МЕДИЦИНСКИЕ НАУКИ

PENDULUM APPLIANCE – PROBLEMS AND POSSIBILITIES IN ITS APPLICATION AT DIFFERENT AGE PERIODS

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Abstract

Aim. Our aim is to research the difference in the amount of distal movement and tipping of the upper molars in permanent dentition in patients during the growth period and in patients who have finished their growth period, both treated with M-pendulum as well as to find the time for its achievement.

Material and methods. We analyzed 72 patients, which were divided in two groups: Group 1 - 30 patients in growth period, Group 2 - 42 patients who have finished growth period.

Result. The treatment time for Group 1 has been 5.33 months and Group 2 - 6.42 months. The average dimension of the distal movement of upper first molars was 3.63 mm for all of the patients and for the second molars - 2.71 mm. We found significant larger amount of distal tipping of the second upper molar, almost 14^0 - group 1.9^0 - group 2. Distal tipping is less in cases with first and second molar – 9.38^0, rather than in cases with presence of a germ of a third molar – 11.42^0.

Conclusion. We found out that there is no significant difference in the dimensions of distal movement in patients in growth period compared to patients who has finished growth period.

Key Words: Pendulum appliance; Upper molar; Growth period; Distal movement

Introduction

In the past 20 years the distalization of the molars by the intraoral fixed appliances has been used more often in the contemporary orthodontics. Distalization of the molars with various appliances gives good result in the treatment of dento-alveolar class 2 malocclusions and mild skeletal discrepancies [1]. These appliances give to the orthodontist the opportunity to use non-extraction treatment, where space gaining is required [2, 3]. The extra oral appliances are less often used for distalization, because they are more uncomfortable for the patient and require a specific cooperation.

The Pendulum appliance [4] is one of the main and more preferable appliances for molar distalization. Having a light construction and great biomechanics the appliance is easily adaptable by the patients. Using this appliance we achieve a space in the dental arch with distalization of the medialized posterior teeth for the correction of crowding, protrusion, decreasing of the overjet and a Class 2 malocclusion. The gained space in the posterior segment is allocated in the middle and anterior segment for the alignment of the crowded teeth [5]. The M-Pendulum is a modification of the original appliance by Takemoto and Scuzzo [6]. The advantage of the modification is the U-loop turn, which is distally opened. The activation of this turn leads to transverse expansion which compensates the pendulum-like movement of the molars and their contraction. The overall result is a distal movement of the molars without any rotations and without decreasing the transversal width of the dental arch in the molars' area of.

The studies on patients treated with M-Pendulum have been conducted with aim at assessing the size of the distal movement of the upper first and second molar as the data we got were from 3.4 мм to 5.7мм [7, 8, 9]. The authors, by the use of the same appliance, have reported even more molar tipping (13.1^0– 15.78^0) [8, 9].

Bussik and McNamara [10], Ghosh and Nanda [7], and Kinzinger [11] suggested methods for finding the distal movement and tipping on consecutive cephalografs, which are correct and easy to apply.

The success of the treatments with distalization of upper molars depends on the amount of distalization and the time for its achievement. The choice of the treatment plan is consulted and suggested by the orthodontist and accepted by the patients as the leading motive for this choice is the duration of the treatment.

Kinzinger [11, 12, 13] conducted many studies on the Pendulum appliance impact and the relationship between the eruption phase of the second and third molars, the presence of decidual molars in the anchorage region as well as the appliance activity on the children and adults.

Flores-Mira et al. [14] carried out a systematic review on molar distalization based on the eruptive stage of the second and/or third molars. They reported that only in one study they found the amount of molar tipping was occurred as a result of distalization and was related to the eruption stage of the maxillary molars.

Different authors discussed the issue of effectiveness of the distal movement of the first and the second molars during the treatment with use of Pendulum и Bi-pendulum or Quad Pendulum [12, 15].

In 2012 and 2014 Yordanova [16, 17] found out on plastic cast short-term dento-alveolar changes of the upper first molar before and after distalization which average was 4.76 mm. Assessing the changes in the position of the crowns of the first molars on plastic cast we found the average increase in the dimension between the medio-buccal tubercle of upper right molar and the referent line is 4.39 mm and for the medio-palatal tubercle is 3.30 mm. The average increase in the dimensions between the medio buccal tubercle of upper left molar and the referent line is 4.51 mm and for the

medio palatal tubercle is 3.49 mm. The severe rotation of upper first molar is the reason that leads to lack of space in the tooth arch. Using the Pendulum appliance we correct firstly the molars' rotation and subsequently open the new space.

An extraction treatment begins immediately with leveling and alignment of teeth after the extraction of the teeth, as the distalization duration of the upper molars, in the non-extraction treatment plan, increases with the time necessary for the gaining the space by the distal movement of the molars [18]. To this duration we also have to add the time for compensating the side effects of the distal movement of the molars that affects the anchorage area. That's why in the last decade the trend is the use of absolute bone anchorage by the means of orthodontic mini-screws [19].

Aim: Our aim is to research the difference in the amount of distal movement and tipping of the upper molars in permanent dentition in patients during the growth period and in patients who have finished their growth period, both treated with M-pendulum as well as to find the time for its achievement.

Material and methods

Material: In this survey are included patients treated only in our private practice from the year 2011 to 2015. They are classified in two main groups: the first group that are still maturing (in growth period) and the second one with finished maturation (finished growth period). The patients who were included have documentation subject to identical norms. The patients were treated only by one orthodontist using the appliance M-pendulum, constructed and activated by the same way each time. The results were made by examination of the cephalometrics taken only by one and the same X-ray machine.

Table 1:

Distribution of the patients by gender and growth (p = 0.096)

Group	Male	Women	Total
Group 1 Patients in growth period	**11** **61.1 %**	**19** **35.2 %**	**30** **41.7 %**
Group 2 Patients with finished growth period	**7** **38.9 %**	**35** **64.8 %**	**42** **58.3 %**
Total	**18** **100.0 %**	**54** **100.0 %**	**72** **100.0 %**

All the patients taken in the survey had a permanent dentition with erupted first and second upper molars without tooth agenesis, a class 2 malocclusion with need of distalization of upper molars, and it was decided to be treated with non-extraction using the distalization with M-pendulum.

The survey is based on 72 patients at average patients' age 15.44±4.29 years old. The patients were between 12 and 35 years old. Eighteen of them (25%) were from male gender and 54 (75%) were from female gender (Table 1). The growing patients were with average age 12.83 and they were between 12 and 15 years old. From them 11 were from male gender 36.66% and 19 (63.34%) from female gender. The non-growing patients were with average age 17.55. From them 7 (16.66%) were from male gender and 35 (83.34%) were from female gender.

Methods:

The patients were treated with distal movement of the first molars till class I molar relations or class III molar relations were achieved. The dimensions of the distal movement of the first molars were various according to the individual needs, but in all cases class I or III molar relations had to be achieved. The decision for distal movement of the upper molars depended on the clinical treatment of the patient, without taking in to consideration the research value of the distal movement among the different groups. In every case there was bilateral distal movement of the upper first molar achieved only with M-pendulum appliance without any other means.

We used M-Pendulum appliance fixed at the first and second premolars. TMA springs with an additional U-loop opened distally have been activated by us up to 45^0-50^0, as the producing power was 125-150 gr. We made one more activation during the course of the treatment. We activated also the compensation U-loop with aim of correcting the distopalatal molar rotation. When a super class I relationship at the first molars was achieved the activation was stopped.

The researched patients were divided in two groups according to the criteria "growing potential". Group 1 were patients during the growth period and Group 2 patients who have finished the growth period. To assess this criterion of each patient we used the method of Baccetti and McNamara [20] while using the initial cephalometrics. We assessed the skeletal growth by the level of maturation of the cervical vertebral – CVM (*cervical vertebral maturation*) according to Baccetti. While applying this method the first three vertebral have to be researched (C2, C3, C4). Patients in stage CVMS I, II and III were classified as patients in growth period. Patients in stage CVMS IV and V were classified in the group of patients who have finished growth period.

The patients in both groups were classified in subgroups according to the number of erupted and present molars:

- Erupted first and second molars and presence of a germ of a third molar 67^8 (subgroup A)
- Erupted first and second molars and absent or extracted third molar 67 (subgroup B)
- Erupted first, second and third molar 678 (in this group there are only non-growing patients) (subgroup C)

The patients' classification and the distribution of the patients by growth potential and erupted and non-erupted third molars is shown in table 2.

Table 2

Distribution of the patients by growth potential (patients in growth period – group 1 and patients finished growth period – group 2) and tooth configuration

Tooth configuration	Upper right molar region		Upper left molar region	
	Group 1	Group 2	Group 1	Group 2
Erupted first and second molar and absence or extracted third molar ⎩67⎭ A	1 patient	7 patients	1 patient	8 patients
Erupted first and second molar and presence of the germ of third molar ⎩67^8⎭ B	29 patients	31 patients	29 patients	30 patients
Erupted first, second and third molar ⎩678⎭ C	-	4 patients	-	4 patients

The initial cephalometrics were analyzed in high resolution and perfect visualization of the reference points and planes. They were taken in the beginning of the treatment (T1) and right after the distal movement was finished (T2). The cephalometrics were analyzed (two times) and drawn with a pencil 0.5BB by the author herself.

For assessing the dimensions of the distal movement we used the reference plane PTV. We measured the dimension between the PTV plane and the point centroid of upper first and second molars, according to the method of Bussick and McNamara (2). Centroid is the point between the vertical axis of the tooth and the line connecting the two most convex points on the mesial and distal surface of the tooth crown (tooth equator). We abbreviate the first upper molar as M1 and the second upper molar as M2. These dimensions decrease after the process of the distal movement. We measured also the sagittal skeletal changes in the dimension between point A and the PTV plane.

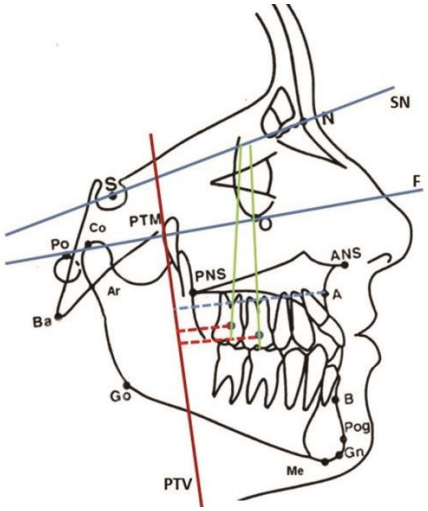

Fig.1 Methods of analysis

We used the SN plane as a reference for the angulation changes in the tipping of the first and second molar after the distal movement.

The data from the cephalometrics analysis were introduced and processed by the statistical software package IBM SPSS Statistics version 22.0. Statistical significance was tested at $p<0.05$. Descriptive statistics were calculated for all the measurement in each group. A T-test was used to compare the two measurements. Exploratory statistics revealed that the all variables were normally distributed.

Results and discussion:

From this survey we made a conclusion that the average time for achieving a required distal movement of upper first molar using the Pendulum appliance for all patients is 6 months (exactly 5.96 months). In group 1 patients the average time was 5.33 months. In group 2 patients the average time was 6.42 months, which is more closely to the overall result.

Table 3

Comparative analysis of the treatment time among the two groups in months

Group 1			Group 2			p
n	$\overline{X}$	SD	n	$\overline{X}$	SD	
30	5.33	0.78	42	6.42	1.19	<0.001

From table 3 it becomes clear that the duration of the treatment for the non-growing patients group was significantly longer compared to the duration of the treatment for the growing patients group. The difference in time was almost one month.

The average dimension of the distal movement of the upper first molars was 3.63 mm for all of the patients and for the second upper molars this value was 2.71 mm per side.

Table 4

Comparative analysis of the distal movement of first and second molars and changes in the dimensions in the maxilla before and after treatment

Index	Group 1 (n=30)		Group 2 (n=42)		p
	$\overline{X}$	SD	$\overline{X}$	SD	
First molar M1/PTV (мм)	**3.92**	**2.03**	**3.42**	**1.94**	**0.136**
Second molar M2/PTV (мм)	**3.08**	**1.19**	**2.62**	**0.86**	**0.099**
Skeletal base of the maxilla p.A/PTV (мм)	**0.53**	**0.41**	**0.29**	**0.48**	**0.004**

What are the dimensions of distal movement in the two groups of patients and is there a significant difference in this movement? The answer of this question is given in Table 4. We show the results from the comparative analyze of the distal movement of upper first and second molar and the sagittal changes in the maxilla before and after treatment. From the table it becomes clear that:

1. The average dimensions of the distal movement of the molars are larger in group 1. The difference is 0.5 mm. We must not forget that this larger dimension of distal movement is achieved one month faster.
2. The changes in the sagittal dimensions of the maxilla are with statistical meaning of p=0.004

One of the differences between the two groups of patients is that in the patients with finished growth period (group 2) there are 4 patients with erupted three molars. The distal movement in these patients is average of 2.56 mm per side for the first molar and 2 mm for the second molar. The results of these patients significantly decrease the total score of the distal movement in group 2 patients.

That's why we consider for it to be more objective to compare results between group 1 and group 2 patients with the same tooth configuration (erupted first and second molar and presence of a germ in the third molar – 1A, 1B and 2A, 2B). The data from these patients show that there is no statistically significant difference in the dimensions of the distal movement of upper molars between patients with finished growth period or still in growth period.

Because most of the patients were with erupted first and second molar and presence of a germ in the third molar, we compared the dimensions of the distal movement among them in the two groups. In one of the patients from group 2A there was unilateral absence of a germ so we exclude him from the survey. The comparison was made between 30 patients from group 2A and 29 patients from group 1A. (Table 5)

Table 5

Comparative analysis of the distal movement of first and second molar before and after the treatment (In patients with erupted first and second molar and germ of third molar – in growth period – group 1A and finished growth period – group 2A)

Index	Group 1A (n=29) bilateral $\lfloor \frac{6}{7}^{8} \rfloor$		Group 2A (n=30) bilateral $\lfloor \frac{6}{7}^{8} \rfloor$		p
	$\overline{X}$	SD	$\overline{X}$	SD	
First molar M1/PTV (мм)	**3.86**	**2.05**	**3.60**	**2.19**	**0.375**
Second molar M2/PTV (мм)	**3.05**	**1.20**	**2.73**	**0.90**	**0.341**

From this comparison it becomes clear that there is no significant difference in the dimensions of the distal movement in patients with growth period and patients with finished growth period. We discovered a difference of 0.26 mm for the first molars and 0.32 mm for the second molars.

In all of the cases a distal movement has been achieved. It has been enough for each clinical case and excludes an extraction treatment.

In a previous our survey[21] for the period 2004 – 2011, we studied 132 patients from which 94 (71.21%) in growth period. We found out that the average dimension of the distal movement of the first molar was 4.52 mm and for the second molar it was 3.88 mm. In this analysis we have included only patients with erupted first molar. The average dimension of distal movement among them was 4.65 mm for the first molar and 3.63 mm for the germ in the second molar. The methods we used in that survey are identical to the ones used in this survey, so we can say that the dimensions of the distal movement depends more on the number of the molars that we move, rather than on the skeletal growth factors.

The amount of distal movement of the first and second upper molars is comparable in both groups of patients and it is useful enough in how we carry out treatments. The conclusion is that the amount of distal movement does not depend significantly on the phase of growth, rather than the number of teeth that will be distalized and their stages of tooth development (mainly middle and position in the bone of the third molar).

Distalization of the well drilled molars is accompanied by a smaller distal tilt. In distalization of the first and second molars, which have not yet entered well in occlusion and available high into the bone of third molar amount of distal tipping would be great. Distal inclination at first and second upper molar was observed in all clinical studies, but it had a larger size in group 1 (growing patients). The distal inclination is greatest in patients with highly located germ of the third molar and the lowest rate in patients with germ missing third molar.

Table 6

Comparative analysis of the tipping of molars before and after the treatment examined in all of the patients included in the survey

Index	n	Before treatment		After treatment		p
		$\overline{X}$	SD	$\overline{X}$	SD	
M1/SN	72	**68.93**	**5.41**	**62.06**	**5.76**	**<0.001**
M2/SN	72	**62.06**	**7.70**	**51.03**	**9.25**	**<0.001**

We researched the change in tipping the first and second molars after distalization them. We compared the results of this between the two groups.

We found out a change in the distal tipping of the molars in all of the patients (72) included in the present survey. The average amount of tipping was 6.870 for the first molar and 11.030 for the second molar. This can be seen in table 6.

Table 7

Comparative analysis of the average change of tipping of the molars in patients in growth period – group 1 and patients who have finished the growth period – group 2

Index	Group 1 (n=30)		Group 2 (n=42)		p
	$\overline{X}$	SD	$\overline{X}$	SD	
Change of the tipping M1/SN (º)	**6.90**	**4.41**	**6.86**	**5.49**	**0.714**
Change of the tipping M2/SN (º)	**13.97**	**6.18**	**8.93**	**5.42**	**<0.001**

There is a statistical significant difference between the distal tipping of the second molar for the patients in growth period and the patients with finished growth period. The amount of distal tipping is larger in patients from group 1 (table 7).

We examined the results in the tipping of the first and second molars of the comparable patients from the two groups – 1A and 2A (table 8). We observed identical results as the previous comparison. There was a significant larger amount of distal tipping of the second upper molar, almost 14° for the patients in group 1A, compared to only 9° for the patients in group 2A.

Table 8

Comparative analysis of the change of tipping in molars among the two groups patients with erupted first and second molar and presence of germ of third molar: in group 1A and group 2A

Index	Group 1A (n=29) bilateral $\lfloor \frac{6}{7}^{8} \rfloor$		Group 2A (n=30) bilateral $\lfloor \frac{6}{7}^{8} \rfloor$		p
	$\overline{X}$	SD	$\overline{X}$	SD	
Change of the tipping M1/SN (º)	**6.76**	**4.42**	**6.74**	**5.60**	**0.990**
Change of the tipping M2/SN (º)	**13.93**	**6.28**	**9.06**	**5.88**	**0.003**

It is very plausible that this was caused because of the presence of the tooth germ in the third molar. The germ is underdeveloped yet and it is positioned higher next to the apical part of the roots of the second molar. In the distalization process, the second molar made distal movement and rotated axially around so that its

movement center presents the area where the germ pressed the roots and it led to bigger tipping of the molar.

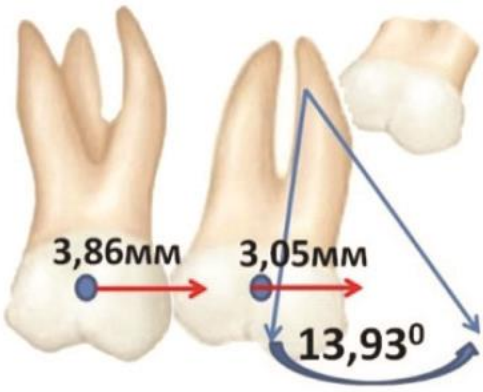

Fig. 2 Distal movement in patients in growth period

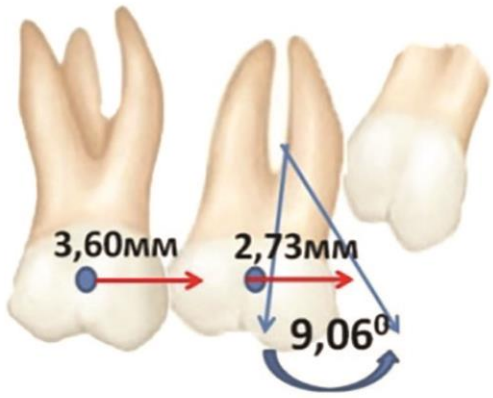

Fig. 3 Distal movement in patients who have finished growth period

From table 9 it becomes clear that the second molars were less tipped – 9.38^0, in cases with distalization only of the two molars in comparison with the tipping of the second molars – 11.42^0, which were fixed in the bond by the germs of the third molars.

Table 9

Comparative analysis of the change of tipping in molars between the groups: erupted first and second molar and absent or extracted third molar bilateral and erupted first and second molar and presence of germ of third molar bilateral, formed by all of the patients included in the survey.

Index	Group 1B and 2B (n=8) |67|		Group 1A and 2A (n=59) |67⁸|		p
	$\overline{X}$	SD	$\overline{X}$	SD	
Change of the tipping M1/SN (º)	**8.25**	**5.87**	**6.75**	**5.02**	**0.439**
Change of the tipping M2/SN (º)	**9.38**	**4.00**	**11.42**	**6.50**	**0.391**

From the presented three comparative studies it can be have concluded that the distal inclination in molars increased more in patients with un-erupted third molar.

This can be explained with the following biomechanics:

When applying the distalization from the M-Pendulum in the time of the erupted first and second molars, the germs of the molars produce a contra-force that will reflect with medial push on the apical root part of the second molar and there the distal tipping will be stronger. By the applying the M-Pendulum for the distalization only of the two molars, a minimal evidence of tipping nearly to the distalization can be watched. The distal tipping of the first and the second molar in this group of patients has similar values for the first molar – 8.25^0 and for the second - 9.38^0.

Therefore, the movements closer to the corps' ones are observed in patients with erupted and entered in occlusion three molar or those with well penetrated two molar and lack of third molar. We cannot always plan treatments with the distalization only in cases of well erupted molars. So we should have provided greater inclination in the second molars that will correct in the second treatment phase.

The observed changes in the sagittal dimension of the maxilla especially in patients from group 1 are associated according to us with the skeletal changes in the tuber of the maxilla, which has been stimulated by the distal movement of the molars. The other reason for the increased dimensions of the maxilla is the dental-root movements of the incisors. They are part of the anchorage region and undergo vestibular inclination. All of the above lead to mild changes in the position of the cephalometrics point A on the one hand and to increased dimension of the point A to the PTV plane on the other hand.

During the time of the M-Pendulum appliance' application, it releases from the blockage in the lower jaw especially at patients with the deep occlusion. The deblocking is achieved by the composite' thickness that has been used for the fixation of the appliance to the molars. This stimulates the process of self-correction of the lower jaw position as well as its spontaneous medial movement. This natural process is really more possible at the growing patients.

Conclusion: From the analysis we made the following conclusions: In all of the clinical cases we achieved distal movement of the upper molars. The amount of the distal movement was satisfactory for each individual case and we treated the patient without extractions of teeth. We found out that, applying the M-Pendulum, there is no significant difference in the dimensions of distal movement in patients in growth period compared to patients who have finished growth period. This process is accompanied with larger value of distal tipping of the second molar in patients in growth period who have presence of third molar’s germ compared to the patients who had finished the growth period. The distal movement of the molars is accompanied with less tipping in cases when all of the molars were erupted compared to the cases with un-erupted third molars. The average treatment time is around 6 months, as the patients in growth period have one month shorter period. This period does not significantly increase the treatment time and makes the non-extraction treatment appropriate and preferred by the patients.

It the conditions for appropriate treatment with distalization are met, than it is more preferable than that one with the extractions. The place formed as a result from the distalization is equal in average to that formed as a result of the premolars’ extraction. The accompanying negative effect of the medial movement of the teeth in the supported area is often favorable for the treatment of the patients with class II malocclusions. The good diagnostics and being familiar how to apply the appliance gives more options at solving of our clinical cases.

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