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Sagittal dentoskeletal modifications associated with different activation protocols of rapid maxillary expansion

ABSTRACT

Aim *The aim of this study is to compare the sagittal dentoskeletal changes associated with different activation protocols of maxillary expander.*

Materials and methods *A total of 101 subjects with constricted maxillary arches (49 males and 52 females; mean age 10.08 ± 1.57 years) were enrolled in the study. The study comprised also a control group of 20 subjects (11 females and 9 males, mean age 10.27 ± 1.24 years) who were not treated during the observation period. All the subjects underwent rapid maxillary expansion with a stainless steel banded expander cemented to the maxillary first molars. The expansion screw was randomly activated with two different rapid maxillary expansion protocols (one-quarter per day or two-quarters per day). A statistical comparison between the sagittal cephalometric variations obtained in the two expansion groups was made, and compared with the untreated control group. Data were then stratified for skeletal maturation of each subject.*

Results *The Wilcoxon rank-sum test shows statistically significant differences between the two RME activation protocols only for overjet. Statistically significant differences were reported in comparison with the control group.*

Conclusions *This study suggests that the increase in overjet after RME could be associated with faster activation protocols especially in subjects with lower skeletal maturation.*

Keywords *Cephalometry, Maxillary expansion, Orthodontic appliances, Orthodontics, Palatal expansion.*

Introduction

Rapid maxillary expansion (RME) is the most effective common orthodontic treatment to correct a transverse deficiency by opening the mid-palatal suture [Cross et al., 2000; Haas, 1961; Lagravere et al., 2005; Lione et al., 2013]. This allows an increase in maxillary width, correction of posterior crossbites and the subsequent maxillary and mandibular arch coordination, thus reducing the need for extractions [Baccetti et al., 2001; Giuca et al., 2009; Grassia, D'Apuzzo, Ferrulli, et al., 2014; Needleman et al., 2000; Perillo et al., 2014].

RME generates large forces to exceed the limits of orthodontic tooth movement with the aim to achieve minimal dental and maximum orthopaedic effect [Haas, 1961]. Anyway, it affects the circummaxillary suture system and more specifically the mid-palatal suture, but also compresses the periodontal ligament, bends the alveolar processes and induces a tipping of the anchoring teeth and other skeletal and dental effects as confirmed by numerous studies [Ballanti et al., 2009; Cameron et al., 2002; Haas, 1970; Rosa et al., 2016]. In particular, the separation of the two palatine bones along the palatal suture median is reflected on the nose-jaw complex in an area of triangular shape, the base of which is located in correspondence of the anterior nasal spine and the apex at the posterior nasal spine [Ballanti et al., 2016; Braun et al., 2000; Fastuca et al., 2015; Santariello et al., 2014].

Consequently, although RME has been recognised as a safe and reliable orthodontic procedure, some investigations and literature reviews [Basciftci et al., 2002; Lione et al., 2013; Rossi et al., 2011], have focused on the unwanted consequences of heavy forces on dento-skeletal structures and reported that RME with conventional appliances promotes the inferior displacement of the maxilla with a consequent posterior-inferior rotation of the mandible [Lione et al., 2013].

Different frequency of the activations, magnitude of

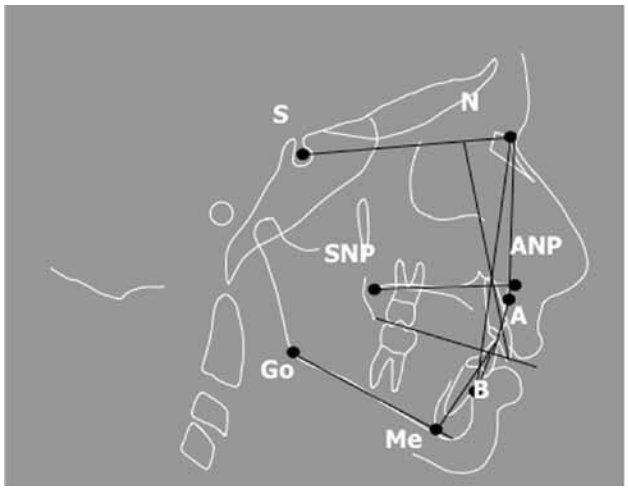


FIG. 1 Cephalometric parameters measured and analyzed.

the applied force, duration of the treatment, and patient age produce different kind of expansions as rapid, semi-rapid or slow maxillary expansion [Ramoglu et al., 2010] with different dental and skeletal effects. The expansion force depends on the activation protocol; the screw is commonly activated once or twice daily for about 2–4 weeks and a single activation produces approximately 3 to 10 pounds of force [Zimring et al., 1965]. Some authors [Geran et al., 2006; Işeri et al., 2004; Sari et al., 2003] used a regimen of one-quarter turn per day (1QD) in young patients reporting success with this protocol and stating that this regimen is not different from the classic regimen of two-quarters turn per day (2QD), suggesting the evaluation of slower rhythms of RME in the mixed dentition. Thus Iseri and Ozsoy [Işeri et al., 2004] called semi-rapid maxillary expansion (SRME) an activation protocol that consisted in a two-quarters turn per day for the first week followed by one-quarter turn per day for the next days, immediately after the separation of the intermaxillary suture by RME, in order to produce less tissue resistance. Recently some authors [Grassia, D'Apuzzo, DiStasio et al., 2014; Grassia, D'Apuzzo, Ferrulli et al., 2014; Perillo et al., 2014] studied the effects of mixed maxillary expansion (MME), which is able to separate the two maxillary halves by multiple activations at the first appointment, and continues with a slow maxillary expansion (SME) protocol of one turn every three days.

To the authors' knowledge only two studies [Perillo et al., 2014; Ramoglu et al., 2010] compared the dento-skeletal effects obtained in patients treated with RME and other expansion procedures and only Ramoglu et al. [2010] analysed the sagittal dento-skeletal effects. There are no studies that evaluate the influence of the RME activation protocol on the associated dento-skeletal effects. Recently, studies by Baldini et al. [2015, 2017] showed that subjects who underwent RME with a 1QD activation protocol reported significantly lower pain sensation compared with 2QD and that there are significant differences in dental arches changes between the two activation protocols.

The aim of this study is to compare the sagittal dento-skeletal changes associated with different activation protocols of maxillary expander.

Materials and methods

A total of 101 subjects with constricted maxillary arches (49 males and 52 females; mean age 10.08 ± 1.57 years) were enrolled in the study after signing an informed consent form. Individual skeletal maturity was determined for each subject with the cervical vertebral maturation (CVM) method assessed on lateral cephalograms [Baccetti et al., 2001, 2002]. Exclusion criteria included age older than 15 years; CVM more advanced than cervical stage (CS) 4 (postpubertal) and the presence of previous periodontal disease, neurological disease, and/or genetic disease. All the subjects underwent RME with a stainless steel banded expander cemented to the maxillary first molars and were randomly assigned to one of two groups according to the expansion protocol to be applied. In Group 1 (28 females and 28 males, mean age 10.13 ± 1.46 years) the expansion screw was activated at 1QD (one activation, 0.2 mm per day), in Group 2 (24 females and 21 males, mean age 10.01 ± 1.71 years) the expansion screw was activated at 2QD (two activations, 0.4 mm per day). In both groups, the expansion screw has been activated until the molar overcorrection was reached; a clinical condition that is verified when the palatal cusps of upper first molars are in contact with vestibular cusps of lower first molar. In the present study a control group of 20 subjects (11 females and 9 males, mean age 10.27 ± 1.24 years) was involved who were not treated during the observation period. Lateral cephalometric radiographs were taken by a single trained radiographer following a standardised protocol, before (T0) and after the removal of the device, 6 months (T1) from the end of the active phase. In the control group lateral

cephalometric radiographs were taken after 7 months. The same operator manually traced each cephalogram, and a second operator checked landmarks and anatomic contours. In case of disagreement the cephalograms were retraced reaching a mutual satisfaction of both operators.

In order to assess the sagittal dento-skeletal changes 9 angular and 3 linear cephalometric parameters were considered (Fig. 1):

- SNA: maxillary position relative to cranial base;
- SNB: mandibular position relative to cranial base;
- ANB: skeletal class;
- SN^PP: angle between cranial base and palatal plane;
- MP^PP: angle between mandibular and palatal plane;
- SN^MP: angle between mandibular plane and cranial base;
- IsiP^SN: angle between cranial base and upper central incisor;
- IiiP^MP: angle between mandibular plane and lower central incisor;
- Inter inc: interincisive angle;
- Wits: distance AO-BO;
- OVJ: overjet;
- OVB: overbite.

Statistical analysis

The distributions of the cephalometric measures are summarised and compared as mean and standard deviation according to the different groups.

The primary interest of this study was to evaluate the sagittal side effects of the two interventions, i.e. one or two daily RME activations, focusing on the comparison of the final changes in measures (T1-T0) of the two active groups. This was performed both with and without adjusting the increases by the number of activations, in order to appreciate the differences of the two interventions independently from the expansion amount. Such adjustment was done dividing the measures by the number of activations. Since a graphical exploratory analysis of the distribution of such changes suggested to reject normality, every comparison was evaluated using Wilcoxon rank-sum tests.

Secondary analyses included comparisons between each intervention arm and the control group. The comparisons were then repeated stratifying by gender, cervical stage at baseline. It should be noted that only cervical stages 1 and 2 were included in this analysis because of the low number of patients at a higher cervical stage (CS3).

The significance level was set at 0.05. All analyses were performed with SAS software 9.4.

Results

Comparison between 1QD and 2QD

Table 1 shows the comparison of the sagittal skeletal changes obtained after RME between the two activation protocols. Analysing the descriptive statistics, all the mean measurements changes between T0 and T1 appear low in both groups. Furthermore, changes between 1QD and 2QD are similar; in fact, the Wilcoxon rank-sum test shows statistically significant differences of the parameters changes between the two RME activation protocols only for the OVJ parameter (p=0.04) that slightly decreases with the 1QD protocol and slightly increases with the 2QD. The mathematical adjustment considering the number of activations of each subject

	1QD		2QD		P-VALUE	CONTROL	
	T1-T0		T1-T0			T1-T0	
	MEAN	SD	MEAN	SD		MEAN	SD
SNA (°)	1,05**	2,06	0,62	2,48	n.s.	-0,34	1,17
SNB (°)	0,87*	1,53	0,68	2,32	n.s.	0,08	1,22
ANB (°)	0,19	1,44	0,24	1,59	n.s.	-0,43	0,71
SN^PP (°)	-0,64	4,42	-0,02	2,38	n.s.	0,40	1,80
MP^PP (°)	-0,90	2,92	-0,31	2,73	n.s.	-1,35	1,99
SN^MP (°)	-0,46	2,97	-1,52	9,24	n.s.	-0,91	2,55
IsiP^SN (°)	-1,64	5,04	-0,78	6,29	n.s.	-0,12	3,54
IiiP^MP (°)	-2,39*	11,56	-0,29	4,97	n.s.	0,74	2,33
WITS (mm)	-0,31*	3,40	0,12	1,96	n.s.	-0,65	1,05
INTER_INC (°)	3,40	6,56	2,50	5,16	n.s.	0,43	3,44
OVJ (mm)	-0,39	1,50	0,23°	1,89	0,038	-0,36	1,65
OVB (mm)	0,68	1,63	1,06	1,61	n.s.	0,43	0,67
p-value 1QD vs Control *=<0.05 **<0.01 ***<0.001 p-value 2QD vs Control °=<0.05 °°<0.01 °°°<0.001							

TABLE 1 Comparison of parameters increases T1-T0 (mm) between the two groups and with the control group

confirm the absence of significant differences, the p-value of the OVJ parameter change (p=0.052) is at the limit of the significance level (Table 2).

A stratified statistical analysis for cervical stage that compares results obtained on CS1 and CS2 subjects shows that the difference observed between the two protocols on the OVJ variation is an effect obtained on the CS1 subjects, where the 2QD protocol causes a mean increase of 0.65mm, while the 1QD protocol causes a mean decrease of 0.44mm (p=0.01). On the contrary, on CS2 subjects both activation protocols cause an OVJ decrease. This difference was also confirmed by the mathematically adjusted analysis (p=0.027) resulting that 0.2 mm of screw activation determined a mean 0.026 mm overjet increase. The 2QD group reported a significantly higher OVB increase of 2.14 mm in CS2 subjects (p=0.013) even after mathematical adjusting by activation number (p=0.015).

Comparison with the control group

Table 1 also shows the comparison of both activation protocols with the untreated control group.

The 1QD protocol caused a statistically significant mean relative increase of SNA (1.39°) SNB (0.79°) and WITS (0,34 mm) and a mean relative decrease of IIIP^MP (3.13°). Differently, the 2QD protocol caused only a statistically significant mean relative increase of the OVJ (0.59 mm).

	1QD		2QD		P-VALUE
	T1-T0		T1-T0		
	MEAN	SD	MEAN	SD	
SNA (°)	0,05	0,11	0,02	0,12	n.s.
SNB (°)	0,05	0,1	0,03	0,12	n.s.
ANB (°)	0,01	0,08	0,01	0,07	n.s.
SN^PP (°)	-0,03	0,22	0,01	0,12	n.s.
MP^PP (°)	-0,9	2,92	-0,31	2,73	n.s.
SN^MP (°)	-0,05	0,17	-0,01	0,14	n.s.
IsiP^SN (°)	-0,09	0,28	-0,04	0,32	n.s.
IiiP^MP (°)	-0,09	0,35	-0,02	0,22	n.s.
WITS (mm)	-0,03	0,16	0,01	0,09	n.s.
INTER_INC (°)	0,2	0,36	0,12	0,26	n.s.
OVJ (mm)	-0,02	0,09	0,01	0,08	n.s.
OVB (mm)	0,04	0,09	0,05	0,07	n.s.

TABLE 2 Comparison between the two groups of parameters increases T1-T0 (mm) adjusted by the number of activations.

Discussion

RME generates large forces to exceed the limits of orthodontic tooth movement with the aim to achieve minimal dental and maximum orthopaedic effect, causing widening and gradual opening the mid-palatal suture [Haas, 1961; Perillo et al., 2014]. The expansion force depends on the activation protocol; the screw, for example, can be activated once or twice daily for about 2–4 weeks and a single activation produces approximately 3 to 10 pounds of force [Zimring et al., 1965].

A literature review by Lione et al. [2013] focused on the unwanted consequences of RME reporting a downward movement of the maxilla and a consequent downward and backward movement of the mandible.

In the present study, 9 angular and 3 linear cephalometric parameters were considered in order to evaluate the influence of the activation protocol on the sagittal dento-skeletal changes determined by RME.

To analyse the possible posterior-anterior movement of mandible and maxilla SNA and SNB angles were considered. In comparison with untreated subjects, a statistically significant relative increase of 1.39° and 0.79° were respectively recorded for SNA and SNB only in the 1QD group indicating an anterior movement of both maxilla and mandible with consequent stable values of ANB. Previously, Ramoglu et al. [2010] – in agreement with this result – also found a significant increase in SNA after SRME and stable values after RME, but differently they did not find variations of SNB and obtained a consequent increase of the ANB value. Furthermore, previous studies [Akkaya et al., 1998; Basciftci et al., 2002; Sari et al., 2003] reported an SNA increase at the end of the RME treatment. Anyway, these changes are probably clinically not significant (lower than 1.05° with 0.43° of difference between the two protocols) and when the two groups changes were compared, no statistically significant differences were observed.

A statistical direct comparison between the 1QD and 2QD activation protocols confirmed the absence of significant differences.

In the 1QD group a significant lingual tipping movement of the inferior incisors teeth was shown by a significant reduction of the IiiP^MP angle that, on the contrary, resulted stable in the 2QD group. Ramoglu et al. [2010] also showed a variation of this parameter in the SRME group and stable values in the RME group, but differently they observed an increase of IiiP^MP. Previously Basciftci and Karaman [2002] found the absence of modifications for IiiP^MP and IsiP^SN after RME. Furthermore, in the present study, the upper incisors inclination and the interincisive angle were not affected by RME with both the activation protocols. The direct comparison between the two groups showed no significant differences.

The results of the present study showed that the 1QD protocol maintained stable values of overjet and overbite differently from the 2QD protocol that determined a significant mean relative increase of the overjet of 0.65 mm compared with the control group. Furthermore, a

direct comparison confirmed a different effect of the two protocols on this parameter, characterised by a small decrease in the 1QD group and an increase in the 2QD group; after the mathematical adjustment by number of activations, this difference is not significant but its p-value is very close to the significance level (p=0.052). The stratified analysis for skeletal maturation probably explained the reason of these results, in fact, both with and without adjusting the data by number of activations, only subjects in CS1 showed a difference between the two activation protocols. Subjects in CS1 that underwent to RME with 2QD protocol showed a mean overjet increase of 0.65mm compared with a decrease of 0.44 mm determined by the 1QD protocol, the analysis adjusted by number of activations showed that, in these subjects, 0.2 mm of screw activation determined on average a 0.026 mm overjet increase. Furthermore, the stratified analysis showed in CS2 subjects a significantly higher overbite increase of 2.14 mm after 2QD-activated RME. These results could be related with the different maturation of the mid-palatal suture between subjects with different skeletal age [Tecco et al., 2017].

The overjet increase and the overbite increase too are effects of RME observed in many studies since decades [Akkaya et al., 1998; Basciftci et al., 2002; Haas, 1970, 1980] but to the authors' knowledge this is the first study that analyses the influence of the activation protocol on this parameter changes and furthermore the influence of the skeletal maturation. This overjet increase could be related with an anterior movement of the maxilla indicated by the reported variation of the SNA. The present study suggests that a voluntary choice of the activation protocol and timing of the RME could be important in the subjective management of clinical cases that need a specific overjet control (skeletal classes III or II with constricted maxilla). Anyway, further specific studies on this argument are needed to confirm these results.

Conclusions

The present study suggests that the increase in overjet after RME could be associated with faster activation protocols, especially in subjects with lower skeletal maturation. Further studies are needed to confirm these results and the absence of other sagittal effects influenced by the activation protocol. However these effects should have no clinical significance.

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