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DOI: 10.23804/ejpd.2018.19.01.06

A comparative assessment of changes in dental arches associated with different activation protocols of rapid maxillary expansion

ABSTRACT

Aim *The aim of this study is to compare dental arch changes associated with different activation protocols of maxillary expander.*

Materials and Methods *A sample of 101 subjects with constricted maxillary arches (49 males and 52 females; mean age 10.96 ± 1.91 years) was enrolled in the study. All subjects underwent RME with a stainless steel banded expander cemented to the maxillary first molars and the expansion screw was randomly activated with two different rapid maxillary expansion protocols (one-quarter per day or two quarters per day). The study also involved a control group of 22 subjects (10 females and 12 males, mean age 10.39 ± 1.32 years) who underwent no treatment. A statistical comparison between the dental arch measures obtained before and after treatment in the two groups was performed.*

Results *The Wilcoxon rank-sum test shows statistically significant differences of the measurement increases between the two activation protocols (at least p=0.01). Statistically significant differences were also reported in comparison with the control group.*

Conclusions *A faster activation protocol could be able to determine a greater anterior opening of the mid-palatal suture. Moreover, it seems to yield a higher width increase in the molar area.*

Keywords *maxillary expansion, palatal expansion, dental arches, orthodontics, orthodontic appliances.*

Introduction

Maxillary expansion has been used for decades to correct transverse deficiency [Cross and McDonald, 2000; Lagravere et al., 2005; Grassia et al., 2015; Perillo et al., 2014] obtaining an increase in maxillary width reducing the need for extractions [Baccetti et al., 2001; Baccetti et al., 2000; Grassia et al., 2014; Perillo et al., 2014]. When evaluated on the basis of frequency of the activations, magnitude of the applied force, duration of the treatment, and patient age, different mechanics produce rapid, semi-rapid or slow expansion [Ramoglu and Sari, 2010].

Rapid maxillary expansion (RME) therapy is the most effective orthopaedic procedure to increase the maxillary transverse dimension in young patients by opening the midpalatal suture [Haas, 1961].

The hyrax appliance is the most common type of RME appliance, with an expansion screw that is attached to 2 or 4 teeth [Needleman et al., 2000; Santariello et al., 2014]. RME generates large forces to exceed the limits of orthodontic tooth movement with the aim to achieve minimal dental and maximum orthopedic effect [Haas 1961]. Anyway, it affects the circum maxillary 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 [Haas 1970; Cameron et al., 2002; Ballanti et al., 2009].

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 and Isaacson, 1965). Some authors [Sari et al., 2003; Geran et al., 2006; Işeri and Ozsoy, 2004] used a regimen of one-quarter turn per day (1QD) in young patients reporting success, stating that this regimen is not superior to the conventional regimen of two-quarters turn per day (2QD) and suggested evaluation of slower RME in the mixed dentition. Thus Iseri and Ozsoy [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

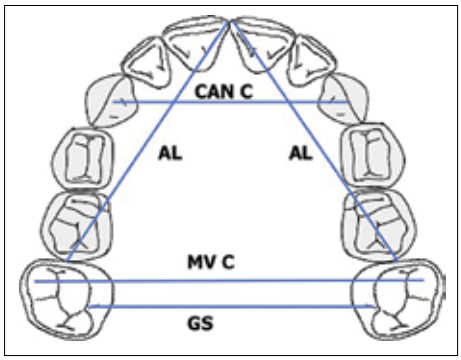


FIG. 1
Parameters measured on the upper dental arch.

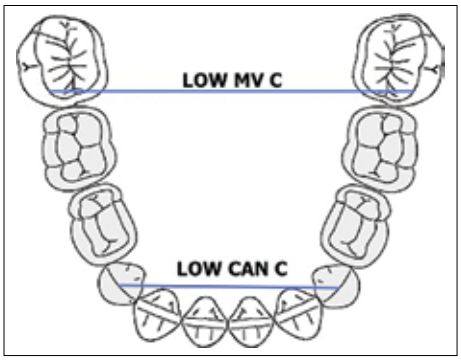


FIG. 2
Parameters measured on the lower dental arch.

one-quarter turn per day every other day immediately after separation of the intermaxillary suture by RME in order to produce less tissue resistance. Recently Perillo et al. [2014] proposed the 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.

Few studies [Grassia et al., 2015; Perillo et al., 2014; Ramoglu and Sari, 2010; Akkaya et al., 1998] compared the dento-skeletal effects obtained in patients treated with RME and other expansion procedures. At the authors knowledge there are no studies that evaluates the influence of the RME activation protocol on the associated dento-skeletal effects. The dento-skeletal effects of the most common activation protocol [2QD] have been widely studied in literature; but few studies analysed the changes of 1QD activation protocol on transversal diameters of superior and inferiorarch [Ramoglu and Sari, 2010]. Recently, a study by Baldini et al.[2015] showed that subjects who underwent RME with a 1QD activation protocol reported significantly lower pain sensation compared with 2QD.

The aim of this study is to compare the dental arch changes associated with different activation protocols of maxillary expansion.

Materials and methods

Partecipants, eligibility criteria, and settings

A sample of 101 subjects with constricted maxillary arches (49 males and 52 females; mean age 10.96 ± 1.91 years) was enrolled in the study. Individual skeletal maturity was determined for each subject with the cervical vertebral maturation (CVM) method assessed on lateral cephalograms [Baccetti et al., 2002]. Exclusion criteria included age older than 15 years, CVM more advanced than cervical stage (CS) 4 (postpubertal) and the presence of previous periodontal, neurological and/or genetic disease. The study followed the Helsinki Declaration and was approved by the Ethics Committee of the University of Rome Tor Vergata, and informed consent was obtained from the patients' parents.

Interventions

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 the group 1QD (27 females and 20 males, mean age 10.70 ± 1.74 years) the expansion screw was activated at 1QD (one activation, 0.2 mm per day) and in the group 2QD (25 females and 29 males, mean age 11.19 ± 2.04 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 palatal cusps of upper first molars are in contact with vestibular cusps of lower first molars.

In the study was also involved a control group of 22 subjects (10 females and 12 males, mean age 10.39 ± 1.32 years) who underwent no treatment.

Dental casts of the treated subjects were taken at the beginning of treatment (T0) and at the removal of the device after 6 months (T1) from the end of the active phase. In the control group two dental casts were taken at a time distance of 7 months.

On plaster models the linear measurements were carried out using a 0.01 digital caliper to measure the upper and lower intermolar and intercanine distances and the upper arch length (Fig. 1, 2).

On the upper arch the measurements were as follows.

- AL- Arch Lenght: The sum of the distances from the mesial contact of the first permanent molar to the interincisal point.
- CAN C - Distance between the cusps of the canines.
- MV C - Distance between the mesial-buccal cusp of the first permanent molars.
- GS - Distance between the first permanent molars at the end of the palatal pit to the gingival margin.

On the lower arch the measurements were:

- LOW MV C., Distance between the mesio-buccal cusps of the first permanent molars;
- LOW CAN C., Distance between the cusps of the canines.

	1QD		2QD		
	T1-T0		T1-T0		
	Mean	SD	Mean	SD	P-value
AL	1.59	2.06	1.78	2.14	n.s.
MV C	3.21	1.90	4.02	1.98	0.0122
CAN C	1.64	1.77	2.88	1.67	0.0022
GS	2.57	2.00	3.96	1.89	0.0001
LOW MV C	1.17	1.89	1.35	1.94	n.s.
LOW CAN C	0.16	2.34	0.93	1.98	n.s.

TAB. 1 Comparison of parameters increases T1-T0 (mm) between the two groups.

	1QD		2QD		
	T1-T0		T1-T0		
	Mean	SD	Mean	SD	P-value
AL	0.09 (45%)	0.2	0.07 (35%)	0.10	n.s.
MV C	0.17 (85%)	0.11	0.17 (85%)	0.08	n.s.
CAN C	0.08 (40%)	0.1	0.12 (60%)	0.07	0.0328
GS	0.14 (70%)	0.09	0.17 (85%)	0.08	0.0418
LOW MV C	0.07 (35%)	0.14	0.06 (30%)	0.09	n.s.
LOW CAN C	0.01 (5%)	0.1	0.04 (20%)	0.09	n.s.

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

Statistical analysis

The values of the analysed parameters were summarised and compared as mean and standard deviation according to the different phases of treatment.

The primary interest of this study was to evaluate the effectiveness of the two interventions, i.e. one or two daily RME activations, in expanding the maxillary dental arch. Thus we first focused on the comparison of the final increases in measure (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 actual differences in effectiveness of the two interventions. Such adjustment was done dividing the expansion by the number of activations. Since a graphical exploratory analysis of the distribution of such increases 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. In this case we only focused on the unadjusted measures of expansions. The comparisons were then repeated stratifying by gender, cervical stage at baseline and age at baseline, using the median age as cut-off. 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.

Finally we investigated potential measurement error in a subset of 15 patients, who had repeated baseline measurements. We assessed the reliability of the measures using descriptive statistics of the differences in measurements and intraclass correlation coefficients with excellent values ranging between 99.62 to 99.90.

All analyses were performed with SAS software 9.4.

Results

Comparison between 1QD and 2QD

Table 1 shows the comparison of the modifications obtained after RME between the two activation protocols. All measurements increased between T0 and T1 after the RME. In particular, in both groups the maximum maxillary expansion effects were reported on the MV C measurement with minimum effects on the CAN C measurement. Similarly, in both groups the mandibular expansion effects were higher on the LOW MV C measurement than on the LOW CAN C measurement.

The Wilcoxon rank-sum test shows statistically significant differences of the measurement increases between the two activation protocols for the MV C, CAN C and GS parameters (at least p=0.01). By the way, after having mathematically adjusted the increases (Table 2) considering the number of activations of each subject (expansion per activation), the MV C increase comparison resulted without statistical significance (p=0.45). CAN C and GS have a higher expansion per activation rate at 2QD than at 1QD (respectively 40% vs 70% and 60% vs 85%). Thus the 1QD protocol achieves an expansion on maxillary molars proportional to the 82% of the expansion obtained with the 2QD protocol and on the upper intercanine distance proportional to the 66% of the 2QD activation protocol.

A stratified statistical analysis for cervical stage that compares results obtained on CS1 and CS2 subjects shows a higher influence of the activation protocol in CS1 subjects, with a significantly higher difference of mean intercanine expansion per activation expressed in 25% vs. 60% in CS1 and 55% vs. 70% in CS2.

Comparison with the control group

Table 3 shows the comparison of both activation protocols with the untreated control group. Both protocols bring to statistically significant increases (at least p=0.002) compared with the untreated control group except for the LOW CAN C measurement (p=0.45 and p=0.07).

Discussion

During RME, forces exerted by the expander exceed

	Control		1QD			2QD		
	T1-T0		T1-T0		Control vs 1QD	T1-T0		Control vs 2QD
	Mean	SD	Mean	SD	P-value	Mean	SD	P-value
AL	0.25	1.30	1.59	2.06	0.004	1.78	2.14	0.002
MV C	0.28	0.70	3.21	1.90	0.000	4.02	1.98	0.000
CAN C	-0.59	1.91	1.64	1.77	0.000	2.88	1.67	0.000
GS	0.16	0.64	2.57	2.00	0.000	3.96	1.89	0.000
LOW MV C	0.20	0.59	1.17	1.89	0.006	1.35	1.94	0.000
LOW CAN C	0.15	1.18	0.16	2.34	n.s.	0.93	1.98	n.s.

TAB. 3
Comparison with the control group of parameters increases T1-T0 (mm).

the limits of orthodontic tooth movement achieving minimal dental and maximum orthopedic effect 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 and Isaacson, 1965].

In this study, four maxillary measurements and two mandibular measurements were considered in order to evaluate the influence of the activation protocol on the arches changes obtained with RME.

The comparison with the untreated control group, showed significant increases after RME with both the activation protocols for all the measurements except for the lower intercanine distance.

A direct comparison between the effects obtained with the two activation protocols showed that a 2QD activation achieves a greater expansion effect on the maxillary arch especially on the intercanine distance.

Previously, Akkaya et al. [1998] compared the effects on dental arch and arch perimeter of RME (2QD) and SME applied with a bonded expander concluding that the increase in upper intercanine width was significantly greater in RME than in SME. Although the comparison is different from the present study, these findings seem to be in agreement with the present study and with the hypothesis that the activation protocol is able to influence the upper intercanine distance after-expansion increase, on the contrary, the SME seem to have similar effects on the intermolar distance.

Ramoglu et al. [2010] analysed the vertical, sagittal and transverse effects of RME (2QD) and SRME without finding significant differences on the dental arch, generally in agreement with the present study. The so-called SRME protocol is a hybrid between the two activation protocols analyzed in this study, thus, the first week of 2QD activation followed by a 1QD activation was able to eliminate the few differences between the two activation protocols.

Grassia et al. [2015] compared RME (2QD; 0.25mm one quarter-turn) with MME, which consists in multiple activations at the first appointment followed by an SME protocol of one turn every three days, showing a significantly higher increase of the intercanine distance and of the mandibular depth (not analysed in the present study) obtained with RME. Also these results are in agreement with the findings of the present study.

Apparently, a faster activation protocol is able to determine a higher increase of the upper intercanine distance as a result of a greater anterior opening of the mid-palatal suture [Grassia et al., 2015]. Moreover, it seems that could achieve a higher width increase in the molar area too. However, previous studies [Grassia et al., 2015; Perillo et al., 2014; Grassia et al., 2014; Ramoglu and Sari, 2010] suggested that faster activation protocols could bring to higher side effects as sagittal modifications, dental tipping or relapse, thus this should be assessed with further studies. This is the first study that adjusted the width increases obtained with the number of activations comparing expansion rates per activation instead of pure after treatment increases. This could be very important for obtaining a reliable analysis considering that all the similar studies [Grassia et al., 2015; Perillo et al., 2014; Grassia et al., 2014; Ramoglu and Sari, 2010] expanded dental arches until the achievement of molar overcorrection, and thus the total expansion amount is different for each individual.

Moreover, the study sample in this study is significantly wider than that of previous ones.

It should be considered that the present study used a maxillary expansion hyrax appliance on two-bands as by Grassia et al. [2015] but differently from Ramoglu et al. [2010] and Akkaya et al. [1998] who used an acrylic bonded expander, this could have brought to different expansion effects between the studies.

In this study the skeletal maturation evaluated with the CVM method seems to be able to influence the effects of different activation protocols; in particular activation protocol related differences are apparently more evident on CS1 subjects rather than CS2. This result could be related with the different maturation of the mid-palatal suture between subjects with different skeletal age and should be evaluated with further studies.

Limitations of the study

Notwithstanding this study represents at the authors' knowledge the first detailed comparison of two different RME activation protocols, further studies with larger samples are needed especially to evaluate the considerable importance of skeletal growth.

Conclusions

This study, flanked by the previous literature, suggests that a faster activation protocol could be able to determine a greater anterior opening of the mid-palatal suture. Moreover, it seems that could achieve a higher width increase in the molar area.

The skeletal maturation seems to be able to influence the effects of different activation protocols, thus these observations should be assessed with further studies.

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