCT) images taken before and after MSE activation were used to demonstrate the disarticulation of midpalatal suture, and the changes involved in dental and nasomaxillary structures, nasal cavity and pharyngeal airway. Respiratory tests included: maximum inspiratory and expiratory pressure, oral peak expiratory flow and inspiratory nasal flow. The 6-min-walk and heart rate recovery tests were also performed. Patient's swimming performances during national swimming competitions were compared. CBCT images showed that palatal expansion was 5.91 mm at the suture, and that nasal and pharyngeal airways increased in volume by 31%. All respiratory indices improved after MSE activation. The 6-min walk test and heart rate recovery test performance also improved after the maxillary expansion. Patient's swimming performance in all category were anemic prior to the treatment, but performance improved considerably after the expansion, particularly the 100 m-Backstroke modality. MSE treatment had a significant positive impact in respiratory functions and sport performance.

1. Background

Several problems may be associated with maxillary constriction such as poor esthetics, occlusal disharmonies, deprived masticatory function, speech impediments, and a compromised airway. A narrow maxilla may have genetic or environmental etiology, or often a combination of both (Carlson, 2015). This may be related to sucking habits, skeletal discrepancies, cleft palate and abnormal functions (Malandris & Mahoney, 2004). One environmental factor that may influence the growth of the maxilla is mouth breathing, leading to a more downward tongue position, rotation of the mandible, less transversal development of the maxilla and functional changes (Okuro et al., 2011).

Functional complications are often presented as collapsed pharyngeal airway, increased resistance in nasal airflow, and altered tongue posture; they result in narrowing of the retroglossal airway, difficulties in nasal breathing, and, consequently, a decline in patient's quality of life (Camacho et al., 2017). Traditionally, in Orthodontics, rapid palatal expansion (RPE) is the most common treatment modalities for the above problems. The increase in nasal airway volume induced by RPE treatment has been illustrated by quantifying post-treatment effects using two-dimensional (2D) cephalometric radiographs and/or three-dimensional (3D) Cone Beam Computed Tomography (CBCT) (Bouserhal, Bassil-Nassif, Tauk, Will, & Limme, 2014). The purpose of the appliance used for RPE is to exert a transverse force on the maxillary dentition aiming to disrupt the midpalatal suture, providing both orthopedic and dental expansion for the correction of skeletal/oclusal disharmony (Mundstock et al., 2007). Although RPE can produce some skeletal expansion, it often produces significant unwanted tooth movements, especially in mature patients. Furthermore, RPE is effective in achieving expansion of the anterior and inferior parts of the maxilla but much less effective for the posterior and

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superior regions of the maxilla (Cantarella et al., 2017; Moschik, 2018).

Alternatively, various Micro-implant Assisted RPE (MARPE) appliances that can localize the lateral forces to the midpalatal suture and minimize the unwanted tooth movements, particularly for older patients have been proposed (Carlson, Sung, McComb, MacHado, & Moon, 2016; Lee, Park, Park, & Hwang, 2010). MARPEs are either completely or partially bone-borne expander and promote more skeletal effects, leading to more midpalatal suture separation and larger nasal cavity volume increase. However, many MARPE designs cause more expansion in the anterior and inferior aspects of the nasal cavity, similar to RPE in young patients, and have limited expansion in the posterior and superior region of the nasal cavity (Ludwig et al., 2013; Park et al., 2017). Maxillary Skeletal Expander (MSE) is a unique MARPE with special features to promote expansion in the posterior and superior aspects of the nasal cavity (Cantarella et al., 2017, 2018; Moon, 2018). This is accomplished by anchoring the expander onto the posterior palate and by achieving the bi-cortical engagement (palatal and nasal cortical bone layers) of the implants (Cantarella et al., 2017, 2018; Lee, Moon, & Hong, 2017; Moon, 2018).

Additionally, functional examinations with rhinomanometry, acoustic rhinometry, inspiratory/expiratory peak flows, and spirometry procedures indicate a significant decrease in nasal airway resistance and increase in airflow after maxillary expansion, possibly due to the improvements in nasal breathing (White, Woodside, & Cole, 1989). However, the enlargement of upper airway space may not necessarily imply an improvement in the respiratory performance. Although some reports have investigated such relationship, results are sometimes contradictory (Iwasaki et al., 2013). This relationship should be further examined for clarification.

Athletes can be distinguished from general population by having better cardiovascular function, larger stroke volume, and greater maximal cardiac output, and therefore would present higher respiratory function parameters (Durmic et al., 2015). Maladaptive changes in respiratory system caused by nasal obstruction, expiratory flow limitation, or other factors can accelerate respiratory muscle fatigue and negatively influence their performance (Durmic et al., 2015; Hackett, Johnson, & Chow, 2013).

The aim of this case report was to evaluate the effects of Maxillary Skeletal Expander (MSE) on airway dimensions, respiratory function and sport performance in a young adult Para-athlete.

2. Case description

2.1. Diagnosis of the malocclusion

An eighteen-year-old male patient presented to the post-graduation orthodontic clinic at Sao Leopoldo Mandic Institute and Research Center for consultation with a chief complain of: “my bite is not right” (Figs. 1 and 2). Although posterior relationship between upper and lower dental arch was acceptable (Class I malocclusion), anterior part of the occlusion was not well related due to two missing teeth in the upper arch. Patient also presented moderate mandibular crowding, an edge-to-edge posterior cross-bite and a “V-shaped” maxillary arch, which is a sign of a constricted maxilla (Fig. 1). Panoramic x-ray showed permanent dentition, including third molars and missing lateral incisors. Lateral x-ray showed a mandible positioned 6 mm in front of the maxilla (skeletal Class III relationship) with vertical growth pattern (Fig. 2). Patient did not present any systemic condition such as chronic respiratory, cardiovascular, neurological or metabolic disorders as well as ongoing medication intake.

Orthodontic treatment objectives included firstly to correct the maxillary constriction with skeletal expansion followed by establishing proper posterior and anterior occlusion.

2.2. Treatment options

In adult patients, due to the rigidly interdigitated sutures and fully matured perimaxillary structures resisting against expansion force, maxillary osteotomies may be necessary, and surgically assisted rapid palatal expansion (SARPE) may be helpful. However, these invasive surgical procedures come with increased risks of morbidity and treatment costs for the patient. Some have suggested a less invasive option such as expansion compensation, utilizing fixed orthodontic appliances with light forces to move teeth (Fleming, Lee, McDonald, Pandis, & Johal, 2014), but this approach presents risks of dental tipping and compromised periodontal support, including bone loss and gingival recession. The other alternative is midfacial expansion by the Maxillary Skeletal Expander (MSE) (Brunetto, Sant’Anna, Machado, & Moon, 2017; Cantarella et al., 2017; C.; Carlson et al., 2016; Moon, 2016, 2017; Moschik, 2018; Suzuki et al., 2016) in order to achieve a midpalatal suture separation without adverse dental side effects, to eliminate the need for surgery (SARPE or Le Fort I), to improve the upper airway volume, and to enhance the respiratory index.

Fig. 1. Initial intraoral photographs.

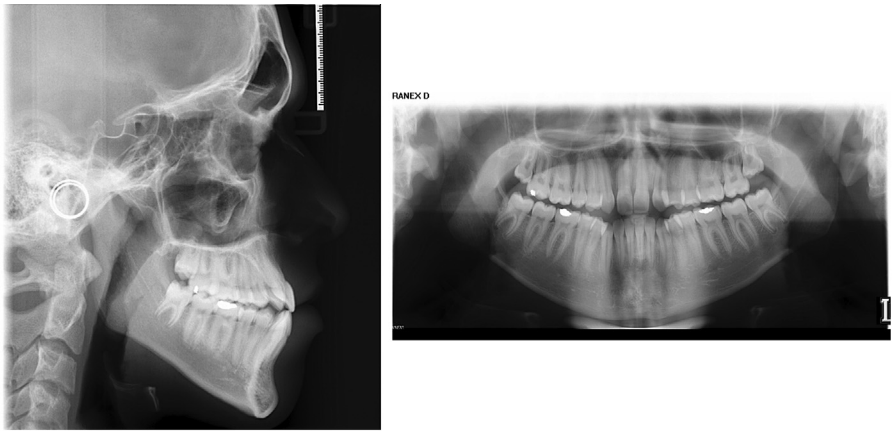

Fig. 2. Initial lateral and panoramic radiographs.

Each option was examined in detail with the patient, and he chose the MSE approach, in order to avoid surgery and to reduce costs.

2.3. *Treatment progress*

MSE expander was composed by a 10 mm jackscrew, which had precision drilled four holes that housed the micro-implants (1.8 × 11 mm). All micro-implants are positioned parallel to each other. The two anterior micro-implants had a slight forward inclination in order to engage the area with thicker bone near the palatal curvature. The two posterior micro-implants were located in the area with thinner bone, and the bi-cortical engagements of the palatal and nasal cortical bone layers were achieved. The MSE was activated two turns per day for two weeks (5.6 mm) with the appearance of a significant diastema between the central incisors seen in the intraoral images (Fig. 3) and also CBCT 3D reconstructed images (Fig. 4).

To evaluate the skeletal, dental and airway changes using MSE therapy CBCT scans were taken before and after expansion. Respiratory tests were performed to evaluate changes in muscle strength and airflow. Functional capacity, physical tests and official swimming records were taken to evaluate the effect of the therapy on the para-athlete performance.

2.4. *Treatment outcomes*

2.4.1. *CBCT measurements*

Cone beam computed tomography (CBCT) images were acquired before and after the expansion, and the measurements performed are listed on Tables 1 and 2 (Park et al., 2017).

The midpalatal suture disarticulated and separated by 5.91 mm and 4.13 mm in the anterior and posterior region, and considerable volumetric increases in both nasal cavity and oropharyngeal area were noted. Minimal tooth movement was observed during the above skeletal changes. With MSE, the entire midfacial structure

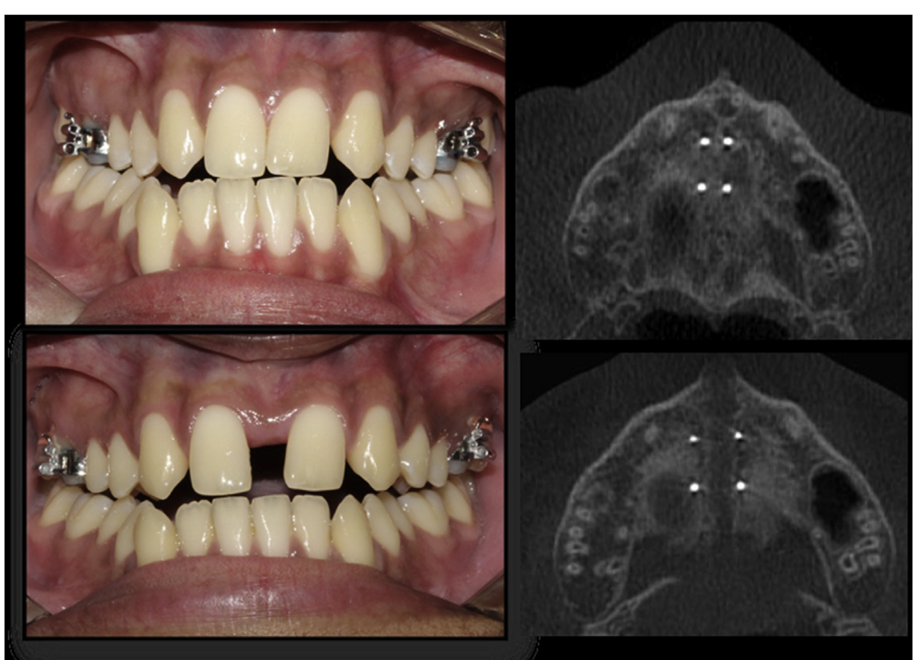

Fig. 3. Intraoral frontal clinical and CBCT axial views before (upper images) and after (lower images) MSE activation.

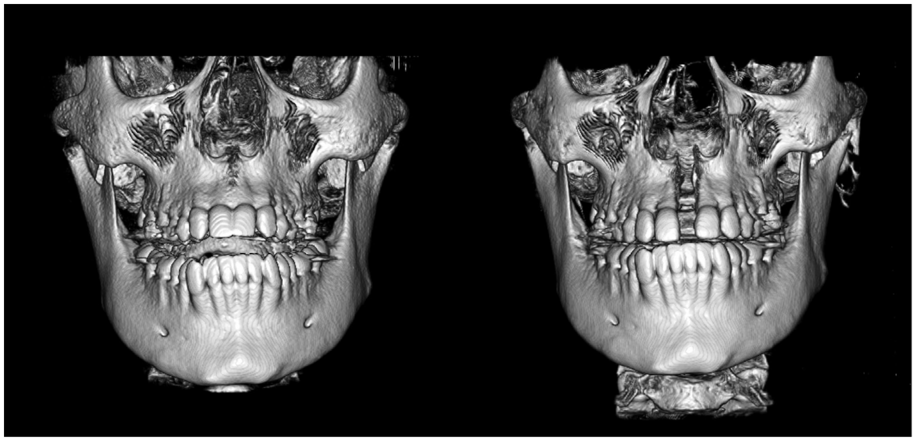

Fig. 4. 3D rendered images before (left) and after (right) MSE.

Table 1
Measurements at the CBCT imagens

CBCT Measurements	T0	T1	T1-T0
Midpalatal suture split – anterior (mm)	0	5.91	5.91
Midpalatal suture split – posterior (mm)	0	4.13	4.13
Angulation first molar - right	100°	104°	4°
Angulation first molar – left	103°	102°	1°
Angulation first premolar - right	104°	104°	0°
Angulation first premolar - left	100°	101°	1°
Volume of Pharyngeal airway (cm^3)	16.5	27.9	11.4
Minimal Pharyngeal Area (cm^2)	79.6	137.8	58.2
Full Airway – Nasal Cavity and Pharyngeal Volumes (cm^3)	35.02	51.35	16.13

Table 2
Nasal Cavity width measurements.

Nasal Cavity linear measurements (mm)		Initial	T1	T1-T0
Anterior Region	Lower	24.16	27.53	3,37
	Intermediate	22.94	25.41	2,47
	Upper	15.95	18.82	2,87
Middle Region	Lower	34.68	37.88	3,2
	Intermediate	25.43	32.71	7,28
	Upper	20.34	22.12	1,78
Posterior Region	Lower	30.83	33.65	2,82
	Intermediate	27.85	28.00	0,15
	Upper	28.13	27.29	−0,84

has expanded resulting in a wide split of the midpalatal suture, an increase in the interzygomatic width, and a widening of the entire nasal cavity including the superior region at the nasal bone. The 2D and 3D superimposition clearly demonstrates the expansion and forward movement of the midfacial structure (Fig. 5). With midfacial expansion, there was a profound increase in total nasal cavity volume. Full airway volume, including nasal cavity and pharyngeal airways, increased 31% as well as an increase in minimum cross-sectional area (Tables 1 and 2, Fig. 6). Nasal airway increased in width (mm) in both superior and inferior, as well as, the anterior and posterior aspects of the structure. The increase in pharyngeal airway at the narrowest area of the lumen was noted after the expansion (Fig. 7).

2.5. Respiratory tests

Respiratory tests were performed in 3 periods: before expansion (T0), immediately after expansion (T1) and after one year (T2). Three assessments were made, and the highest value was considered as the end result.

In order to measure respiratory muscle strength, an analogue manometer from Instrumentation Industries® (Coverdale, USA) with a numerical scale of 0–120 cmH2O (Fig. 8B) was used to measure the patient's respiratory muscle strength using 2 measurements: MIP and MEP, these methods were calculated using a

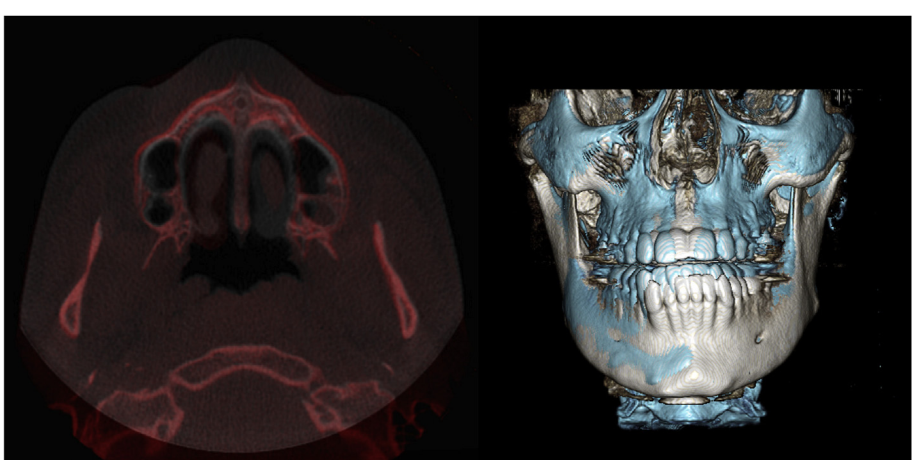

Fig. 5. Superimposition before and after expansion: (Left) axial view, (Right) 3D view.

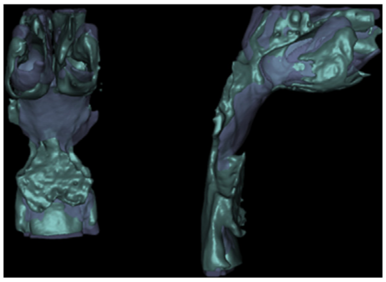

Fig. 6. Segmented nasal airway measured using ITK-SNAP open-source software (http://www.itksnap.org). (Left) Coronal view, (Right) Sagittal view.

mathematical equation, which considered age and gender as mains factors (Costa, Gonçalves, & Lima, 2010).

To assess expiratory peak flow meter, a device from ASSESS® (Cedar Grove, New Jersey, USA) (Fig. 8A) with a numerical range of 60–900 l/min. was used to measure the maximum airflow speed achieved during a forceful expiratory maneuver, beginning with the lungs fully inflated. Results were compared with a reference table and chart according to gender and age (Boaventura et al., 2007). To evaluate nasal inspiratory peak flow, a measuring device of nasal inspiratory flow (Fig. 8C) from In Check Nasal® (Clement Clarke, UK, England) with a numerical range of 30–370 l/min was used to quantify maximum inspiratory flow.

All respiratory tests indicated that patient's function improved with MSE (Table 3). The initial MIP value was 108 cmH2O, and it reached above 120cmH2O after the treatment (more than 20% improvement). This positive change was maintained after one year. The MEP values were 76 cmH2O and 112 cmH2O before and after the expansion respectively, indicating a 47% improvement with the MSE treatment. The MEP at one year follow up was 90 cmH2O, indicating some reversal of the improvement. The expiratory peak flow measurements were 468 L/m and 570 L/m before and after the expansion respectively, indicating a 21.8% improvement with the MSE treatment. One year later, the expiratory peak flow reached

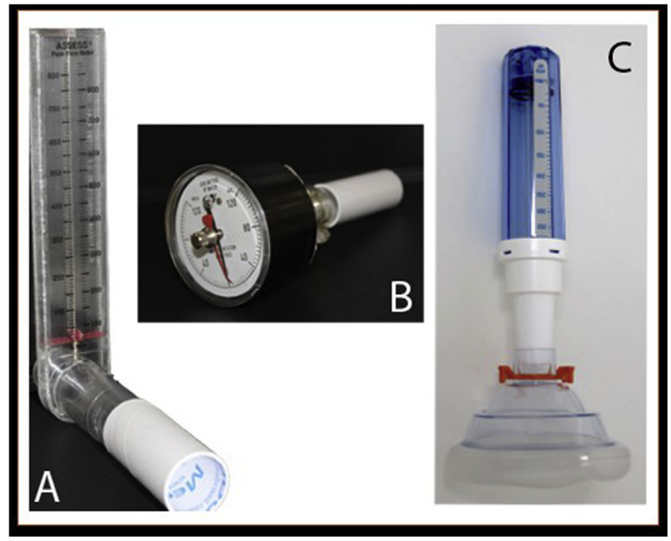

Fig. 8. A) Peak flow meter, B) Respiratory muscle strength meter, C) Nasal inspiratory peak flow meter.

beyond 850 L/m. Nasal peak flow also increased from 90 L/m to 126 L/m, a 40% improvement, and it reached 150 L/m one year later.

2.6. Functional capacity, physical evaluations and swimming performance

To evaluate patient's functional capacity, he performed the 6-min walking test (6-MWT) multiple times. This test is a modification of the 12-min Field Performance Test or Copper Test, designed for the individuals with disabilities, heart problems or pulmonary diseases (Butland, Pang, Gross, Woodcock, & Geddes, 1982). Following the Statement of American Thoracic Association (ATS Committee on Proficiency Standards for Clinical Pulmonary

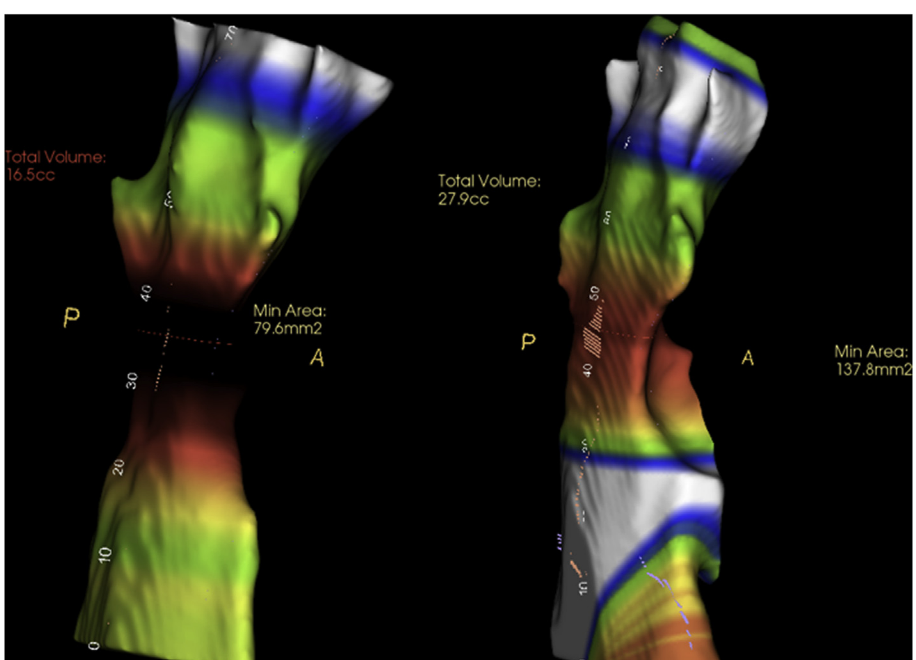

Fig. 7. Pharyngeal Airway Changes before (left) and after (right) expansion.

Table 3
Respiratory Tests included: maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), oral expiratory flow (Peakflow) and Inspiratory nasal flow (Nasal Peakflow).

Tests	Initial	After Expansion	Improvement % Initial x Imediately After	1 year later
MIP (cmH2O)	108	>120	˃ 20%	< - 120
MEP (cmH2O)	76	112	47%	90
Peakflow (L/m)	468	570	21,8%	>850
Nasal Peakflow (L/m)	90	126	40%	150

Function Laboratories, 2002), the test was performed indoor on a 30-m flat and straight corridor with marks every 2 m. Patient was instructed to walk as far as possible during the 6-min test, going back and forth around the two cones, but not to run or jog. After the start, the total distances covered at the end of each minute were disclosed to the patient, and these values were recorded.

The patient also took a submaximal exercise test and his heart rate recovery (HRR) was measured, in order to assess the cardiorespiratory fitness impact of the MSE. He performed a 50-m freestyle swimming at his maximal speed. The initial and final heartrates (before and after the exercise), and the subsequent heartrates (1 min and 3 min thereafter) were recorded. Both tests were performed one year before, immediately before, and six months after the maxillary expansion.

Functional capacity measured with the 6-min walking tests, taken one year and immediately before the treatment, did not presented a significant improvement (330 m and 370 m, respectively). However, a substantial improvement was found 6 months after the MSE treatment (370 m–674 m). The cardiorespiratory fitness measured by heart rate recovery (HRR) presented similar results, with an improvement after treatment.

The patient in this case report is a Paralympic athlete classified as S-9 by the World Para Swimming, which represents athletes with joint restrictions in one leg or with double below-the-knee amputations. He has been participating in swimming competitions national and internationally, representing Brazil, for 5 years in 50- and 100-m freestyle and 100-m backstroke modalities. His completion times were recorded during the official Paralympic competitions of Brazilian Aquatic Sports Confederation, which follows the recommendations and rules of International Paralympic Committee during the 2015–2016 and 2016–2017 seasons. These events took place one year before the expansion, immediately before the expansion, six months and one year after the expansion.

His sport performance was directly affected by the MSE treatment (Table 4). His performance six months after the MSE treatment improved by 00:01.53, 00:07.50 and 00:09.07. These improvements were held stable one year after the expansion with the relatively minor changes (−00:00.13, −00:02.64 and 00:01.21).

3. Discussion

There is a consensus in the literature regarding the benefits of RPE for improving the upper, middle and sometimes even lower airway dimensions and decreasing the nasal airway resistance (Ballanti, Lione, Baccetti, Franchi, & Cozza, 2010; C.; Carlson et al., 2016; Fastuca, Perinetti, Zecca, Nucera, & Caprioglio, 2015). However, the daily benefits of these improvements in the patient's life are scarcely reported. Fastuca et al.(Fastuca et al., 2015) reported significant changes in oxygen saturation with expansion, and McNamara Jr. et al.(McNamara et al., 2015) stated that RPE can reduce the symptoms of obstructive sleep apnea. Izuka et al.(Izuka, Feres, & Pignatari, 2015) also concluded that RPE can positively impact the quality of life in mouth-breathing patients with the maxillary constriction. However, the respiratory function and sport performance changes related to maxillary expansion have not been well documented. To the best of our knowledge, this is the first case report demonstrating the impact of maxillary expansion on the respiratory function and sport performance of a swimming athlete.

The airflow is dependent on airway resistance during breathing, and an adequate volume of airflow is essential for good pulmonary function. The nasal cavity seems to be responsible for almost two thirds of this resistance, and most of this resistance occurs due to the upper airway dimensions (Jalowayski, Yuh, Koziol, & Davidson, 1983). Changes in the nasal structures can induce both pathological and physiological changes to airflow (Neeley, Edgin, & Gonzales, 2007). The airway resistance (R) can be reduced drastically by increasing the radius of the airway (r), and subsequently the reduced airway resistance (R) increases the volume air-flowrate (F), as illustrated below. Implicating that 19% increase in the radius can double the volume flowrate. The MSE appliance can enlarge the size of nasal cavity and significantly increase the airflow through the nasal airway.

In this case report, 3D CBCT analysis confirmed a skeletal separation of midpalatal suture and morphological changes in the midfacial region of the skull (Figs. 3 and 4). Consequently, this change increased the nasal cavity width in its entirety. Both the anterior and posterior, as well as the superior and inferior aspects of the nasal cavity were expanded, illustrated by both the cross-sectional views and 3D superimpositions (Fig. 5). The posterior and superior changes are important in increasing the airflow through the nasal cavity since these areas can create more resistance by trapping the volume of air passing through these narrow parts of the nasal passage. The MSE appliance is designed to produce posterior and superior expansion (Cantarella et al., 2018; Moschik, 2018), and this is well illustrated in this report (Fig. 6).

Maxillary expansion with a tooth-borne expander and its impacts on surrounding structures have been widely observed in literature (Bouserhal et al., 2014; Izuka et al., 2015; Mundstock et al., 2007), especially for young patients (9–16 years old) (Giuca et al., 2009). For mature patients, a bone-borne expander, microimplant assisted rapid palatal expander (MARPE), became more common approach in order to avoid or to reduce the adverse dental side effects. Maxillary Skeletal Expander (MSE) is a particular type of MARPE, designed to deliver the expansion force to the posterior and superior aspects of the nasal cavity (Cantarella et al., 2017; Moschik, 2018), by directing the expansion force posteriorly and by engaging both layers of the palatal and nasal cortical bone (Lee et al., 2017). Also by placing the jack-screw and anchoring implants closer to the resisting structure, more posteriorly and superiorly, more horizontal and vertical translation of the maxilla will take place during the expansion. Cantarella et al. (Cantarella et al., 2017) illustrated a complete disarticulation of Pterygopalatine Sutures at the level of Palatal Plane with MSE treatment, indicating a significant posterior expansion. The patient in this report exhibited similar morphological changes as the previous studies sited above. The MSE appliance was anchored to the palate, and a negligible tooth movement was observed (Table 1).

With a significant increase in the size of nasal cavity, the

Table 4
Time recorded at official National competitions during season 2015/2016 and 2016/2017 registered in minutes, seconds and 1/100th of seconds.

	June 2015	June 2016 (just before expansion)	Nov 2016 (after expansion)
50 m freestyle	00:31.91	00:31.55	00:30.02
100 m freestyle	01:16.79	01:14.87	01:07.37
100 m backstroke	01:28.01	01:30.73	01:21.66

patient's pharyngeal airway has also inflated (Fig. 7), although no direct stimulation of this area rendered. Three possible explanations can be offered:

1. The increased airflow through the nasal cavity after MSE treatment inflated the previously deflated pharyngeal airway.
2. The posterior expansion of the palate caused an expansion of the superior pharyngeal tissue, causing the neuromuscular changes.
3. The increased intraoral cavity after the MSE treatment allowed the tongue to be posited more superiorly, and this tongue movement stretched the pharyngeal tissue.

Although it is logical to assume that one or more of the above possibilities may be involved, more future studies are necessary to fully explore these hypotheses.

The nasal airflow can be measured by various means. The "gold standard" approach is rhinomanometry; however, this method is expensive, difficult to perform, and not widely available. More convenient ways to quantify nasal airflow are measuring the inspiratory and expiratory peak flows (Bathala & Eccles, 2015; Neeley et al., 2007). The peak flow measurement is useful in monitoring the narrowing of airway in patients with respiratory disorders, such as asthma (Ottaviano & Fokkens, 2016). Both inspiratory and expiratory peak flows are valid for measuring both oral and nasal airflows, and they are well tolerated by patients. All respiratory tests in this case report improved with MSE treatment, and the improvements were maintained one year after the expansion. Compared to the MIP expected by gender, age and height, the initial MIP was 51.1% lower, but it was normalized after the MSE treatment. The MEP before the expansion was 53.1% lower than expected; however, it improved to 31% below the expected value after treatment. These functional improvements are probably due to the reduced airflow resistance after the MSE treatment. Interestingly, the initial expiratory peak flow was slightly greater than expected for gender and age, and it further increased after the MSE treatment. The inspiratory peak flow also had similar results. By increasing the nasal airway volume with MSE, the airflow resistance seems to be lowered enough to improve the respiratory function. The above results were in line with the previous studies (Camacho et al., 2017; Fastuca et al., 2015).

Generally speaking, for an athlete in optimal circumstances, the ventilation should not be a limiting factor in determining the oxygen consumption; however, the ventilatory function can be limited by a lack of adequate force exerted by the ventilatory muscles, and this deprived function could have a direct impact in sport performance, especially in swimming (Bertholon, Carles, & Teillac, 1986). Since the MSE has increased the size of the nasal airway significantly for this patient, the nasal airflow resistance should decrease as a consequence, which in turn, the influence of ventilatory muscles will be enhanced. The ventilatory function and oxygen saturation should improve, leading to a better quality of life during his training period. These positive improvements may affect his physical fitness and swimming efficiency. Durmic et al. (Durmic et al., 2015) reported that, amongst all sport modalities, water-based athletes tend to present higher respiratory parameters then land-based sports.

The 6-min walking test and the heart rate recovery (HRR) test were used to assess the physical condition of this athlete. To differentiate the effects of his normal training program and the MSE treatment, the physical and HRR tests were performed one year before, immediately before, and six months after the expansion. The effects of his normal training were assessed by comparing the first two test results during the one-year period prior to the MSE treatment, and the treatment effects were assessed by comparing the test results before and after the MSE treatment. The walking tests during his training period had an improvement of less than 20% in distance travelled, but more than 80% with the MSE treatment. The HRR tests also had similar results. These results can be attributed to better cardiorespiratory fitness, stemming from much improved respiratory functions, as previously have suggested (Agrawal & Awad, 2015; Cataneo, Kobayasi, Carvalho, Paccanaro, & Cataneo, 2010).

These improvements in respiratory functions, observed in this case report, may have a profound impact for athletes with a high-performance expectation, particularly for swimmers. During immersion, water pressure increases the load on the chest wall, thus elevating airway resistance. The ventilatory restriction that occurs momentarily in every respiratory cycle leads to intermittent hypoxia, which triggers an increase in respiratory rate, heart rate, and muscle fatigue (Anderson, Hopkins, Roberts, & Pyne, 2008). The improvement in respiratory function, in this case, was accompanied by the improvement in physical condition, cardiovascular function and swimming performance. During the one year of training period prior to the MSE treatment, this patient's 50-m and 100-m freestyle resulted in only slight improvements, 00:00.34 (1.0%) and 00:01.92 (1.6%); but he has experienced drastic improvements, 00:01.53 (4.8%) and 00:07.50 (6.5%), in both categories six months after the MSE treatment. His 100-m backstroke results were not favorable during the training period, −00:02.72 (−2.1%), but improved drastically, 00:09.07 (6.9%), six months after the expansion. Although maturation may play a role in this young adult patient, little improvement was observed in one year before treatment. During the entire period of observation, no major change was registered in training section that contemplated 2-h workout, varying speed, effort, rhythm, aerobic and anaerobic physical activity/exercise and frequency of swimming practice (2 h daily). Same coach and training staff, including physical therapist, physician and psychologist.

Shaving off over 7 and 9 s in 100-m swimming competition clearly demonstrates the patient's physical improvements in strength and endurance. Even in a shorter event of 50-m, he was able to reduce his time by 1.53 s, indicating a significant improvement in strength. The improvements were replicable one year after the expansion in 50-m freestyle event, −00:00.13 (−0.4%), and further improved with the 100-m backstroke event, 00:01.21 (1.0%). He did not swim as fast in the 100-m freestyle event, −00:02.64 (−2.5%), but still 4.86 and 6.78 s better than the performances prior to the MSE treatment. The swimming performances seem to be directly related to the changes in respiratory function and subsequent physical conditioning. The MSE treatment resulted in a larger airway dimension, less nasal airflow resistance, increased influence of ventilatory muscles, improved ventilatory function, higher oxygen consumption/saturation, enhanced physical fitness/endurance and improved swimming efficiency. These physical advances continued after one year, indicating that the airway changes and its related functional improvements can be sustained.

Although many authors have reported the effects of various expanders on the respiratory system, the previous studies have not studied the effects on sport performance. This case report has illustrated that MSE treatment can influence the nasomaxillary structures and improve the nasal airflow. These changes can positively aid in physical conditioning and eventual performance in a rigorous sport competition. However, further studies are necessary to demonstrate the effectiveness of this therapy across a larger number of patients.

Ethical approval

None declared.

Financial disclosure and conflict of interest

No potential conflict of interest was reported by the authors.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2019.01.005.

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