ORIGINAL PAPER

COMPARATIVE STUDY OF TRANSVERSE DENTAL CHANGES INDUCED BY PALATALLY-BUCCALLY APPLIED 2K-LOOP APPLIANCE AND PALATALLY APPLIED PENDULUM APPLIANCE

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ABSTRACT

Introduction: Difference in design of distalization appliances resulted in a difference in dimensions of dental arch after ending of distalization.

Objectives: The current study aimed to evaluate transverse dental changes caused by using both 2K-loop and pendulum appliances, and to compare different effects of both appliances using transverse dental measurements.

Material and methods: Study group included 16 participants with dental bilateral full cusp or end-to-end class II molar relationship equally divided into two groups. First group, 2K-loop group, consisted of 5 girls and 3 boys (mean age, 10.8 ± 1.2 years) treated with PB applied 2K-loop appliance. Second group, pendulum group included 5 girls and 3 boys (mean age, 11.1 ± 1.1 years) treated with palatally applied pendulum appliance. Study models were taken at the beginning of treatment and at the end of molar distalization. Paired samples *t*-test was applied to evaluate mean changes during treatment in each group, and to compare measurement differences between the two groups.

Results: Statistical analysis of the measurements showed an increase in inter-molar distance of the first molars in the two groups. The increase was significant in the 2K-loop group, with 4.33 ± 0.81 mm, and not significant in the pendulum group (2.19 ± 2.00 mm). There was a significant distal rotation in the upper right first molars of 7.83° ± 2.92°, and 8.66° ± 2.73° on the left with PB 2K-loop appliance. Also, significant mesial rotation on the upper right first molars was observed with 4.83° ± 3.97°, and 4.83° ± 2.71° on the left with palatally applied pendulum appliance.

Conclusions: PB acting on 2K-loop appliance causes an increase in the inter-molar distance and distal rotation of maxillary first molars. Palatally acting pendulum appliance results in mesial rotation of maxillary first molars. In cases where maxillary molars need to be de-rotated and to increase inter-molar distance, PB 2K-loop appliance is a better choice.

Key words: molar distalization, class II malocclusion, 2K-loop appliance, pendulum appliance.

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INTRODUCTION

Class II malocclusion patients represent about 35% of cases in European and American populations [1]. For patients with class II molar relationship, distalization of the upper molar is frequently chosen as a treatment alternative to extraction [2].

Intra-oral non-cooperated intra-maxillary distalization appliances rely on various kinds of anchorage means, such as palatally anchorage, mini-plate anchorage, and

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palatal bone screw anchorage. Temporary anchorage devices (TADs) are not recommended before ages of 12 to 13, because of inappropriate bone density [3, 4]. Therefore, there is a need for distalization appliances that use traditional palatally anchoring (Nance palatal arch) in patients under the age of 12 years [3]. Although palatally anchorage is preferred at this age, there are several contraindications to the use of this anchorage method, such as patients with increased overjet with proclination of maxillary incisors, increased mandibular plane angle, and skeletal or dental open bites [5].

According to the literature, in patients with class II molar relationship, 85% of maxillary first molars rotate mesially [6]. Derotation of maxillary first molars is the first step in class II treatment, and merely correcting mesial rotation of molars changes in molar relationship in a class I direction [3].

Many studies examine the changes in the appliance design in terms of the side of force application and their impact on dimensions of dental arch at the end of distalization. Several studies [7-9] investigated the side of force application or the presence of active components, such as buccally, palatally, or palatally-buccally (PB), as the factor impacting the effectiveness, quality, and duration of molar distalization using intra-oral non-cooperated molar distalization appliances. In the literature, there are studies that evaluated the nature and magnitude of transverse changes in the dental arch during distalization [10-12]. According to our knowledge, there is only one study by Bellini-Pereira [13], who compared the transverse dental changes induced by palatally and PB acting molar distalization appliances. Therefore, the aim of the current study was to compare the transverse dental changes resulting from the molar distalization of 2K-loop appliance [14] not studied in a controlled clinical study that used two active components to apply force. The first was buccally and the other was palatally applied force, using molar distalization pendulum appliance [15] with only one palatally active component.

OBJECTIVES

The current study aimed to evaluate transverse dental changes caused by using both 2K-loop and pendulum appliances, and to compare different effects of both appliances using transverse dental measurements.

MATERIAL AND METHODS

This study was a two-arm, parallel, prospective clinical trial, conducted between August 2020 and April 2022. Ethical approval was obtained from Scientific Research Council of Tishreen University (approval number: 1787; dated on May 5, 2020). A written consent was taken from patients' guardians, since all participants were underaged.

SAMPLE SIZE CALCULATION

Sample size was calculated using G*Power software, version 3.1.9.6 (Franz Faul, University of Kiel, Germany), with the following assumptions: significance level of 0.05, power of 95%, and based on measurements of the amount of rotation of the right maxillary first molars that were obtained by conducting a pilot study among 12 patients. The power analysis showed that 8 patients in each group were required to conduct two-sample *t*-tests.

PARTICIPANTS AND ELIGIBILITY CRITERIA

The study sample included 16 participants, who were randomly divided into two groups of eight each: 2K-loop group (5 girls, 3 boys; mean age, 10.8 ± 1.2 years) treated with PB applied 2K-loop appliance, and pendulum group (5 girls, 3 boys; mean age, 11.1 ± 1.1 years) treated with palatally applied pendulum appliance. Duration of the study was approximately six months. Inclusion criteria were skeletal class I malocclusion (ANB angle, 1-5°), bilateral class II or end on molar relationship, low to moderate mandibular plane angle (SN/Go GN, ≤ 37°), late mixed dentition with upper second molars that were not emerging to the functional occlusal level, eruption upper first premolars to functional occlusal level, no fractures or severe wear of molars and premolar cusps, overjet less than 5 mm, treatment plan without extraction. Exclusion criteria were congenital syndromes, such as cleft lip/palate, degenerative temporo-mandibular joint disease, congenitally missing teeth, periodontal disease, prosthodontics rehabilitation of maxillary molars, endodontic treatments of maxillary molars.

APPLIANCES USED IN THE STUDY

A Nance button supported by 0.043-inch stainless steel wire welded to the palatal side of bands of the upper first premolars was applied for anchorage control in both appliances.

PB ACTING 2K-LOOP APPLIANCE

The appliance consisted of four identical active springs, two on the palatal side and the other two on the buccal side, and it was made from a 0.017 × 0.025-inch titanium-molybdenum alloy (TMA) wire. Springs were designed as described by Kaltra [16], with each leg of 8 mm long and 1.5 mm wide, and bent 20° down to help counteract torques generated by horizontal forces of the appliance. Buccal loop was inserted between the buccal bracket, with 0.022 × 0.028-inch of the first upper premolars and main tube of 0.022 × 0.028-inch of the first upper molar bands, while the anterior end

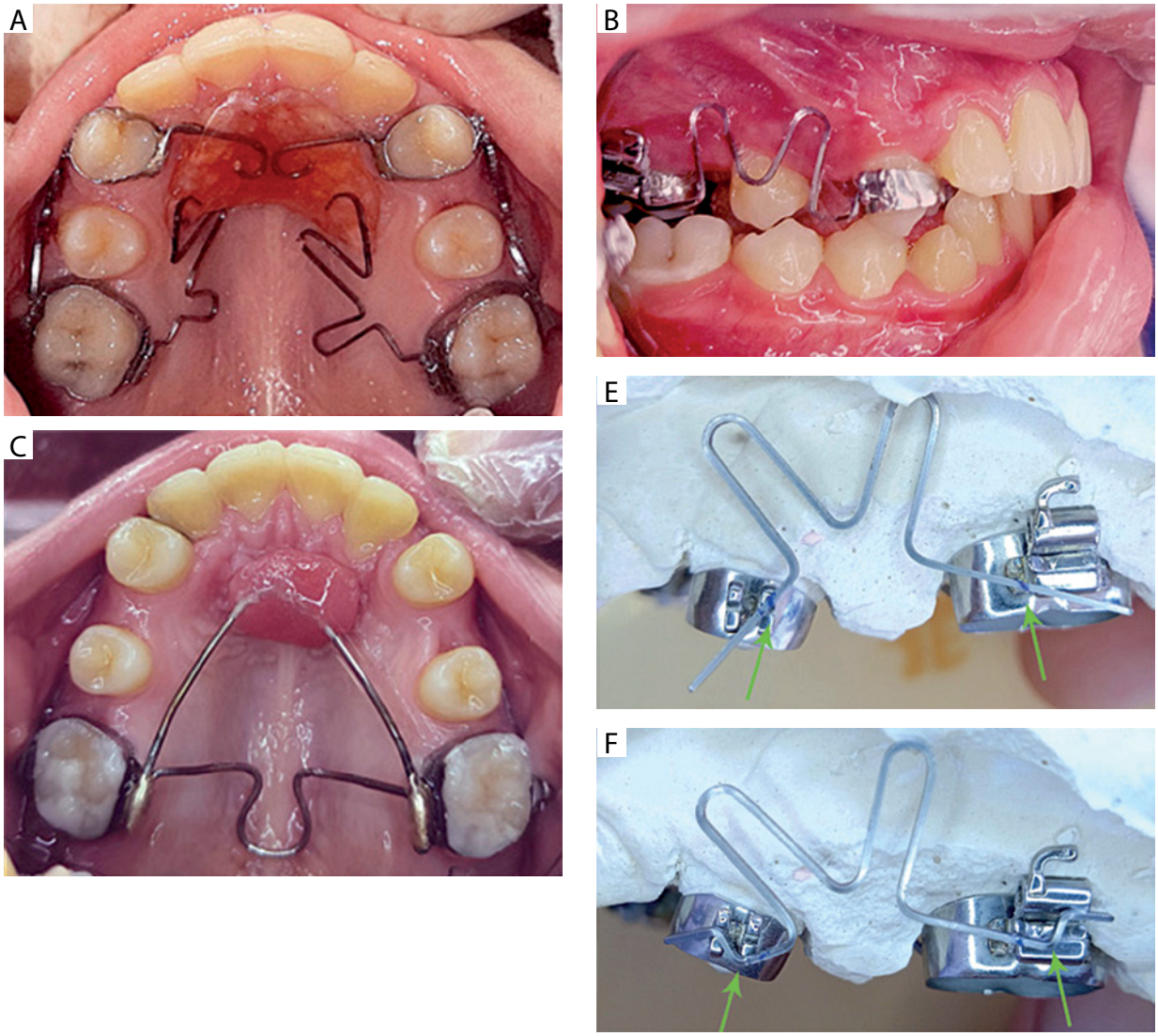

FIGURE 1. 2K-loop appliance. **A**) Intra-oral occlusal view after two weeks of placement. **B**) Buccal view before displacement of the appliance. **C**) Occlusal view of trans-palatal bar with Nance button used for molars retention after distalization. **D**) K-loop spring before placement of high step bend. **E**) K-loop spring after placement of 2 mm high step bend, 1.5 mm distally to the molar mark and 1.5 mm mesially to the premolar mark

of the palatal loop was inserted into an acrylic pad of Nance button, with its posterior free-end inserted into palatal sheaths of the molar bands (Figures 1A and 1B).

Regarding device activation, the wire was marked distally of the premolar bracket and mesially of the molar tube after that (1.5 mm). High step bends were bent into the wire (1 mm) distally to the distal mark and (1 mm) mesially to the mesial mark. This allowed 2 mm of activation (Figures 1D and 1E), and the appliance was re-activated (2 mm) after 6 to 8 weeks. The buccal loop was re-activated extra-orally, while palatal, intra-orally. This was sufficient to include the molars into super class I relationship after 5 to 6 months from the start. Trans-palatal bar with Nance button was used for retention of distalized molars within 24 hours of removing distalization appliance (Figure 1C).

PALATALLY ACTING PENDULUM APPLIANCE

The appliance consisted of two active springs located palatally. Each spring was made from a 0.032-inch (TMA) round wire. Its anterior end was inserted into the acrylic Nance button, and its posterior end remained free. After activation, it was re-curved at the end and fit into palatal sheaths of the upper first molar bands (Figure 2A). Two pre-activation bends were made of spring: 1. A toe-in bend (10-15°) at the transverse level, as described by Kinzingeret *et al.* [17], to reduce molar rotation during molar distalization by producing distal rotation of the upper first molars (Figure 2D). 2. An up-righting bend (10-15°) at the anterior-posterior level, as described by Byloff *et al.* [18], to reduce molar distal tipping during molar distalization (Figure 2B);

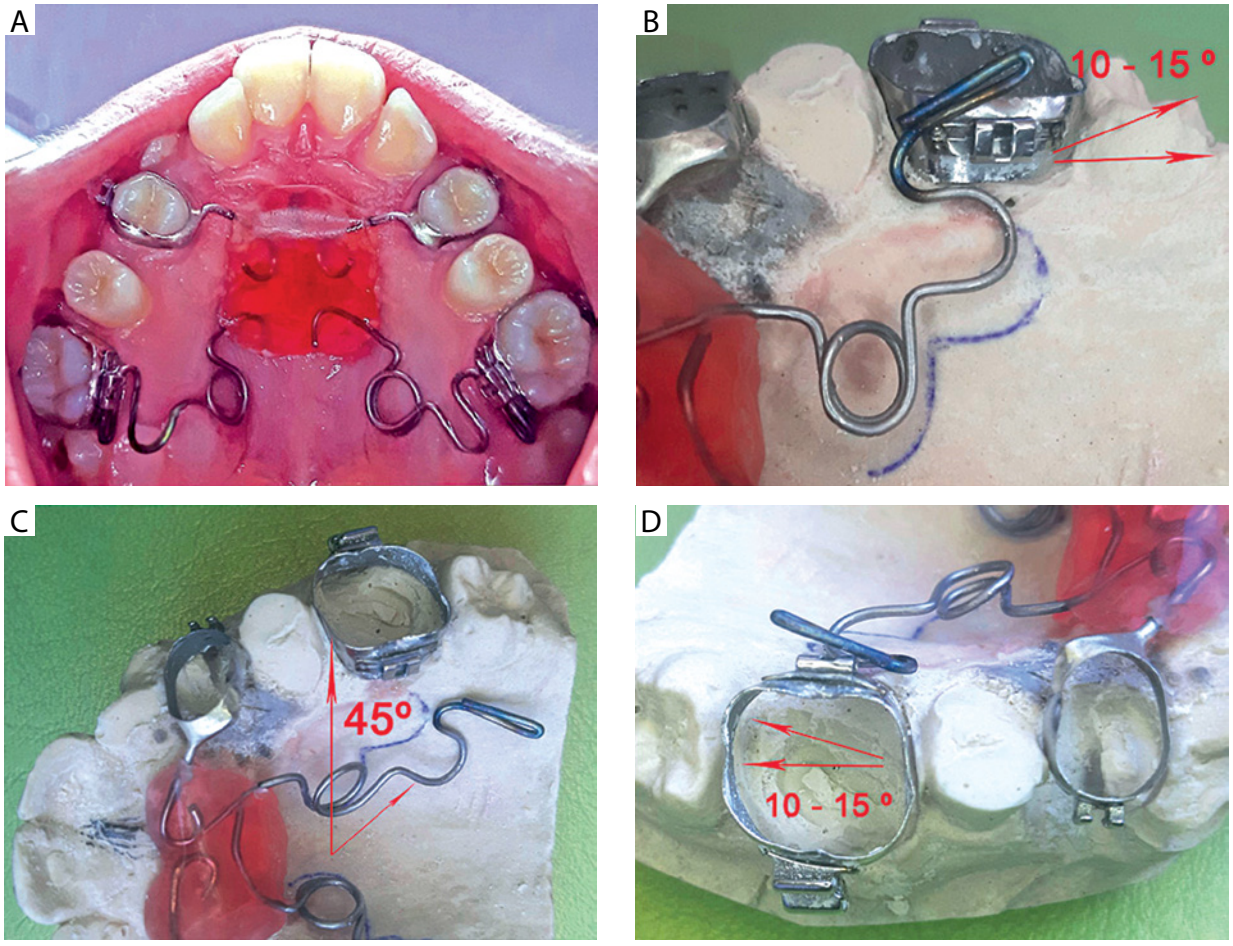

FIGURE 2. Pendulum appliance. **A**) Intra-oral occlusal view after two weeks of placement. **B**) 10-15º of up-righting bend, (**C**) 45º of distal activation bend, (**D**) and 10-15º of toe-in bend

the springs were activated at 45º in the center of helices, with an initial force of 200 g (Figure 2C).

Activation was repeated according to the amount of molar distalization, and super class I molar relationship was achieved after 6 months. To obtain identical springs in all appliances, all appliance springs were manufactured using an acrylic guide with a groove of the desired spring shape (Figures 3A and 3B).

STUDY MODELS MEASUREMENTS

Study models taken before and after treatment were used to evaluate transverse dental changes. Eight points and three lines were used to determine the median palatal suture and position of the maxillary first molars. Model's cast landmarks applied in this study are shown in Figure 4. Transverse dental changes of upper first premolars were not evaluated because the bands of upper first premolars were welded to Nance palatal arch, and second premolars did not erupt in all patients.

A line was used as the midline reference plane. Transverse movements of the maxillary molars (distance, UR6F–UL6F) were calculated by measuring the distance between UR6F and UL6F. The amount of rotation of the maxillary first molars per degree was determined by measuring the angles between R line, L line, and A line. All calculations were derived from measurements directly made on the model casts (Figure 4).

Scanned dental casts of two patients before and after treatments are shown in Figure 5, one was treated with the 2K-loop appliance and another with the pendulum appliance.

Ten randomly selected models were marked, and measurements were recorded by another orthodontist. A method error and intra-observer reliability were determined with Dahlberg's formula [19] and paired samples *t*-test.

STATISTICAL ANALYSIS

SPSS version 26 (SPSS Inc., Chicago, IL, USA) was applied to execute all statistical analyses. To check for data normality, Shapiro-Wilk test was applied. Because data was normally distributed, paired samples *t*-test was used to evaluate the mean changes during treatment in each group, and compared measurement differences between the two groups.

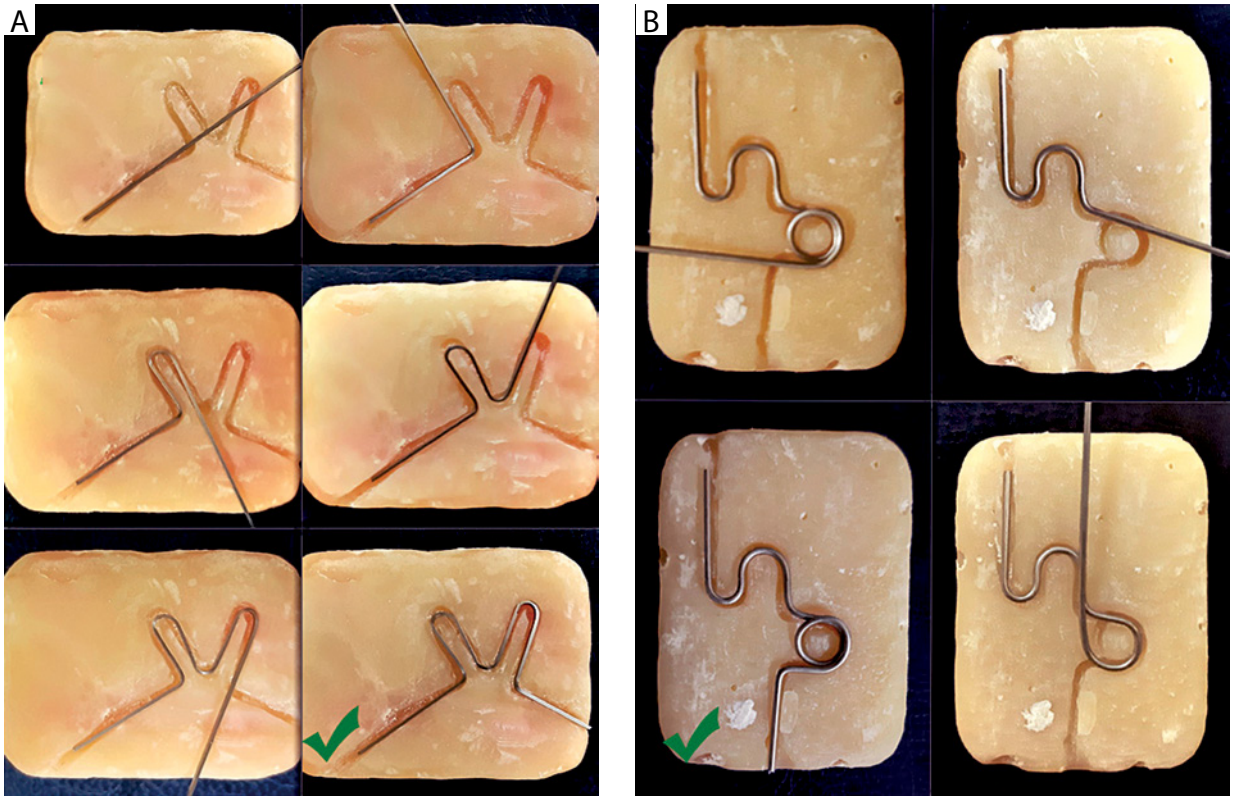

FIGURE 3. Acrylic guide used for springs manufacturing. **A**) Manufacture of a pendulum spring. **B**) Manufacture of a 2K-loop spring

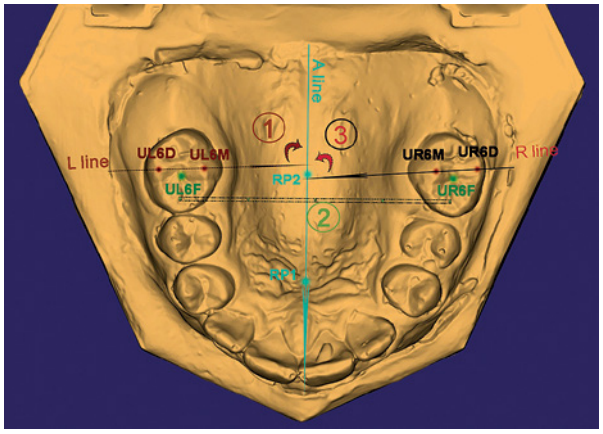

FIGURE 4. Scanned image of a dental cast with landmarks and measurements used in the model analysis. **A**) A–R angle, (**B**) UR6F–UL6F distance, (**C**) A–L (RP1) angle. The point, where the two second palatal rugae meet median palatal suture. RP2 – cross-point of the line connecting central fossa of the upper first molars with median palatal suture. UR6M – mesio-palatal cusp tip of the right upper first molar. UR6D – disto-buccal cusp tip of the right upper first molar. UR6F – central fossa of the right upper first molar. UL6M – mesio-palatal cusp tip of the left upper first molar. UL6D – disto-buccal cusp tip of the left upper first molar. UL6M – central fossa of the left upper first molar

RESULTS

The method error did not surpass 0.2 mm for linear measurements and 0.6° for angular measurements of the variables investigated, and the duplicated measurements were not significantly different ($p > 0.05$).

Measurements taken before the initiation of treatment and Shapiro-Wilk test results are presented in Table 1. The assessment of the maxilla casts before and after molar distalization showed the following transverse dental changes in each variable in the two groups and intra-group and inter-group comparisons of these changes (Table 2).

In the 2K-loop group, a significant increase was observed in the intermolar distance of the first molars (distance, UR6F–UL6F; $p < 0.01$). Furthermore, significant distal rotation was observed for the bilateral maxillary first molars (A–L and A–R angles, $p < 0.001$).

In the pendulum group, a non-significant increase was observed in the inter-molar distance of the first molars (distance, UR6F–UL6F; $p > 0.05$). In addition, there were a significant increase in the maxillary left and right first molar angles (A–L and A–R angles; $p < 0.01$ and $p < 0.05$, respectively), which indicated mesial rotation.

The increase in the distances between the central fossa of the upper first molars was significantly greater in the 2K-loop group than in the pendulum group

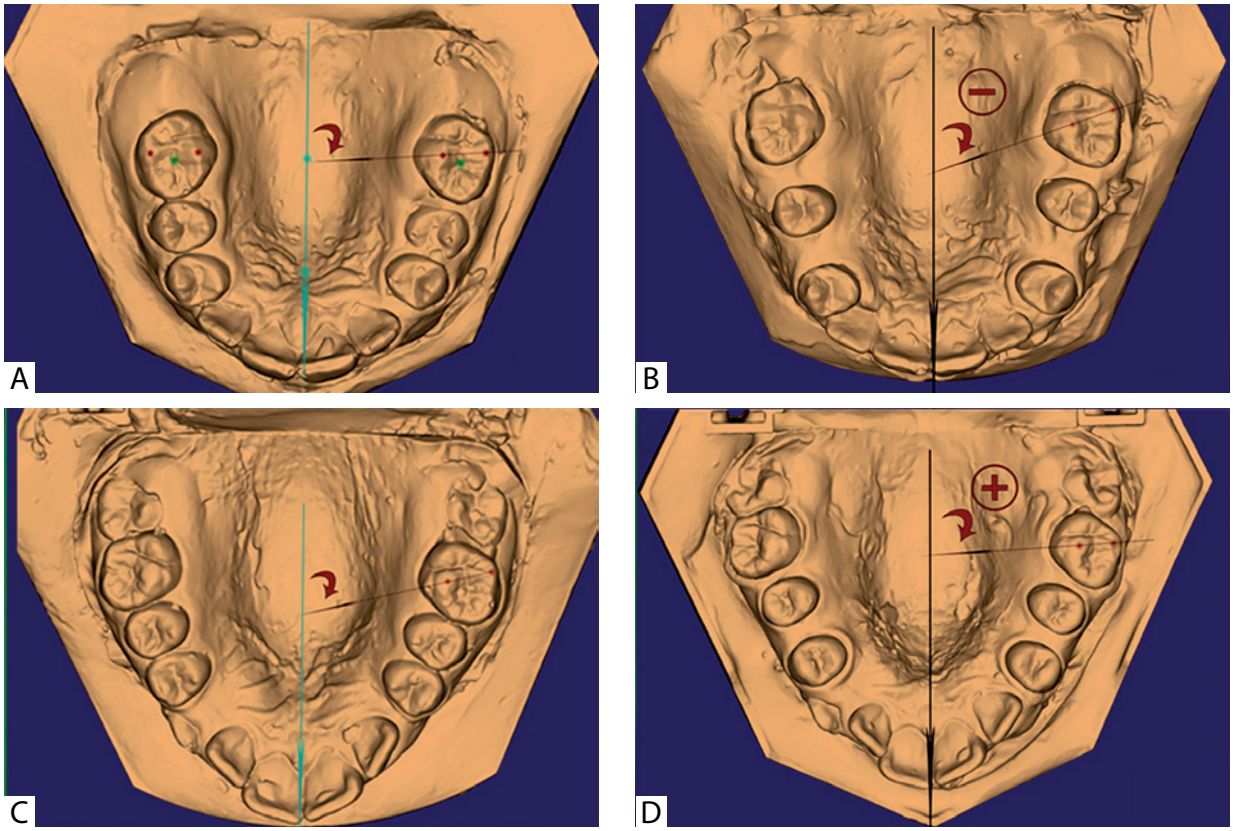

FIGURE 5. Scanned images of dental casts of two patients, one from the 2K-loop group and another from the pendulum group before and after treatments. **A**) Pre-distalization of a 2K-loop patient. **B**) Post-distalization of a 2K-loop patient with distal rotation of molars. **C**) Pre-distalization of a pendulum patient. **D**) Post-distalization of a pendulum patient with mesial rotation of molars

($p < 0.05$). Furthermore, the decrease in the maxillary first molar angles (A–L and A–R angles) induced by PB acting forces in the 2K-loop group was significantly less than the increase induced by palatal force in the pendulum group ($p < 0.001$).

DISCUSSION

Several studies [7-9] concluded that different sides of force application (buccally, palatally, or PB) in intra-oral non-compliance intra-maxillary distalization appliances had an important effect on the antero-posterior dimensions of the dental arch. However, very few studies [10, 11, 20] compared the transverse changes of the dental arch resulting from the difference in the design of these appliances. But no study evaluated transverse dental changes caused by using both PB acting 2K-loop and palatally acting pendulum appliances, and compared different effects of both appliances with the type and amount of the maxillary first molars rotation.

Regarding the rotation of the upper first molars, in the case of the pendulum, where the force was acting from the palatal side, palatally from the center of resistance, there was a significant mesial rotation of 4.83 ± 3.97° on the right and 4.83 ± 2.71° on the left. Our findings were consistent with those of Kircelli *et al.* [21], who observed a mesial rotation of the first molars of 9.0 ± 4.1° with pendulum, and Uzuner *et al.* [10], who used palatally acting frog appliance and induced mesial rotation ranging from 4.4 to 5.9°. Our results differed from those of Hourfar *et al.* [11], who used frog appliance, and observed a distal rotation when they added a toe-in bending to the springs of their appliances, as in the present study. This was probably because Hourfar *et al.* compared the casts before treatment with the casts after completing the alignment, and leveling stage by fixed appliances.

Derotation of the maxillary first molars is the first step in class II treatment of almost every type [3]. In the case of 2K-loop, where the force is acting from the palatal and buccal sides, there was a significant distal rotation of 7.83 ± 2.92° on the right and 8.66 ± 2.73° on the left. Our findings were consistent with those of Acar *et al.* [22], who used a pendulum appliance supported with a K-loop buccally, and induced distal rotation ranging from 2.0 to 2.5° as well as Bellini-Pereira *et al.* [13], who observed a distal rotation of the first molars of 1.76° with PB acting first class appliance.

The distal rotation in molars that was observed in the case of 2K-loop, although equal forces were applied

TABLE 1. Values of measurements taken before initiation of treatment in 2K-loop and pendulum groups. Shapiro-Wilk test results

Pre-treatment measurement	2K-loop group ($n = 8$)	Shapiro-Wilk test		Pendulum group ($n = 8$)	Shapiro-Wilk test	
	Pre-treatment	Statistic	Sig.	Pre-treatment	Statistic	Sig.
Distance UR6F–UL6F (mm)	44.17 (2.63)	0.966	0.863 (NS)	46.00 (1.41)	0.982	0.960 (NS)
Angle A–R (°)	84.67 (6.71)	0.960	0.816 (NS)	74.67 (5.27)	0.877	0.256 (NS)
Angle A–L (°)	78.83 (4.49)	0.929	0.576 (NS)	71.00 (6.89)	0.981	0.957 (NS)

Values presented as mean (standard deviation of the mean).
Pendulum group used pendulum appliance (Hilgers, James J; palatally acting). 2K-loop group used 2K-loop appliance (2K-loop appliance; PB acting).
Sig. – significant, NS – not significant

TABLE 2. Intra-group and inter-group comparisons of transverse dental changes resulting from 2K-loop and pendulum groups

Measurement	2K-loop group			Pendulum group			Differences		
	Pre-treatment	Post-treatment	*p*-value	Pre-treatment	Post-treatment	*p*-value	2k-loop group	Pendulum group	*p*-value
Distance UR6F–UL6F (mm)	44.17 (2.63)	48.50 (2.42)	< 0.01	46.00 (1.41)	48.00 (2.44)	0.076 (NS)	4.33 ± 0.81	2.00 ± 2.19	< 0.05
Angle A–R (°)	84.67 (6.71)	76.83 (6.52)	< 0.001	74.00 (5.27)	79.50 (5.24)	< 0.05	7.83 ± 2.92	4.83 ± 3.97	< 0.001
Angle A–L (°)	78.83 (4.49)	70.17 (3.86)	< 0.001	71.00 (6.89)	75.83 (5.23)	< 0.01	8.66 ± 2.73	4.83 ± 2.71	< 0.001

Values presented as mean (standard deviation of the mean) ± standard deviation of the mean difference.
Pendulum group used pendulum appliance (Hilgers, James J; palatally acting). 2K-loop group used 2K-loop appliance (2K-loop appliance; PB acting).
NS – not significant. Paired samples t-test was used.

on both sides, was probably caused by a greater thickness of the bone supporting the palatal root compared with the vestibular roots of the upper first molars [23]. This makes the palatal root act as a rotational axis during distalization. Regarding transverse movements of the maxillary first molars, both the groups achieved an increase in posterior width, but the increase was significant in the 2K-loop group with 4.33 ± 0.81 mm, and not significant in the pendulum group, with 2.19 ± 2.00 mm. Oberti *et al.* [24] reported a significant increase in intermolar width of 4.7 ± 2.0 mm with PB acting dual-force distalizer. Also, Papadopoulos *et al.* [25] observed a significant increase of 2.74 mm with PB acting first class appliance (FCA). This increase was probably caused by the new position of the first molars on the natural V-shape of the arch form. Uzuner *et al.* [10] suggested that a greater amount of rotation per millimeter of the first molar produces a more buccal position of the molar, regardless of the rotation direction. In the present study, this was observed in the 2K-loop group, where the distal rotation per millimeter was greater than the mesial rotation in the pendulum group.

One important limitation of this study was the lack of measurements of sagittal and vertical dental changes, which can be obtained by analysis of lateral cephalograms. Another limitation is a short-term evaluation period of about 22 weeks. Therefore, future research should focus on long-term evaluation of post-retention period.

CONCLUSIONS

The current study results support that the PB acting 2K-loop appliance causes an increase in the intermolar distance and distal rotation of maxillary first molars. Palatally acting pendulum appliance cause mesial rotation of maxillary first molars. In cases, where maxillary molars need to be derotated, and in case of need to increase inter-molar distance, PB acting appliance, such as the 2K-loop is a better choice than palatally acting appliance, such as a pendulum appliance.

CONFLICT OF INTERESTS

The authors declare no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

References

1. Quinzi V, Marchetti E, Guerriero L, Bosco F, Marzo G, Mummolo S. Dentoskeletal class II malocclusion: Maxillary molar distalization with no-compliance fixed orthodontic equipment. Dent J 2020; 8: 26-35.

2. Chandra P, Agarwal S, Singh D, Agarwal S. Intra oral molar distalization: a review. J Dentofac Sci 2012; 1: 15-18.
3. Proffit WR, Fields HW, Msd DM, et al. Contemporary orthodontics, 6th ed. South Asia Edition-E-Book. Elsevier India 2019; 6e: 422.
4. Mizrahi E. The use of miniscrews in orthodontics: a review of selected clinical applications. Primary Dent J 2016; 5: 20-27.
5. Kaur S, Soni S, Garg V, Kaur M, Singh R. Pendulum appliance and its modifications – a review. Int J Curr Res Med Sci 2018; 4: 1-9.
6. Liu D, Melsen B. Reappraisal of class ii molar relationships diagnosed from the lingual side. Clin Orthodont Res 2001; 4: 97-104.
7. Bellini-Pereira SA, Pupulim DC, Aliaga-Del Castillo A, Castanha Henriques JF, Janson G. Time of maxillary molar distalization with non-compliance intraoral distalizing appliances: a meta-analysis. Eur J Orthodont 2019, 41: 652-660.
8. Ravera S, Castroflorio T, Garino F, Daher S, Cugliari G, Deregibus A. Maxillary molar distalization with aligners in adult patients: a multicenter retrospective study. Prog Orthod 2016; 17: 12. DOI: 10.1186/s40510-016-0126-0.
9. Antonarakis GS, Kiliaridis S. Maxillary molar distalization with noncompliance intramaxillary appliances in Class II malocclusion: a systematic review. Angle Orthod 2008; 78: 1133-1140.
10. Uzuner FD, Kaygisiz E, Unver F, Tortop T. Comparison of transverse dental changes induced by the palatally applied Frog appliance and buccally applied Karad's integrated distalizing system. Korean J Orthod 2016; 46: 96-103.
11. Hourfar J, Ludwig B, Kanavakis G. An active, skeletally anchored transpalatal appliance for derotation, distalization and vertical control of maxillary first molars. J Orthod 2014; 41 Suppl 1: S24-S32.
12. Nalcaci R, Kocoglu-Altan AB, Bicakci AA, Ozturk F, Babacan H. A reliable method for evaluating upper molar distalization: superimposition of three-dimensional digital models. Korean J Orthod 2015; 45: 82-88.
13. Bellini-Pereira SA, Aliaga-Del Castillo A, Vilanova L, et al. Sagittal, rotational and transverse changes with three intraoral distalization force systems: Jones jig, distal jet and first class. J Clin Exp Dent 2021; 13: e455-e462. DOI: 10.4317/jced.57993.
14. Tripathi T, Rai P, Singh N. Molar distalization with 2K appliance. one-year follow-up. J Orthod Sci 2017; 6: 97-103.
15. Hilgers JJ. The pendulum appliance for class II non-compliance therapy. J Clin Orthod 1992; 26: 706-714.
16. Kalra V. The K-loop molar distalizing appliance. J Clin Orthod 1995; 29: 298-305.
17. Kinzinger GS, Gross U, Fritz UB, Diedrich PR. Anchorage quality of deciduous molars versus premolars for molar distalization with a pendulum appliance. Am J Orthod Dentofacial Orthop 2005; 127: 314-323.
18. Byloff FK, Darendeliler MA. Distal molar movement using the pendulum appliance. Part 1: Clinical and radiological evaluation. Angle Orthod 1997; 67: 249-260.
19. Statistical methods for medical and biological students. Br Med J 1940; 2: 358-359.
20. Nalcaci R, Kocoglu-Altan AB, Bicakci AA, Ozturk F, Babacan H. A reliable method for evaluating upper molar distalization. Superimposition of three-dimensional digital models. Korean J Orthod 2015; 45: 82-88.
21. Kircelli BH, Pektaş Z, Kircelli C. Maxillary molar distalization with a bone-anchored pendulum appliance. Angle Orthod 2006; 76: 650-659.
22. Acar AG, Gursoy S, Dincer M. Molar distalization with a pendulum appliance K-loop combination. Eur J Orthod 2010; 32: 459-465.
23. Porto OCL, Santos de Freitas Silva B, Silva JA, et al. CBCT assessment of bone thickness in maxillary and mandibular teeth: an anatomic study. J Appl Oral Sci 2020; 28: e2019.0148. DOI: 10.1590/1678-7757-2019-0148.
24. Oberti G, Villegas C, Ealo M, Palacio JC, Baccetti T. Maxillary molar distalization with the dual-force distalizer supported by mini-implants: a clinical study. Am J Orthod Dentofacial Orthop 2009; 135: 282.e1-282.e5. DOI: 10.1016/j.ajodo.2008.11.018.
25. Papadopoulos MA, Melkos AB, Athanasiou AE. Noncompliance maxillary molar distalization with the first class appliance: a randomized controlled trial. Am J Orthod Dentofacial Orthop 2010; 137: 586.e-586.e13. DOI: 10.1016/j.ajodo.2009.10.033.