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Short Term Changes of Dental Arches Dimensions in Patients Treated with Rapid Palatal Expansion Followed by Fixed Orthodontic Appliances

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Abstract

Aim: The aim of this longitudinal study was to evaluate short-term changes in dental arches dimensions in patients who had been treated with rapid palatal expansion (RPE) followed by fixed orthodontic appliances.

Materials and Methods: The sample comprised of the casts of 29 patients (9 boys of a mean age of 9.6 and 20 girls of a mean age of 9.4 years), who had undergone orthodontic treatment using RPE with Hyrax type device and fixed orthodontic appliances. For every patient three pairs of casts were used: T1 before the treatment, T2 after the RPE and T3 after the end of the overall treatment. For every pair of casts 8 variables were measured at three-time intervals. Differences between all variables were calculated and compared using the t-test. The method error was determined using the intraclass correlation coefficient.

Results: The results indicated that the inter-molar, inter-premolar, and inter-canine maxillary widths as well as the perimeter of the maxillary dental arch increased at T2. The expansion at the molar region was found to be greater of the corresponding expansion in the premolars and canine's regions. The maxillary arch perimeter after RPE (T2), presented increase of 6.6 mm. In the mandibular dental arch at T2 a significant increase of the mandibular inter-molar width by 2.1 mm and mandibular inter-canine width by 1.5 mm was found. During the treatment with fixed orthodontic appliances (T3) very small changes occurred in the calculations of the width of both maxillary and mandibular arches (T3-T2) in comparison with the changes that occurred at T2. Consequently, it was observed increase of the maxillary inter-premolar width by 2 mm and in both maxillary and mandibular inter-canine width by 1.3 mm and 0.8 mm, respectively. In contrast, a reduction was observed of the maxillary inter-molar width by 1 mm and of the mandibular inter-molar width by 0.2 mm. The only variables that were increased significantly during treatment with fixed appliances were the maxillary inter-canine width and the palatal height.

Conclusion: Treatment by RME followed by fixed appliances seems to be an effective way of creating space in dental arches with mild to medium crowding.

Keywords: *Rapid Palatal Expansion; Dental Crowding; Narrow Maxilla; Orthodontic Treatment, Tooth-Size/Arch-Size Discrepancies; Arch Perimeter*

Introduction

The clinical technique of rapid palatal expansion (RPE) has been used in orthodontic treatment for long time to manage maxillary transverse deficiencies. Maxillary transverse deficiencies could be accompanied by posterior crossbite, bilateral or unilateral, narrow

nasal cavity and dental crowding. RPE not only separates the midpalatal suture but also effects the circummaxillary and circumzygomatic sutural system. The force applied to the suture widens the halves of the maxillary process and new bone is deposited in the area of expansion [1,2]. RPE has been used not only to correct maxillary constriction but also to relieve crowding by creating space in the dental arches.

Purpose of the Study

The purpose of this longitudinal prospective study was to evaluate the short-term changes of the dimensions of the dental arches in casts of patients that were treated with rapid palatal expansion (RPE) and fix orthodontic appliances.

Materials and Methods

The sample comprised of the casts of 29 patients, 9 of which were boys of a mean age of 9.6 years and 20 girls of a mean age of 9.4 years, who had undergone orthodontic treatment using RPE and fixed orthodontic appliances without extractions; the treatment had been undertaken at the same orthodontic practice by the same orthodontist. RPE was performed in all patients using Hyrax type device.

Inclusion criteria of the patients were to have a) narrow maxilla with or without posterior crossbite, b) crowding greater than 4 mm, c) fully erupted the first permanent molars, d) been treated without extractions of any permanent teeth and e) to be caucasians. Exclusion criteria of the patients were to have a) craniofacial syndromes or pathological anomalies, b) tooth agenesis, c) dysplastic teeth or restorations (prosthodontics or fillings) that could alter the dimensions of the teeth, d) been treated with extractions of permanent teeth and e) had a previous orthodontic treatment.

The patients were treated to resolve their crowding with a standardized protocol of RPE with 2 turns each day (0.25 mm per turn) until the palatal cusps of the maxillary first permanent molars occlude with the buccal cusps of the mandibular first permanent molars in maximum intercuspation. After reaching the above transverse relationship the RPE device remained in place as a passive retention device for an average of 10 months. This period was followed by a full fixed appliances orthodontic treatment. For every patient three pairs of casts were used, and they were made in three different time intervals of their treatment. The first was before the orthodontic treatment with RPE (T1) (initial casts), the second was after the expansion and its retention (T2) (intermediate casts) and the third was after the end of the treatment with fixed orthodontic appliances and their removal (T3) (final casts). All the measurements in the dental casts were made by the same orthodontist.

Measurements in the dental casts:

1. The inter-molar width of the maxillary dental arch
2. The inter-canine width of the maxillary dental arch
3. The inter-premolar width of the maxillary dental arch
4. The palatal height
5. The maxillary dental arch perimeter
6. The inter-molar width of the mandibular dental arch
7. The inter-canine width of the mandibular dental arch.

In every dental cast, the inter-molar width of the maxilla, and the palatal height were measured with the use of a three-dimensional bow divider of Korkhaus, as it was described by Rakosi., *et al*. (1993) [3]. The inter-canine and inter-premolar widths of the maxilla, the inter-molar, and inter-canine widths of the mandible were measured with a digital caliper. The maxillary dental arch perimeter was defined with the help of a flexible wire.

Statistical analysis

The Shapiro-Wilk normal distribution test was performed for every measurement [4]. Descriptive statistics were performed on dental cast measurements at T1, T2 and T3. A 95% confidence interval were calculated [5]. The correlation coefficient Pearson was used for the

correlation between two variables. Investigation of the mean value variance per measurement at the three-time intervals was performed using the Repeated Measures ANOVA test [6]. Furthermore, the effect of the sample size was calculated in the control with the partial eta square: η^2. Sphericity check W of Mouchy was taken into consideration for the control of the significance. In cases where the sphericity check was not satisfied, it was taken into consideration the Greenhouse-Geisser check for the calculation of the degrees of freedom of the statistical check of the analysis variation.

Differences between all variables at the three-time intervals were calculated and compared by using the t-paired samples test.

The model APA style (determined by the American Psychological Association) was used for the performance of the calculations. All statistical tests were two-sided. The significance level that was taken into consideration was 5%, while all the calculations were done using the statistical software SPSS vers 17.

Method error

The method error was determined using the Intraclass Correlation Coefficient (ICC). A random selection of 15 samples was made to perform a second measurement, by the same researcher two weeks after the first one. Paired t-test was used to compare the two measurements of each variable at every time interval. No statistically significant difference for any of the variables was found; therefore, the method of measurement was very reliable for all variables (Table A).

Variables	Time Interval	1st measurement mm (Mean ± standard deviation)	2nd measurement (Mean ± standard deviation)	ICC (95% CI)*
Maxillary Inter-molar width	T1	43,03 ± 3,25	42,93 ± 3,27	0,996 (0,989-0,994)
	T2	49,17 ± 3,00	49,27 ± 2,98	0,998 (0,993-0,999)
	T3	47,63 ± 1,94	47,73 ± 1,98	0,994 (0,983-0,998
Mandibular Inter-molar width	T1	40,57 ± 2,45	40,63 ± 2,42	0,994 (0,984-0,998)
	T2	43,07 ± 1,84	43,05 ± 1,89	0,990 (0,972-0,997)
	T3	42,53 ± 2,25	42,53 ± 2,30	0,994 (0,981-0,998)
Maxillary Inter premolar width	T1	33,60 ± 2,41	33,63 ± 2,40	0,993 (0,979-0,998)
	T2	38,87 ± 2,02	38,83 ± 1,94	0,989 (0,969-0,996)
	T3	41,07 ± 2,12	41,13 ± 2,11	0,993 (0,979-0,997)
Maxillary inter-canine width	T1	30,37 ± 3,23	30,27 ± 3,22	0,998 (0,992-0,999)
	T2	35,43 ± 2,66	35,40 ± 2,72	0,994 (0,983-0,998)
	T3	36,03 ± 1,03	36,10 ± 1,02	0,968 (0,911-0,989)
Mandibular inter-canine width	T1	25,97 ± 1,69	25,93 ± 1,75	0,980 (0,943-0,993)
	T2	27,27 ± 1,54	27,23 ± 1,59	0,983 (0,951-0,994)
	T3	28,43 ± 1,46	28,37 ± 1,49	0,977 (0,935-0,992)
Palatal height	T1	15,10 ± 2,30	15,00 ± 2,40	0,992 (0,978-0,997)
	T2	15,77 ± 2,84	15,73 ± 2,99	0,995 (0,986-0,998)
	T3	16,13 ± 1,67	16,07 ± 1,63	0,988 (0,965-0,996)
Maxillary dental arch perimeter	T1	98,00 ± 4,44	98,12 ± 4,21	0,989 (0,968-0,996)
	T2	102,17 ± 3,82	102,23 ± 3,93	0,984 (0,955-0,995)

Table A: *Statistical indicators for the method of error for every parameter and time interval.*
**Intraclass Correlation Coefficient; 95% CI = 95% Confidence Interval.*

Results

Maxillary inter-molar width

Statistical indices for maxillary inter-molar width at T1, T2 and T3 are presented in table 1.

	Mean Value (mm)	Standard Deviation	95% CI	Min	Max	Range
T1	42,8***	3,3	41,6 - 44,1	37,0	49,0	12,0
T2	48,9	2,6	47,9 - 49,8	44,0	55,0	11,0
T3	47,9	2,4	47,0 - 48,8	44,0	53,0	9,0

***Table 1**: Descriptive statistics on the maxillary inter-molar width in the three-time intervals.*

****p < 0,001.*

Statistically significant increase ($p < 0.001$) of maxillary inter-molar width between T1 and T2, and T1 and T3 was found. The difference between T2 and T3 was found to be not statistically significant. The acceptance of the difference of the mean values can be justified from the high value of the index η^2 (0.861).

Mandibular inter-molar width

Statistical indices for mandibular inter-molar width at T1, T2 and T3 are presented in table 2.

	Mean Value (mm)	Standard Deviation	95% CI	Mean	Max	Range
T1	40,7 ***	2,4	39,8 - 41,6	36,5	45,0	8,5
T2	42,8	2,4	42,0 - 43,7	38,0	47,0	9,0
T3	42,6	2,2	41,8 - 43,5	39,0	47,0	8,0

***Table 2:** Statistical indices of the mandibular inter-molar width in the three-time intervals.*

****p < 0,001.*

Statistically significant increase ($p < 0.001$) of mandibular inter-molar width between T1 and T2, and T1 and T3 was found. The difference between T2 and T3 was found to be not statistically significant. The acceptance of the difference of the mean values can be justified from the relatively high value of the index η^2 (0.605).

Maxillary inter-premolar width

Statistical indices for the maxillary inter-premolar width at time intervals T1, T2 and T3 are presented in table 3.

	Mean Value (mm)	Standard Deviation	95% CI	Min	Max	Range
T1	33,3***	3,0	32,1 - 34,4	27,0	38,0	11,0
T2	38,8	2,2	38,0 - 39,7	34,0	43,0	9,0
T3	40,8	2,3	40,0 - 41,7	35,0	45,0	10,0

***Table 3:** Statistical indices of the maxillary inter-premolar width in the three-time intervals.*

****p < 0,001.*

Statistically significant increase ($p < 0.001$) of maxillary inter-premolar width between T1 and T2, and T1 and T3 was found. The difference between T2 and T3 was found to be not statistically significant. The acceptance of the difference of the mean values can be justified from the high value of the index $\eta^2 = 0.813$.

Maxillary inter-canine width

Statistical indices for the maxillary inter-canine width at time intervals T1, T2 and T3 are presented in table 4.

	Mean Value (mm)	Standard Deviation	95% CI	Min	Max	Range
T1	30,0 ***	3,0	28,9 - 31,1	23,5	36,0	12,5
T2	34,7	2,7	33,6 - 35,7	29,0	41,0	12,0
T3	36,0	1,7	35,4 - 36,6	32,0	40,0	8,0

Table 4: *Statistical indices of the maxillary inter-canine width in the three-time intervals.*

**** p < 0,001.*

Statistically significant.

Statistically significant increase ($p < 0.001$) of maxillary inter-canine width between T1 and T2, and T1 and T3 was found. The difference between T2 and T3 was found to be not statistically significant. The acceptance of the difference of the mean values can be justified from the high value of the index $\eta^2 = 0.787$.

Mandibular inter-canine width

Statistical indices for the mandibular inter-canine width at time intervals T1, T2 and T3 are presented in table 5.

	Mean Value (mm)	Standard Deviation	95% CI	Min	Max	Range
T1	25,6***	2,1	24,7 - 26,4	20,0	29,0	9,0
T2	27,1	1,6	26,4 - 27,7	23,0	31,0	8,0
T3	27,9***	1,5	27,3 - 28,5	24,0	32,0	8,0

Table 5: *Statistical indices of the mandibular inter-canine width in the three-time intervals.*

****p < 0,001.*

Statistically significant increase ($p < 0.001$) of mandibular inter-canine width between T1 and T3 was found. The difference between T1 and T2 was found to be not statistically significant.

There was found statistically significant difference ($p < 0.001$) in between the mean value of the mandibular inter-canine width before treatment (T1 25.6 mm) and the mean value after the total treatment with RPE and fixed appliances (T3 27.9 mm). The acceptance of the difference of the mean values cannot be justified from the value of the index η^2. The low value of the index η^2 ($\eta^2 = 0.441$) shows the risk of error type II, which means that we must accept the existence of the difference without existing in real. Consequently, we accept that the increase of the mean value of the mandibular inter-canine width between T1 and T3 is not.

The palatal height

In table 6, the statistical indices (mean value, standard deviation, minimum and maximum value) are presented for the palatal height of the time intervals T1, T2 and T3.

	Mean Value (mm)	Standard Deviation	95% CI	Min	Max	Range
T1	14,8	2,0	14,0 - 15,6	11,0	19,0	8,0
T2	15,1	2,3	14,3 - 16,0	12,0	20,0	8,0
T3	16,7***	1,9	16,0 - 17,4	13,5	20,0	6,5

Table 6: *Statistical indices of the palatal height in the three-time intervals.*

****p < 0,001.*

There was found statistically significant increase ($p < 0.001$) of the palatal height between T3 and T1, while the difference of the mean value of the palatal height after RPE was not found to be statistically significant (between T1 and T2). The acceptance of the difference of the mean values cannot be justified from the value of the index η^2 ($\eta^2 = 0.496$). Consequently, we accept that the increase of the mean value of palatal height after the total treatment with RPE and fixed appliances (between T1 and T3) is not statistically significant.

Taking into consideration the low value of the η^2, further investigation should be done for the variable of the palatal height to prove its incremental or not effect after the total treatment.

Maxillary dental arch perimeter

Statistical indices for the maxillary dental arch perimeter at time intervals T1, T2 and T3 are presented in table 7.

	Mean Value (mm)	Standard Deviation	95% CI	Min	Max	Range
T1	97,6***	3,9	96,1 - 99,1	90,0	105,0	15,0
T2	104,2	4,1	102,6 - 105,7	97,0	113,0	16,0
T3	104,5	4,4	102,8 - 106,2	96,0	115,0	19,0

Table 7: *Statistical indices of the maxillary arch perimeter in the three-time intervals.*

****p < 0,001.*

Statistically significant increase ($p < 0.001$) of the arch perimeter between T1 and T2, and T1 and T3 was found. The difference between T2 and T3 was found to be not statistically significant. The acceptance of the difference of the mean values can be justified from the high value of the index $\eta^2 = 0.769$.

Mean values of all the variables at time intervals T1, T2, T3 and their difference in between them

Measured mean values for each variable and their difference in between them (T2-T1, T3-T2 and T3-T1) are presented in table 8. After treatment with RPE (T2-T1) a greater increase of all the variables measurements was found compared to the after total treatment with RPE and fixed appliances (T3-T1) except for the palatal height variable. For the palatal height variable, it was found greater increase of its mean value after treatment with fixed appliances. The greatest differences were found after RPE (T2-T1), while the differences of the treatment with fixed appliances were small (T3-T2).

Results of the statistically significant differences in the mean values of all the variables at time intervals T1, T2 and T3

Mean values of all variables and their statistically significant differences in the three-time intervals are presented in table 9. The effect size η^2 is relatively low for the variable of the mandibular inter-canine width, the palatal height, and the maxillary length arch. It seems that sample size affects the above variables even though there is statistically significant difference in the check of the statistical error type

	Mean Value at T1	Mean Value at T2	Mean Value at T3	Difference (T2 - T1)	Difference (T3 - T2)	Difference (T3 - T1)
Maxillary Inter-molar width	42,8	48,9	47,9	6,1	-1,0	5,1
Mandibular Inter-molar width	40,7	42,8	42,6	2,1	-0,2	1,9
Maxillaey interpremolar width	33,3	38,8	40,8	5,5	2,0	3,5
Maxillary intercanine width	30	34,7	36	4,7	1,3	6,0
Mandibular intercanine width	25,6	27,1	27,9	1,5	0,8	2,3
Palatal height	14,8	15,1	16,7	0,3	1,6	1,9
Maxillary dental arch perimeter	97,6	104,2	104,5	6,6	0,3	6,9

Table 8: *Cumulative results of the mean values of all the variables and their differences in the three-time intervals.*

I Consequently, we accept that the increase of the mean value of the mandibular inter-canine width, the palatal height, and the maxillary arch length after the total treatment (between T1 and T3) are not statistically significant.

	T1	T2	T3	p	Effect size η^2
Maxillary Inter-molar width	42,8***	48,9	47,9	< 0,001	0,861
Mandibular Inter-molar width	40,7***	42,8	42,6	< 0,001	0,605
Maxillaey interpremolar width	33,3***	38,8	40,8	< 0,001	0,813
Maxillary intercanine width	30,0***	34,7	36,0	< 0,001	0,787
Mandibular intercanine width	25,6***	27,1	27,9***	< 0,001	0,441
Palatal height	14,8	15,1	16,7***	< 0,001	0,496
Maxillary dental arch perimeter	97,6***	104,2	104,5	< 0,001	0,769

Table 9: *Cumulative table of the statistically significant differences in the mean values of all the variables in the three-time intervals.*

Discussion

The current study assessed the short-term changes of the dimensions of the dental arches in 29 orthodontic patients that were treated with RPE and fixed appliances. These patients had narrow maxilla, part of their general orthodontic problem and they had at least 4 mm crowding in the maxillary dental arch. The treatment with RPE was necessary to improve the transverse dimension of the maxillary dental arch before the treatment with fixed appliances. The active phase of RPE lasted 2-3 weeks and after the overcorrection, the RPE appliance remained in place passively for an average of 10 months. In this study it was chosen for the RPE appliance to remain in place in the waiting time between RPE and treatment with fixed appliances to reduce the percentage of relapse in its minimum.

In this study increase of the maxillary inter-molar, inter-premolar and inter-canine width was identified at T2 (Table 9). Many authors have found similar results [7-14]. Moreover, similar increase was found by Melgaco., *et al*. 2014 [15], Toklu., *et al*. 2015 [16], Luebbert., *et al*. 2016 [17], Furtado., *et al*. 2018 [18], Araújo., *et al*. 2020 [19], and Garib., *et al*. 2021 [20], who's studied CBCT images of patients that were treated with RPE.

These changes occur in response to the opening of the median palatal suture, the movement of the alveolar ridges to the side and the buccal inclination of the teeth that are used as anchorage of the expansion appliance [21-26].

Comparing the expansion of the maxillary dental arch in the region of the molars with this one in the region of premolar and canines, it was found that the greatest expansion was found to be in the region of the molars. This expansion was reduced gradually towards the anterior part of the maxillary dental arch (Table 8). This could be since the RPE appliance uses the posterior teeth for anchorage and in these teeth direct forces of the expansion are applied resulting in moving further compared to all the other teeth [8,15,27-30]. Knowing that the expansion of the median palatal suture is greater in the anterior part of the palate compared to the posterior [1,21,31], this finding supports the fact that the expansion is not only skeletal but part of it is also dental. This finding agrees with the results of the meta-analysis of Lagravere., *et al*. [32] who by comparing the expansion in the region of molars, canines and in the diastema between the central incisors they found that the molars had the greatest expansion that was reduced gradually towards the anterior part of the maxillary dental arch. In addition, it agrees with the study of Akkaya., *et al*. (1998) [33] who found that the changes in the width between molar and premolars are similar and greater from these of the canines and they supported that this finding shows that part of the expansion after RPE is dental. On the contrary, Mutinelli., *et al*. (2008) [12] found that the changes in width between canines are greater from these of the molars and they explained it due to the triangular shape of the opening of the median palatal suture. This difference between the study of Mutinelli., *et al*. (2008) [12] and the current study is possibly due to the different age of the patients that were studied. The mean age of the patients of the current study was 9.6 years and of Mutinelli., *et al*. (2008) [12] was 7,5 years.

In the mandibular dental arch at T2 a significant increase of the mandibular inter-molar width by 2.1 mm (Table 2) and mandibular inter-canine width by 1.5 mm (Table 5) was found. Similar results were found by Moussa., *et al*. 1995 [10], Akkaya., *et al*. 1998 [33] and Grassia., *et al*. 2015 [13].

The increases in the mandibular inter-molar width and inter-canine width that were found in the current study could be due to the change of the muscle balance and the different distribution of the occlusal forces after the end of the active phase of RPE. The cheeks are retracted because of the expansion of the maxillary dental arch, while the same time the tongue is placed lower due to the existence of the RPE appliance in the palatal dome. Consequently, the tongue puts pressure in the lingual surfaces of the mandibular posterior teeth that is not balanced from the force that comes from the cheeks. This new balance can over time allow the upright of the lower molars and canines [15,33-35]. In the current study, the RPE appliance remained for retention for approximately 10 months after the active expansion and thus allowed the upright of the mandibular molars and canines.

Furthermore, all the patients of this study were treated with RPE until the palatal cusps of the maxillary first permanent molars occlude in the maximum intercuspation with the buccal cusps of the mandibular first permanent molars. After achieving the above transverse relation, the RPE appliance remained in the maxillary dental arch as appliance of passive retention for approximately 10 months. Akkaya., *et al.* (1998) [33] by calculating the inter-molar and the inter-canine width of the mandibular dental arch straight after the end of RPE and after 3 months, where the RPE appliance remained in place, they found that the expansion between the above teeth increased during the retention period. Consequently, in the current study we assume that the new occlusal relation that has different contact points gives extra load in the mandibular buccal cusps resulting in the time of remain of the RPE appliance for the expansion to be favoured in the mandibular dental arch [9,15,21,33,36-38].

Moreover, the expansion and upright of the mandibular dental arch limits the percentage of the expansion relapse of the maxillary dental arch, holding it in the expanded occlusal relation [33]. The expansion of the mandibular dental arch in the current study, meaning the increase in the mandibular inter-molar and inter-canine width, after the removal of the RPE appliance and before the placement of the fixed appliances, is due to its adjustment in the expansion of the maxillary dental arch, which happened because of the stay of the RPE appliance as a fixed retention appliance.

The palatal height after RPE (Table 8) showed increase of 0.3 mm, which was found to be statistically significant. One possible explanation is the fact that after RPE the expansion of the width between the maxillary molars is also dental, these teeth have buccal inclination, the curve of Wilson is increased and the points that are taken for the calculation (meaning the centres of the occlusal pits of two maxillary first permanent molars) are transferred higher resulting in less increase of the palatal height in this phase of the treatment. Similar results with the current study are showed by Bruder., *et al*. (2019) [39] and Mosleh., *et al*. (2015) [40], using CBCT scans. In the end of the total treatment the increase of the height of the maxillary dental arch was 1.9 mm and it was found statistically significant. This increase of the palatal height can be explained by 50% due to the displacement of the maxilla (related with the growth of the facial sutures) and 50% due to the new bone formation on the hard palate's surface and resorption of the nasal cavity floor [39].

The maxillary arch perimeter after RPE (Table 8), presented increase of 6.6 mm. The finding shows the effectiveness of the expansion for finding space for rotated, impacted, or crowded teeth to be arranged in the arch. This finding agrees with Lima., *et al*. (2005) [11] who studied dental casts of 30 patients in Class I and transverse skeletal discrepancy that had mild or no crowding and were treated only with RPE without any extractions.

During the treatment with fixed orthodontic appliances (T3) very small changes occurred in the calculations of the width of both maxillary and mandibular arches in the patients that were under treatment (T3-T2) in comparison with the changes that occurred after RPE (Table 8). Consequently, it was observed increase of the maxillary inter-premolar width by 2 mm and in both maxillary and mandibular inter-canine width by 1.3 mm and 0.8 mm, respectively. In contrast, a reduction was observed of the maxillary inter-molar width by 1 mm and of the mandibular inter-molar width by 0.2 mm, probably as a compensatory result of the reduction of the maxillary corresponding width. The only variables that were increased significantly during treatment with fixed appliances were the maxillary inter-canine width and the palatal height (Table 5 and 6). The reduction of the expansion in the region of the maxillary molars was possibly due to the correction of the inclination of these teeth with the treatment with fixed orthodontic appliances resulting in the centres of the occlusal pits of the two maxillary first permanent molars to come to a lower place and the increase of the palatal height, as it was expected. The phase of the treatment with the fixed orthodontic appliances after RPE seems to, with small changes in the calculation of the variables that were studied, generally have maintained the changes of the dental arches that mainly came from the treatment with RPE and have contributed to the correct occlusion of the maxillary and mandibular dental arch.

After the total treatment with RPE and fixed appliances (T3-T), all patients of this study demonstrated significant changes of the dimensions of the maxillary and mandibular dental arch. All the widths of the maxillary dental arch, but also the mandibular inter-molar width and the maxillary arch perimeter, showed significant increases (Table 9). In the total time of the overall treatment, that was around 32 months, the maxillary arch width demonstrated a mean increase of 4.8 mm. The mean increases of the width of the mandibular arch were 1.9 mm in the region of the molars and 2.3 mm in the region of the canines. The palatal height showed a mean increase of 1.9 mm and the arch length of 0.7 mm. As far as the increase of the maxillary arch perimeter is concerned, it was of 6.9 mm (Table 8).

The literature permits us to compare the results of the total treatment (T3-T1) (Table 8) of the current study with the results that are mentioned by Moussa., *et al*. (1995) [10], McNamara., *et al*. (2003) [41] and D'Souza., *et al*. (2015) [14]. The above researchers used a therapeutic protocol that was very similar with the one that was used in the current study. In all the above studies, serial casts of the patients were studied and the RPE was combined in a later phase with fixed orthodontic appliances.

Taking into consideration the reduction of the 3 mm of the perimeters in both maxillary and mandibular arches, that was observed to happen in the change of the late mixed dentition to the early permanent dentition in sample that did not have any treatment [41], the combination of treatment with RPE and fixed orthodontic appliances of the current study can resist the normal tendency of the dental arches to lose perimeter and to result in significant increase of the maxillary arch perimeter.

Conclusion

The findings of this study led to the conclusion that treatment with RPE, and fixed orthodontic appliances can cause significant increase of the width of the dental arches and specifically in the width of the maxillary arch and thus to be effective in patients with narrow maxillary dental arch. An increase of 2mm was found in the inter-molar mandibular width. In addition, the combination of treatment with RPE and fixed orthodontic appliances seems to be an effective way to significantly increase the maxillary arch perimeter and to create additional space to relieve dental crowding.

Conflict of Interest

No financial interest or any conflict of interest exists.

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