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EVALUATION OF THE EFFECT OF PLATELET RICH PLASMA ON THE RATE OF MAXILLARY FIRST MOLARS DISTALIZATION; A RANDOMIZED CLINICAL TRIAL

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Abstract

Objective *to evaluate the effect of platelet rich plasma (PRP) on the rate of maxillary first molars distalization.*

Materials and methods: *twenty class II subjects of age range between 19-30 years who required bilateral maxillary first molars distalization as a part of their orthodontic treatment were randomly allocated into two equal groups: PRP group and control group. Distalization was carried out with a miniscrew implant-aided modified transpalatal bar appliance. The PRP group received PRP injection on the day of distalization appliance placement. Digital models were obtained every four weeks to evaluate the rate of maxillary first molars distal movement for a period of six months.*

Results*: the control group showed a statistically significant higher rate of distal movement of the first molars compared to the PRP group from the third to the sixth month of the study.*

Conclusion: *The PRP did not accelerate the rate of maxillary first molars distalization. It rather decreased the rate of distalization.*

Introduction

Class II malocclusion has a high prevalence in the population and is presented in a great percentage of patients demanding orthodontic treatment [1]. Treatment of class II malocclusion in an adult patient could be either orthodontic camouflage by tooth movement or surgical correction for the more sever class II cases with no further growth potential. For treatment of class II malocclusion by orthodontic camouflage premolars extraction or non-extraction treatment can be performed. Non-extraction treatment involves maxillary molars distalization, expansion, uprightening and derotation of tilted posterior teeth and interproximal reduction. Maxillary molar distalization is one of the most common approaches for correction of class II malocclusion [2].

Comprehensive orthodontic treatment usually requires at least 1 and a half years in moderate to severe cases of malocclusion [3]. As a result of this long duration of treatment with the fixed appliances, several adverse effects may develop like pain, discomfort, caries, gingival recession and apical root resorption [4,5]. In addition, most adult patients desire to finish their treatment as early as possible for social and esthetic reasons [6]. Therefore, to prevent these adverse effects and encourage patients to accept orthodontic treatment, approaches for acceleration of

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orthodontic tooth have been studied and investigated including: local injection of biological substances, surgical, mechanical, and physical methods [7].

Platelet rich plasma (PRP) is an autologous concentration of platelets in a small volume of plasma. It is rich in cytokines and growth factors that can stimulate the activity of osteoblasts and osteoclasts, also they can mediate differentiation, activation and survival of all bone cells. Therefore, PRP could possibly affect the orthodontic tooth movement [8].

This study was dedicated to evaluate the effect of platelet rich plasma (PRP) on the rate of maxillary first molars distalization.

Materials and Methods

Trial design and setting:

This study was a two-arm, parallel group, randomized clinical trial with the allocation ratio of 1:1. The Consolidated Standards of Reporting Trials (CONSORT statement) were used as a guide for this study. The study was performed in the outpatient clinic of the Orthodontic Department at the Faculty of Dentistry, Ain Shams University. The ethical committee at the Faculty of Dentistry Ain-Shams University approved the study design after reviewing the study protocol. Before treatment was carried out a detailed written Arabic consent was signed by all the subjects after full explanation of the procedure and the aim of the study.

Sample size calculation:

The power analysis for this study was generated based on a study by Rashid [8] for evaluating the effect of PRP injection on the rate of tooth movement. Two-sample t-test at a conventional alpha-level (p = 0.05) with desired power of 80% was done. The calculations were performed with the computer application G*Power[1]. The test resulted in a total number of 16 patients, 8 in each group. However, a total sample size of 20 participants (10 in each group) was enrolled to further increase the power of the study

Participants and eligibility criteria

Twenty subjects (ten in each group) were included in the current study following these inclusion criteria: age range from 19 to 30 years, bilateral class II molar relationship, normal to low mandibular plane angle and no previous orthodontic treatment. Whereas exclusion criteria included subjects having medical problems that affect tooth movement (e.g. osteoporosis, bisphosphonate therapy, etc...) or bad oral hygiene.

Randomization

Patients who met the inclusion criteria and approved participation in the study were randomly assigned to either control or experimental (PRP) group. Randomization was done using computer software which generated random number sequence with an allocation ratio of 1:1.

Intervention

After clinical examination and obtaining diagnostic records that indicated the need for bilateral maxillary first molars distalization, the distalization appliance was fabricated. A modified transpalatal arch (TPA) of 1 mm stainless steel wire that runs along the palatal

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gingiva, 4-5 mm away from the gingival margin with two hooks soldered in the lateral incisors area was fabricated for maxillary first molars distalization. Two miniscrews (8mm in length and 1.6mm in diameter) were inserted in the palatal inter-radicular area between the second premolars and first molars bilaterally under local anesthesia. The miniscrews were inserted at the same level as the hooks of the TPA and perpendicular to the palatal tissue. A closed Ni-Ti coil spring was used to apply molar distalization force. The Ni-Ti coil spring extended from the miniscrew posteriorly to the TPA hook anteriorly (Fig. 1).

Figure 1: Distalization Appliance in the patient mouth.

Subjects that were randomly assigned to be in the experimental group received PRP injection just before TPA and miniscrews insertion. The PRP was prepared following **Liou** [9] protocol were a sample of whole blood was drawn from the medial cubital vein of the patient using syringes that contain sodium citrate solution as an anticoagulant. One mL of blood was used to check platelet count in the whole blood. The rest of the sample was first centrifuged under 1000 rpm for 12 min and separated into the red blood cells at the bottom, the buffy coat (platelets) in the middle, and the platelet poor plasma at the top. The buffy coat and platelet poor plasma were collected and centrifuged again under 3000 rpm for 8 min. After the second centrifugation, the platelet poor plasma was removed until 4 mL remained and then the remaining platelet poor plasma was mixed with the buffy coat to become PRP. Under such a preparation, the PRP contains anticoagulant, high concentration of platelets, and a few of RBCs and WBCs (Fig. 2). One mL of PRP was used to check platelet count in the PRP.

Figure 2: The Prepared PRP.

Before the injection of PRP, local anesthesia was injected at the target sites for pain control. 0.7 mL of PRP was then injected at each target site. PRP was injected submucosally on the buccal and palatal sides and intraligamentally on the distobuccal and distopalatal sides of the maxillary first molars bilaterally (Fig. 3). Acetaminophen (500 mg) could be prescribed for the post-injection pain control.

Figure 3: PRP Injection

Follow up

Subjects in both groups were recalled for follow up every two weeks for a period of 6 months. Impression of the upper arch was taken every 4 weeks.

Method of assessment and data collection:

Measuring the rate of distalization on digital models:

Alginate impressions for the upper arch taken every 4 weeks were poured into stone casts. Stones casts were scanned using 3-Shape R-750 scanner* in the orthodontic digital center at Ain-Shams university. Scanned models were opened in 3-shape OrthoAnalyzer software. On the initial models, the 3 planes of space (anteroposterior, horizontal and midsagittal planes) were aligned in accordance to the occlusal plane and considered as reference planes during superimposition to measure the amount of tooth movements.

Digital models from impressions taken at 4weeks interval were superimposed on the initial digital model and the rate of first molar distal movement was measured on them.

For accurate 3D superimposition, the digital models following the initial model were superimposed on the initial model by 2 steps: first by selecting surface 3-points on both models (the posterior end of the incisive papilla, the medial and lateral limits of the third rugae). The second step was carried out by selecting large surface area across the palate including the first, second and third rugae which is referred to as the local best-fit alignment (10) (Fig. 4).

* 3shape A/S. Copenhagen, Denmark

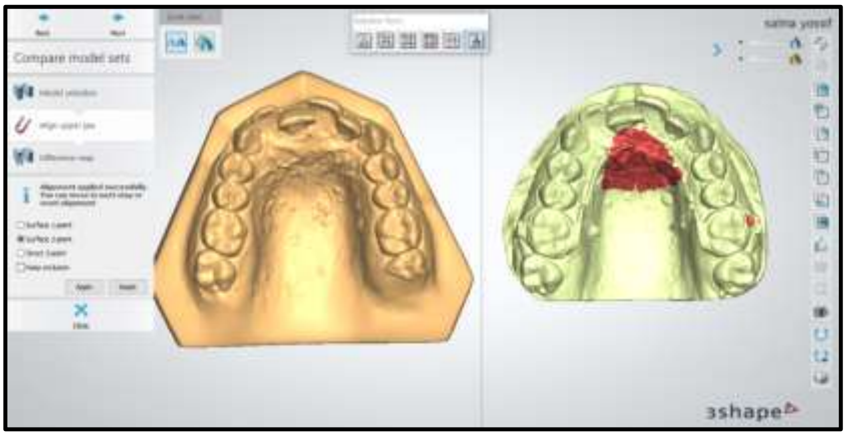

Figure 4: Superimposition of digital models.

The distance from the mesiobuccal cusp tips of the maxillary first molars on the right and left sides to the anteroposterior plane were measured on the initial and following superimposed models to evaluate the rate of distal movement of the maxillary first molar (Fig. 5 a,b).

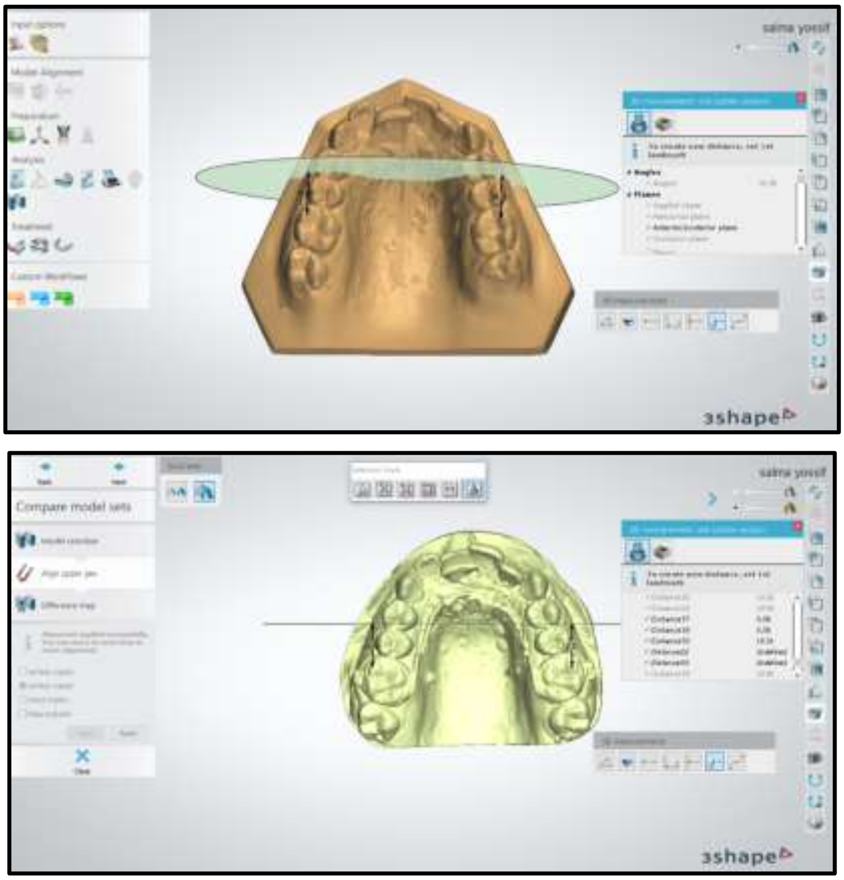

Figure 5: Measuring distal molar movement at a: initial model and b: after 4 weeks model.

Error Measurement (inter-observer and intra-observer error):

Intra-observer and inter-observer error were done to assess the reliability of measurements. Five subjects were randomly selected from each group for assessment of the reliability of measurements.

Statistical analysis

Data were collected, revised, coded and entered to the Statistical Package for Social Science (IBM SPSS) version 23. The quantitative data were presented as mean, standard deviations and ranges when parametric. The comparison between two independent groups with quantitative data and parametric distribution was done by using Independent t-test while with non-parametric distribution were done by using Mann-Whitney test. The comparison between two paired groups regarding quantitative data and parametric distribution was done by using Paired t-test. The comparison between more than two paired groups regarding quantitative data and parametric distribution was done by using Repeated Measures ANOVA test. The confidence interval was set to 95% and the margin of error accepted was set to 5%.

Results

Intra and inter-observer reliability

There was very good intra-observer and inter-observer agreement for ALL Variables in the control and experimental groups showing very good Reliability.

Anteroposterior (AP) measurements

Highly statistically significant changes were found for every two consecutive month readings in both groups. Comparing the 2 groups, there was no statistically significant difference in the maxillary molar position each month.

Mean, standard deviation (SD), minimum and maximum values for the maxillary first molar positions each month in group A (control group) and group B (experimental group**)** are shown in (table 1) and (Fig. 6).

Table 1: Comparison between maxillary first molar positions each month in group A (control group) and group B (experimental group).

Anteroposterior position		Group A	Group B	Test value	P-value	Sig.
		No. = 20	No. = 20			
Baseline	Mean ± SD	13.35 ± 1.63	12.48 ± 4.31	0.847•	0.402	NS
	Range	11.59 – 16.24	7.62 – 22			
1 month	Mean ± SD	13.56 ± 1.64	12.81 ± 4.42	0.713•	0.480	NS
	Range	11.72 – 16.51	7.78 – 22.28			
2 month	Mean ± SD	13.85 ± 1.65	13.14 ± 4.40	0.677•	0.502	NS
	Range	11.9 – 16.86	8.07 – 22.64			
3 month	Mean ± SD	14.50 ± 1.65	13.35 ± 4.41	1.088•	0.284	NS
	Range	12.54 – 17.34	8.21 – 22.89			
4 month	Mean ± SD	15.11 ± 1.63	13.63 ± 4.35	1.420•	0.164	NS
	Range	13.18 – 17.87	8.49 – 22.94			
5 month	Mean ± SD	15.81 ± 1.65	14.01 ± 4.45	1.689•	0.099	NS
	Range	13.85 – 18.51	8.56 – 23.4			
6 month	Mean ± SD	16.34 ± 1.69	15.06 ± 4.76	1.118•	0.272	NS
	Range	14.4 – 19.08	8.83 – 23.67			
Repeated Measures ANOVA test	**F**	934.816	64.450			
	P-value	0.000 (HS)	0.000 (HS)			

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant
•: Independent t-test; ≠: Mann-Whitney test

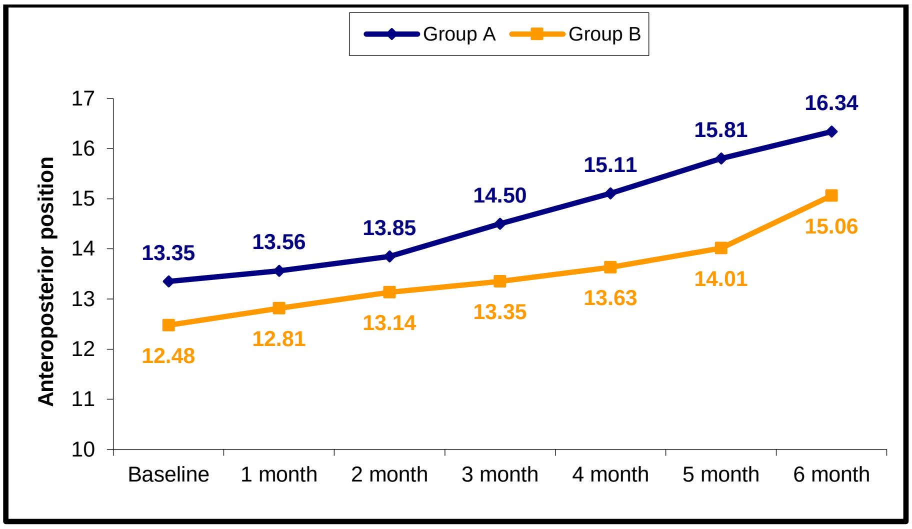

Figure 6: Maxillary first molar movement each month in group A (control group) and group B (experimental group).

Comparing both groups, there was a highly statistically significant increase in the rate of anteroposterior first molar movement in group A (control group) compared to group B (experimental group) in the third, fourth and fifth months (p-value< 0.01) followed by statistically significant increase in the sixth month of the study period (P-value < 0.05).

Mean and standard deviation (SD) values for the change in maxillary first molar rate of tooth movement in group A (control group) and group B (experimental group) is shown in (table 2) and (Fig. 7).

Table 2 : Comparison of the rate of maxillary first molar movement between every two consecutive months in group A (control group) and group B (experimental group).

Anteroposterior position		Group A No. = 20	Group B No. = 20	Test value	P-value	Sig.
Rate from baseline to 1month	Mean ± SD	0.21 ± 0.06	0.34 ± 0.33	-0.921≠	0.357	NS
	Range	0.13 – 0.32	0.05 – 1.17			
Rate from 1month to 2month	Mean ± SD	0.28 ± 0.08	0.32 ± 0.16	-0.271≠	0.786	NS
	Range	0.17 – 0.45	0.12 – 0.6			
Rate from 2month to 3month	Mean ± SD	0.65 ± 0.21	0.22 ± 0.11	-4.877≠	0.000	HS
	Range	0.24 – 0.91	0.05 – 0.43			
Rate from 3month to 4month	Mean ± SD	0.61 ± 0.07	0.28 ± 0.25	-3.415≠	0.001	HS
	Range	0.52 – 0.73	0 – 0.72			
Rate from 4month to 5month	Mean ± SD	0.70 ± 0.08	0.38 ± 0.49	-4.332≠	0.000	HS
	Range	0.54 – 0.85	0.03 – 1.76			
Rate from 5month to 6month	Mean ± SD	0.55 ± 0.16	0.32 ± 0.27	-2.560≠	0.010	S
	Range	0.16 – 0.77	0.03 – 0.88			

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant
•: Independent t-test; ≠: Mann-Whitney test

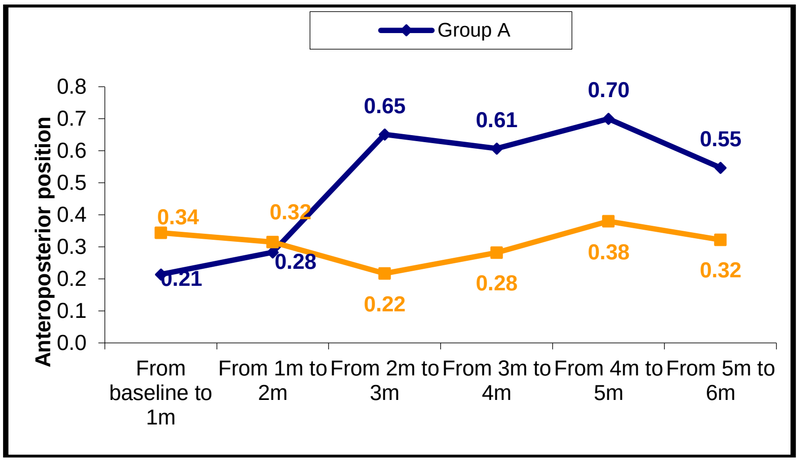

Figure 7: Maxillary first Molar rate of Movement (mm/month) for group A (Control group) and group B (experimental group).

Comparing the initial and final positions of the first molars before and after distalization in each group, both groups showed highly statistically significant changes in their anteroposterior position. Comparing the 2 groups, there was a highly statistically significant difference in the amount of the anteroposterior movement between the 2 groups.

Maxillary first molar anteroposterior position before and after distalization in both groups is shown in (table 3) and (Fig. 8).

Table 3: Maxillary first molar anteroposterior (AP) position in group A (control group) and group B (experimental group).

AP		Group A No. = 20	Group B No. = 20	Test value	P-value	Sig.
Pre	Mean ± SD	13.00 ± 1.69	12.48 ± 4.30	0.499•	0.621	NS
	Range	11.59 – 16.24	7.62 – 22			
Post	Mean ± SD	16.11 ± 1.63	14.32 ± 4.50	1.677•	0.102	NS
	Range	14.53 – 19.08	8.83 – 23.67			
Paired t-test	**t**	-35.836	-13.066			
	P-value	0.000 (HS)	0.000 (HS)			
Difference	Mean ± SD	3.08 ± 0.37	1.83 ± 0.63	-4.659≠	0.001	HS
	Range	2.3 – 3.5	1.21 – 3.25			

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant.
•: Independent t-test; ≠: Mann-Whitney test.

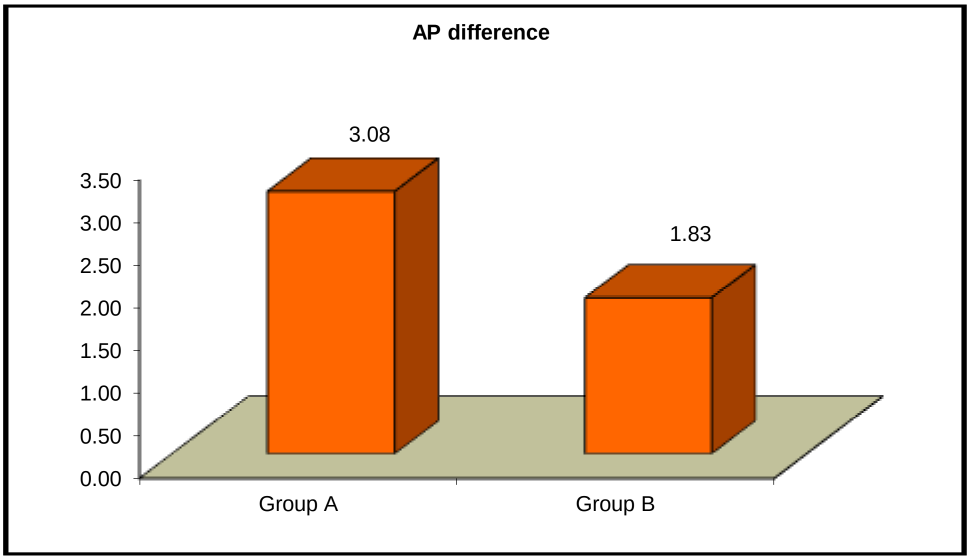

Figure 8: Maxillary first molar anteroposterior (AP) movement in group A (control group) and group B (experimental group).

Discussion

Class II malocclusion has high prevalence among the population and represents about 21% of the Egyptian adult orthodontic patients [11]. Treatment of mild to moderate class II cases in adults could be either by extraction or non-extraction treatment. Molar distalization is one of the most commonly used non-extraction treatment for class II cases.

The prolonged duration of orthodontic treatment can have several adverse effects that may push the patients especially adults to accept non-orthodontic treatment that may be less than optimal. Accelerating orthodontic tooth movement is desirable to prevent those effects and encourage patients to undergo orthodontic treatment. Several approaches have been studied in an attempt to accelerate orthodontic tooth movement, including local injection of biological substances, surgical, mechanical, and physical methods.

Platelet rich plasma (PRP) is an autologous concentration of platelets in a small volume of plasma. PRP has been used in dentistry for over 20 years for enhancing osseointegration around dental implants, stimulating alveolar bone repair after third molars extraction, reducing pain during treatment of temporomandibular disorders and accelerating wound healing. Recently, PRP was used in orthodontics for acceleration of orthodontic tooth movement [12].

Several researches have been performed to evaluate the effect of the PRP on the orthodontic tooth movement in animals [7,2,8].

No previous research was conducted to evaluate the effect of PRP on maxillary molars distalization in humans.

The aim of this study was to evaluate the effect of Platelet Rich Plasma on the rate of maxillary molar distalization using a miniscrew implant-aided modified transpalatal bar appliance.

All patients included in the study were 19 to 30 years old and therefore the effects of remnant growth that could affect the study results were excluded. All collected patients had bilateral half to full unit class II molar relationship that required bilateral maxillary molar distalization. Distalization was carried out with a modified TPA with two hooks at the lateral incisors area and two palatal inter-radicular miniscrews placed between maxillary first molars and second premolars bilaterally.

Bonding of the orthodontic brackets was delayed until the end of the study period (6 months) so that the effects of tooth movement by the orthodontic brackets is excluded. Closed Ni-Ti coil spring was used to produce the distalizing forces. Patients were recalled every 2 weeks for a period of 6 months for follow up.

In this study, the experimental group received PRP injection on the same day of the appliance placement. The PRP was prepared by a double centrifugation techique following **Liou** [9] protocol where $CaCl_2$ and thrombin were not used for the preparation of the PRP, instead, sodium citrate was used as an anticoagulant so that PRP is prepared into an injectable form to have a long duration of action.

According to the previous study by **Liou** [9], the target sites for the PRP injection for acceleration of orthodontic tooth movement are the buccal and lingual sides for acceleration of alignment and leveling, the lingual side of anteriors for acceleration of enmasse retraction and the buccal, lingual and mesial sides for molar protraction. Therefore, in this study for maxillary molar distalization the target sites for PRP injection were chosen to be the buccal, palatal and distal sides of the maxillary first molars.

Before PRP injection, target sites received local anesthetic injection for pain control. Each target site received 0.7 mL of PRP.

Acetaminophen 500 mg was prescribed for post injection pain control only if necessary.

Liou reported that a single PRP injection lasts for 5-6 months, therefore the experimental group received only one PRP injection at the day of appliance insertion and no other PRP was injected during the study period (6 months).

Patients were recalled every 2 weeks to evaluate treatment progress. Alginate impressions were taken every 4 weeks that were poured to obtain stone casts. Stone casts were scanned using 3-shape digital desktop scanner to obtain 3 dimensional (3D) digital models. Digital models facilitate storage, manipulation, measurements 3-dimensionally and 3D superimposition.

The rate of distal movement of maxillary molars was assessed on digital models obtained every 4 weeks that were superimposed on the pretreatment digital model. The use of palatal rugae, in particular the third rugae as reference points for measuring tooth movement on serial 3D models has been evaluated and reported to be suitable landmark for studying serial models [9,10]. Serial 3D models were superimposed by best-fit method over the palatine rugae area which was proven to be reliable and accurate [10].

The results of our study showed the following:

- The PRP group showed minimal rate of molar distal movement of 0.22 ± 0.11 mm between the second and third months of the study period and maximum rate of tooth movement of 0.38 ± 0.49 mm between the fourth and fifth month of the study period. The mean distal movement during the study period was 1.83 ± 0.63 mm which is highly statistically significant.
- For the control group, the minimal rate of distal molar movement was 0.21 ± 0.06 mm in the first month of treatment while the maximum rate was 0.7 ± 0.08 mm between the fourth and fifth months of treatment. The mean distal movement during the study period was 3.08 ± 0.37 mm which is highly statistically significant.
- Comparing the rate of distal molar movement between the 2 groups, there was no statistically significant difference in the first 2 months of distalization followed by a high statistically significant difference between the 2 groups in the third, fourth and fifth months and a statistically significant difference in the sixth month of distalization where the control group showed faster molar distal movement compared to the PRP group.

The results of our study reveal that PRP was not effective in acceleration of maxillary molar distalization. This was agreed with **Akbulut et al.** [17] who found that the application of PRP was not beneficial for acceleration of orthodontic tooth movement in rats. Also **Zhou et al**. [18] conducted a systematic review to evaluate the effects of PRP injection on the rate of tooth movement and found that the use of PRP for acceleration of orthodontic tooth movement was not confirmed.

Previous studies on PRP reported conflicting results regarding bone remodeling. Although many previous studies favored the idea that PRP stimulated the activation and proliferation of osteoblast and osteoclast progenitor cells and stimulated bone regeneration [13,14], other studies found that PRP did not stimulate bone regeneration [15,16].

The method of PRP preparation, PRP concentration, PRP dosage and method of application are all factors that could influence the effect of PRP on orthodontic tooth movement.

Previous studies prepared PRP with various techniques. In our study, PRP was prepared based on **Liou** [9] technique where the PRP was prepared from a whole blood sample through a double centrifugation technique: first 1000 rpm for 12 minutes then 3000 rpm for 8 minutes. **Gülec et al**. [13] prepared PRP in a rat study by double centrifugation of whole blood sample: The blood sample was centrifuged at 113 g for 5 minutes then the plasma was centrifugated again for additional 2 minutes at 3772 g to separate the platelets. **Sufarnap et al.** [23] prepared PRP from Guinea pigs blood that was centrifuged at 1500 rpm for 5 minutes.

In our study, the number of platelets in the PRP preparation was assured to be at least 1000000 per cc. Various studies prepared PRP with different concentrations [7,17].

In our study, 0.7 mL of PRP was injected at every target site as recommended by **Liou** [9]. PRP was injected submucosally on the buccal and palatal sides and intraligamentally on the distobuccal and distopalatal sides of the maxillary first molars bilaterally. **Gülec et al**. [13] injected 0.01 mL of PRP submucosally at the target sites. **Sufarnap et al.** [23] injected 0.5 mL of PRP at each target site. **Akbulut et al.** [17] injected 0.1 mL of PRP submucosally at each target site. **El-Timamy et al**. [24] injected 0.25 mL of PRP at each target site: intraligamentally on middle, distobuccal and distopalatal of the canine and submucosally on the buccal and palatal sides of the canine.

In our study, the PRP was prepared without mixing with calcium chloride and thrombin as favored by **Liou** [9]. Other studies advocated using calcium chloride for activation of PRP after its injection [24].

In our study, PRP was injected once at the beginning of the study and was not repeated again till the end of the study period (6 months). This was based on the recommendation by **Liou** [9] . **El-Timamy et al.** [24] prepared and injected PRP each 3 weeks and repeated till the sixth week.

In the light of our study results, it appears that our technique for preparation of the PRP was not effective in acceleration of maxillary molars distalization.

Conclusion

The PRP did not accelerate the rate of maxillary molars distalization. It rather decreased the rate of distalization.

Recommendations

1. High powered studies are needed to further investigate the effect of PRP on the distalization with different PRP preparation techniques, PRP concentrations, PRP dosage and methods of application.

2. The technique used for preparation of PRP in this study could be investigated to be used as a means for anchorage in orthodontic treatment.

3. The effect of PRP on the periodontal health should be investigated in orthodontically treated patients.

4. A comparison between the effect of PRP and other different methods of acceleration of tooth movement during maxillary molar distalization is recommended in future studies.

References

1. Josefsson E, Bjerklin K, Lindsten R. Malocclusion frequency in Swedish and immigrant adolescents--influence of origin on orthodontic treatment need. Eur J Orthod. 2007 Feb;29(1):79–87.

2. Miresmaeili A, Sajedi A, Moghimbeigi A, Farhadian N. Three-dimensional analysis of the distal movement of maxillary 1st molars in patients fitted with mini-implant-aided trans-palatal arches. Korean J Orthod. 2015;45(5):236–44.

3. Tsichlaki A, Chin SY, Pandis N, Fleming PS. How long does treatment with fixed orthodontic appliances last? A systematic review. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod its Const Soc Am Board Orthod. 2016 Mar;149(3):308–18.

4. Talic NF. Adverse effects of orthodontic treatment: A clinical perspective. Saudi Dent J. 2011 Apr;23(2):55–9.

5. Segal GR, Schiffman PH, Tuncay OC. Meta analysis of the treatment-related factors of external apical root resorption. Orthod Craniofac Res. 2004 May;7(2):71–8.

6. Rosvall MD, Fields HW, Ziuchkovski J, Rosenstiel SF, Johnston WM. Attractiveness, acceptability, and value of orthodontic appliances. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod its Const Soc Am Board Orthod. 2009 Mar;135(3):276.e1-12; discussion 276-7.

7. Kau CH, Kantarci A, Shaughnessy T, Vachiramon A, Santiwong P, de la Fuente A, et al. Photobiomodulation accelerates orthodontic alignment in the early phase of treatment. Prog Orthod. 2013 Sep;14:30.

8. Rashid A, ElSharaby FA, Nassef EM, Mehanni S, Mostafa YA. Effect of platelet-rich plasma on orthodontic tooth movement in dogs. Orthod Craniofacial Res. 2017;20(2):102–10.

9. Liou EW. The development of submucosal injection of platelet rich plasma for accelerating orthodontic tooth movement and preserving pressure side alveolar bone. APOS Trends Orthod. 2016;6(1):5.

10. Choi D-S, Jeong Y-M, Jang I, Jost-Brinkmann PG, Cha B-K. Accuracy and reliability of palatal superimposition of three-dimensional digital models. Angle Orthod. 2010 Jul;80(4):497–503.

11. El-Mangoury NH, Mostafa YA. Epidemiologic panorama of dental occlusion. Angle Orthod. 1990;60(3):207–14.

12. Singh P, Namarach K, Rashed Salem W, Shahzadi K. The current and potential future uses of plateletrich plasma in orthodontics. Ann Dent Oral Heal. 2018;1(1).

13. Güleç A, Bakkalbaşı BÇ, Cumbul A, Uslu Ü, Alev B, Yarat A. Effects of local platelet-rich plasma injection on the rate of orthodontic tooth movement in a rat model: A histomorphometric study. Am J Orthod Dentofac Orthop. 2017;151(1):92–104.

14. Nakornnoi T, Leethanakul C, Samruajbenjakun B. The influence of leukocyte-platelet-rich plasma on accelerated orthodontic tooth movement in rabbits. Korean J Orthod. 2019;49(6):372–80.

15. Ashmore JL, Kurland BF, King GJ, Wheeler TT, Ghafari J, Ramsay DS. A 3-dimensional analysis of molar movement during headgear treatment. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod its Const Soc Am Board Orthod. 2002 Jan;121(1):18–30.

16. Jang I, Tanaka M, Koga Y, Iijima S, Yozgatian JH, Cha BK, et al. A novel method for the assessment of three-dimensional tooth movement during orthodontic treatment. Angle Orthod. 2009 May;79(3):447–53.

17. Akbulut S, Yagci A, Yay AH, Yalcin B. Experimental investigation of effects of platelet-rich plasma on early phases of orthodontic tooth movement. Am J Orthod Dentofac Orthop. 2019;155(1):71–9.

18. Li Z, Zhou J, Chen S. The effectiveness of locally injected platelet-rich plasma on orthodontic tooth movement acceleration: A systematic review of animal studies. Angle Orthod. 2021;91(3):391–8.

19. Gerard D, Carlson ER, Gotcher JE, Jacobs M. Effects of platelet-rich plasma at the cellular level on healing of autologous bone-grafted mandibular defects in dogs. J oral Maxillofac Surg Off J Am Assoc Oral Maxillofac Surg. 2007 Apr;65(4):721–7.

20. Otero L, Carrillo N, Calvo-Guirado JL, Villamil J, Delgado-Ruíz RA. Osteogenic potential of platelet-rich plasma in dental stem-cell cultures. Br J Oral Maxillofac Surg. 2017 Sep;55(7):697–702.

21. Cömert Kılıç S, Güngörmüş M, Parlak SN. Histologic and histomorphometric assessment of sinus-floor augmentation with beta-tricalcium phosphate alone or in combination with pure-platelet-rich plasma or platelet-rich fibrin: A randomized clinical trial. Clin Implant Dent Relat Res. 2017 Oct;19(5):959–67.

22. Casati MZ, de Vasconcelos Gurgel BC, Gonçalves PF, Pimentel SP, da Rocha Nogueira Filho G, Nociti FHJ, et al. Platelet-rich plasma does not improve bone regeneration around peri-implant bone defects--a pilot study in dogs. Int J Oral Maxillofac Surg. 2007 Feb;36(2):132–6.

23. Sufarnap E, Sofyanti E, Ilyas S. The

Effect of Platelet-Rich Plasma to Orthodontic Tooth Movement. 2018;8(Idcsu 2017):80–3.

24. El-Timamy A, El Sharaby F, Eid F, El Dakroury A, Mostafa Y, Shaker O. Effect of platelet-rich plasma on the rate of orthodontic tooth movement: A split-mouth randomized trial. Angle Orthod. 2020;90(3):354–61.