REVIEW

Effect of Low-level Laser Therapy on Orthodontic Movement of Human Canine: a Systematic Review and Meta-analysis of Randomized Clinical Trials

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ABSTRACT

Background: Low-level Laser Therapy (LLLT) is a noninvasive method of accelerating tooth movement. Herein, this meta-analysis was aimed to assess the efficacy of LLLT in accelerating orthodontic tooth movement of human maxilla or mandible canine. **Methods:** Five databases including Web of Science, Scopus, PubMed, ScienceDirect, and Cochrane Library were used for searching the studies. Studies on LLLT for orthodontic tooth movement of human canine, randomized clinical trial (RCT), and outcome variables such as distance or speed of the tooth movement in treatment duration were considered for the final analysis. RevMan 5.3 was used for calculating the mean difference (MD) and 95% confidence intervals (CIs) on random-effects model. **Results:** Out of 275 studies retrieved from five databases, six RCTs were included and analyzed in this meta-analysis. The results showed that the orthodontic movement of canine was statistically increased in the LLLT group compared with the control group in 21 days (MD: 0.74; 95%CI: 0.17, 1.31; P = 0.01), one month (MD: 0.40; 95%CI: 0.10, 0.69; P = 0.008), 1.5 months (MD: 0.72; 95%CI: 0.51, 0.93; P < 00001), two months (MD: 0.84; 95%CI: 0.23, 1.44; P = 0.006) three months (MD: 0.92; 95%CI: 0.06, 1.78; P = 0.04), and 4.5 months (MD: 1.53; 95%CI: 0.92, 2.14; P < 0.00001). **Conclusion:** The LLLT can speed up the rate of tooth movement of human canine and consequently decrease the treatment time. LLLT represents a proper adjuvant therapy for fixed orthodontic treatment.

Keywords: Low-level laser, orthodontic tooth movement, canine.

1. INTRODUCTION

Orthodontic treatment with fixed appliances is a lengthy and painful process (1). The length of long treatment and painful teeth are the main concerns of patients undergoing fixed orthodontic treatment (2, 3). The time required for this treatment is 20 to 30 months (3). In general, long-term treatment is one of the main reasons for patients to refrain from treatment (4). It also has other disadvantages such as increasing the amount of decay, gingivitis and root resorption (5). Thus, a noninvasive method of accelerating tooth movement in a physiologic manner is needed (6).

Low-level laser is a type of laser with various photobiomodulation effects, and these potential effects of laser stimulate the velocity of tooth movement and thereby facilities the tooth movement in orthodontics (6). Low-level Laser Therapy (LLLT) has an energy output that is low enough not to cause the temperature of the treated tissues to rise above $36.5°C$ or normal body temperature (7).

Also, it has been reported to enhance the velocity of tooth movement by accelerating bone remodeling (8, 9). In addition to its analgesic effect, some studies have indicated that LLLT stimulates tissue biostimulation, and specific wavelengths with specific energy densities have been purposed for application in bone remodeling (10).

The studies have investigated the efficacy of low-level lasers in reducing pain (11, 12) and the time of orthodontic treatment (2). To the best of our knowledge, a number of studies examining the effect of LLLT on the rate of orthodontic tooth movement have reported different results. Therefore, the aim of this meta-analysis was to evaluate the efficacy of LLLT on accelerating orthodontic tooth movement of human maxilla or mandible canine.

First author, year	Country	Study design	Number of teeth in LLLT group	Number of teeth in control /placebo group	Type of laser	Wavelength: energy density	Power output: time	Frequency of laser treatment	Modified Jadad scale
Cruz, 2004 (8)	Brazil	RCT, split-mouth Design	11	11	GaAlAs semi-conductor diode laser	780 nm: 5 J/cm²/point	20 mW: 10 s/ point	Days 0, 3, 7, 14 of each month and for 2 months	3
Sousa, 2011 (15)	Brazil	RCT, split-mouth design, double blind	13	13	GaAlAs semi-conductor diode laser	780 nm: 5 J/cm²/point	20 mW: 10 s/point	Days 0, 3, 7 of each month and for 4 months	6
Doshi-Mehta, 2012 (2)	India	RCT, split-mouth design, single blind	20	20	GaAlAs semi-conductor diode laser	810 nm: 8 J/cm²/point	100 mW: 10 s/ point	days 0, 3, 7, and 14 in the first month, and thereafter on every 15th day	8
Heravi, 2014 (16)	Iran	RCT, split-mouth design, single blind	20	20	GaAlAs semi-conductor diode laser	810 nm: 6 J/cm²/point	200 mW: 30 s/ point	Days 4, 7, 11, 15 and 28 over the first month and days 32, 35, 39, 43, and 56	5.5
Qamruddin, 2017 (17)	Malaysia	RCT, split-mouth design, single blind	22	22	GaAlAs semi-conductor diode laser	940 nm: 7.5 J/cm²/point	100 mW: 3 s/point	Days 0, 21,42	6.5
Üretürk, 2017 (18)	Turkey	RCT, split-mouth design	15	15	GaAlAs semi-conductor diode laser	820 nm: 5 J/cm²/point	20 mW: 10 s/ point	Day 0, the 3rd, 7th, 14th, 21st, 30th, 33rd, 37th, 44th, 51st, 60th, 63rd, 67th, 74th, 81st, 84th, 90th days	4

Table 1. The characteristics of participants included in the studies (n=6). Abbreviation: LLLT: low-level laser therapy.

2. MATERIALS AND METHODS

This systematic review and meta-analysis was done based on the guidelines of Cochrane Handbook for Systematic Reviews of Interventions and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (13).

Search strategy

The Web of Science, Scopus, PubMed, ScienceDirect, and Cochrane Library databases were used for searching the studies using the key terms "low level laser therapy", "LLLT", "low-power laser", "laser therapy", "laser irradiation", or "LLLI", "tooth movement" or "dental movement", and "orthodontic". The search was limited to human studies in PubMed, articles in Web of Science and Scopus; journals in ScienceDirect, and Cochrane Library without restriction up to October 2017. There was no language restriction in the search.

Selection criteria

The inclusion criteria were: a) Studies on LLLT for orthodontic tooth movement of human canine, b) Randomized clinical trials (RCTs) with split-mouth design, and c) Studies on outcome variables such as distance or speed of the tooth movement in treatment duration.

The exclusion criteria were: a) Reviews, case reports, commentaries, and abstracts, b) Animal studies, c) Studies without vital data, and 4) Studies reporting orthodontic tooth movement of molars.

Data extraction

One author (M.S) searched the studies and screened the titles and abstracts of each study based on the criteria and extracted data. Two authors (M.M.I & M.S) independently rechecked the full-text of the screened studies. Data collected for every study included the first author, publication year, country, number of teeth in patients/controls, type of laser, wavelength/energy density, power output/total time per tooth(s); frequency of laser treatment, distance, and speed of tooth movement.

Risk of bias

Evaluation of risk of bias was performed according to Co-

chrane Handbook for Systematic Reviews of Interventions. The qualities of included studies were categorized as follows:

a) Low risk of bias was evaluated by six domains;

b) Moderate risk of bias was evaluated by one or more domains;

c) High risk of bias was evaluated by one or more domains.

Quality assessment

The methodological quality of each study was evaluated independently by two researchers (M.S and R.S.-F) using the modified Jadad score (range: 0-8 points) for eight items. Trials were considered to be of low quality if they obtained 0-3 points and of high quality if they achieved 4−8 points (14).

Statistical analysis

A random-effects meta-analysis was done by Review Manager 5.3 (RevMan 5.3, The Cochrane Collaboration, Oxford, United Kingdom) using the mean difference (MD) and 95% confidence intervals (CIs) for the feasible data that were statistically pooled. Heterogeneity between the estimates was evaluated by Cochrane's test (I^2 test) at α=0.10. Also, the statistical significance for testing the hypothesis was set at P-value (two-tailed) less than 0.05. The unit of measurement of distance of tooth movement was millimeter (mm).

3. RESULTS

Search results

A total of 275 studies were retrieved from four databases (Figure 1). After removing the duplicate studies, screening the title, abstract, and/or full text; six RCTs were included and analyzed in the meta-analysis.

Characteristics of the studies

Out of six studies included in meta-analysis, two studies were reported in Brazil (8,15), one in Iran (16), one in India (2), one in Malaysia (17), and one in Turkey (18). One study (8) plotted the results on graph; therefore, we estimated them. The number of teeth undergoing LLLT was 95 versus 95 teeth without LLLT (Table 1).

Item assessed	Response	Score
Was the study described as randomized?	Yes No	+1 0
Was the method of randomization appropriate?	Yes Not described No	+1 0 -1
Was the study described as blinded?	Yes No	+1 0
Was the method of blinding appropriate?	Yes Not described No	+1 0 -1
Was there a description of withdrawals and dropouts?	Yes No	+1 0
Was there a clear description of the inclusion/exclusion criteria?	Yes No	+1 0
Was the method used to assess adverse effects described?	Yes No	+1 0
Was the method of statistical analysis described?	Yes No	+1 0

Table 2. The modified Jadad score Note: aDouble-blind got 1 score; single-blind got 0.5 score.

Methodological and quality assessment

Randomization was performed among all included RCTs. Five of the included studies showed a moderate risk of bias, and four of them exhibited a high risk of bias. Reviews about the risk of bias for each included study are shown in Figures **2** and **3**. The validity of the six studies was evaluated using the modified Jadad score that was previously described. By assessing every study, the mean modified Jadad score was 5.5. The modified Jadad scores of included studies are shown in Table 2, and the results of each study are located in Table 1.
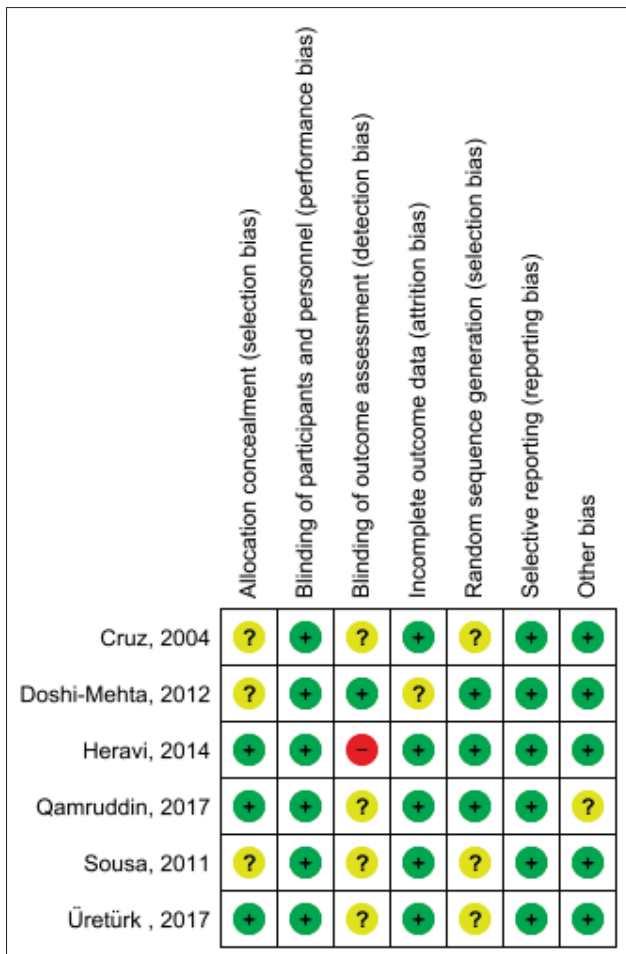

Figure 2. Risk of bias summary. Red, green, and yellow colors refer to high risk of bias, low risk of bias, and unclear risk of bias, respectively
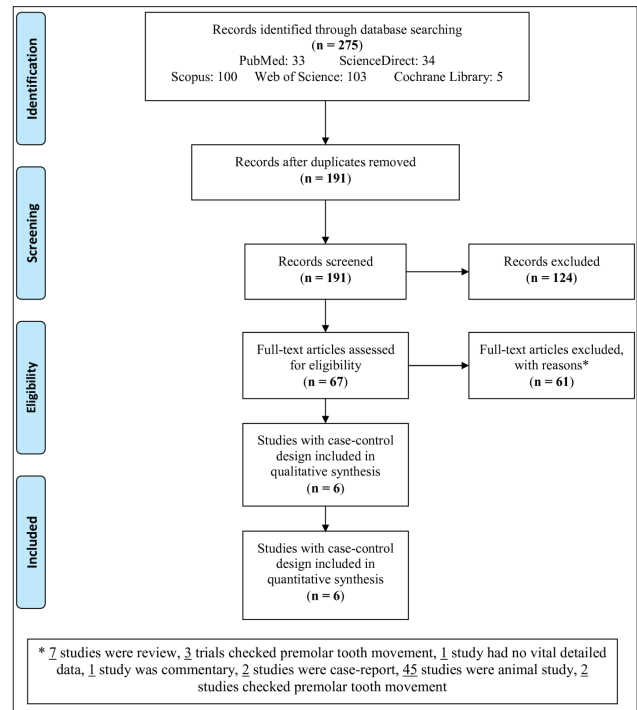

Figure 1. Flowchart of the study

The efficacy of LLLT

Figure 4 shows the pooled MD of subgroup analyses in three follow-ups after orthodontic movement. In study of Heravi et al., (16) there were three moved distances that we used "canine cusp tip to mesiobuccal cusp of the first molar". The meta-analysis was done to investigate the overall efficacy of LLLT regarding six follow-ups (25 days, 1, 1.5, 2, 3, and 4.5 months). The results showed that the orthodontic movement of canine was statistically increased in the LLLT group compared with the control group in 21 days ((MD: 0.74; 95%CI: 0.17, 1.31; $P = 0.01$; I^2=91% ($P = 0.0006$)), one month (MD: 0.40; 95%CI: 0.10, 0.69; $P = 0.008$; I^2=57% (P=0.07)), 1.5 months (MD: 0.72; 95%CI: 0.51, 0.93; $P < 00001$)), two months (MD: 0.84; 95%CI: 0.23, 1.44; $P = 0.006$; I^2=78% (P=0.01)), three months (MD: 0.92; 95%CI: 0.06, 1.78; $P = 0.04$; I^2=82% (P=0.004)), and 4.5 months (MD: 1.53; 95%CI: 0.92, 2.14; $P < 0.00001$).

4. DISCUSSION

Long-term orthodontic treatment is a major concern for patients, and reducing this time requires an increase in orthodontic tooth movement (2). This meta-analysis showed that LLLT significantly increased the orthodontic tooth movement of human canine in the patients compared with the controls after 21 days, one month, 1.5 months, two months, three months, and 4.5 months. With a rise in time, the rate of orthodontic tooth movement is increased. The findings of this meta-analysis are in agreement with those of some animal studies (4, 19-23).

It has been established that laser has photobiomodulation effects at low doses (1, 24). Kawasaki and Shimizu (10) for the first time reported that LLLT can accelerate the orthodontic movement by increasing the amount of bone formation and rate of cellular proliferation in the tension side and the number of osteoclasts in the compression side. Saito and Shimizu (25) studied the effects of a low-dose treatment on the

expansion of a midpalatal suture and found that the effects of a laser therapy depended on the total amount of irradiation, its frequency, and duration of its application. In this meta-analysis, type of laser was similar, but wavelength, energy density, power output, the frequency of laser treatment, and total time per tooth were different.

The difference observed between the results of the studies can be attributed to the different irradiation dose employed, which can cause variable photobiomodulation effects on laser-treated tissues (16). Low-level laser as a beneficial method can double the rate of orthodontic tooth movement if used at intervals of three weeks (26). The radiation has a cumulative effect, which means that a part of the administered dose in the next radiation can be accumulated (27). Therefore, researchers need to be careful not to exceed the biostimulating dose range or reach the inhibition range. It has been showed that a significant increase in the total amount of tooth movement is reached in the group with low-level laser energy density (5–8 J/cm2) compared to the group with high-level laser energy density (20–25 J/cm^2) (18,24). Goulart et al. (28) suggested that the canine and premolars irradiated at 5.25 J/cm^2 (780 nm, 70 mW, and 3s/d) showed faster orthodontic movements initially; whereas, those irradiated at 35 J/cm^2 (780 nm, 70 mW, and 20s/d) represented slower movements. Seifi et al. (29) on rabbits found that the amounts of tooth movement after LLLT with both pulsed 850 nm laser (Optodan; 5 mW, 180s/d, 8.1 J/cm^2) and continuous 630 nm laser (KLO3; 10 mW, 300s/d, and 27 J/cm^2) were diminished. Limpanichkul et al. (30) suggested that the energy density of 25 J/cm^2 (860 nm, 100 mW, 23s/d) around a human canine is probably very low to express either stimulatory effects or inhibitory effects on the velocity of tooth rate. One study (2009) (31) showed that 808 nm laser (763 mW, 20s/d, 41.7 J/cm^2, pulsed wave, and noncontact mode) had higher accelerating effects on the experimental movement compared than in any of the previous studies. Youssef et al. (32) used 809 nm laser (8 J/cm^2, 100 mW, and 80 s/tooth) which had the highest canine movement in the first month after orthodontic therapy, while 780 nm laser (5 J/cm^2, 20 mW, and 100 s/tooth) had the highest movement compared to other low-level lasers in second and third months after treatment (15). Goulort et al. (27) found that low-level laser at 5 J/cm^2 might accelerate tooth movement; whereas, higher doses at 35 J/cm^2 might decelerate it, which are similar to the results of several other studies (2, 4, 6, 8, 10). Further long-term studies are warran-
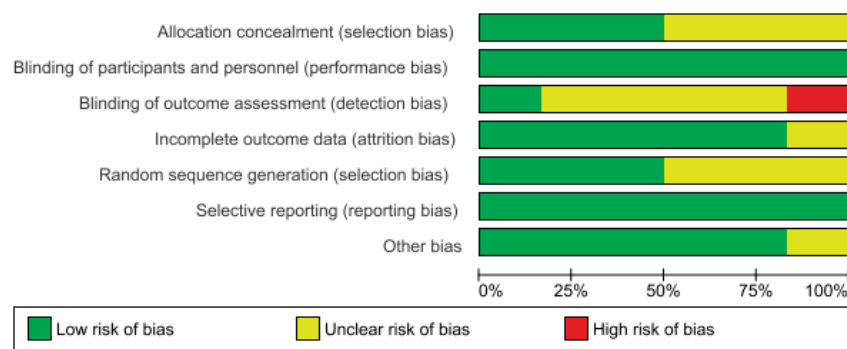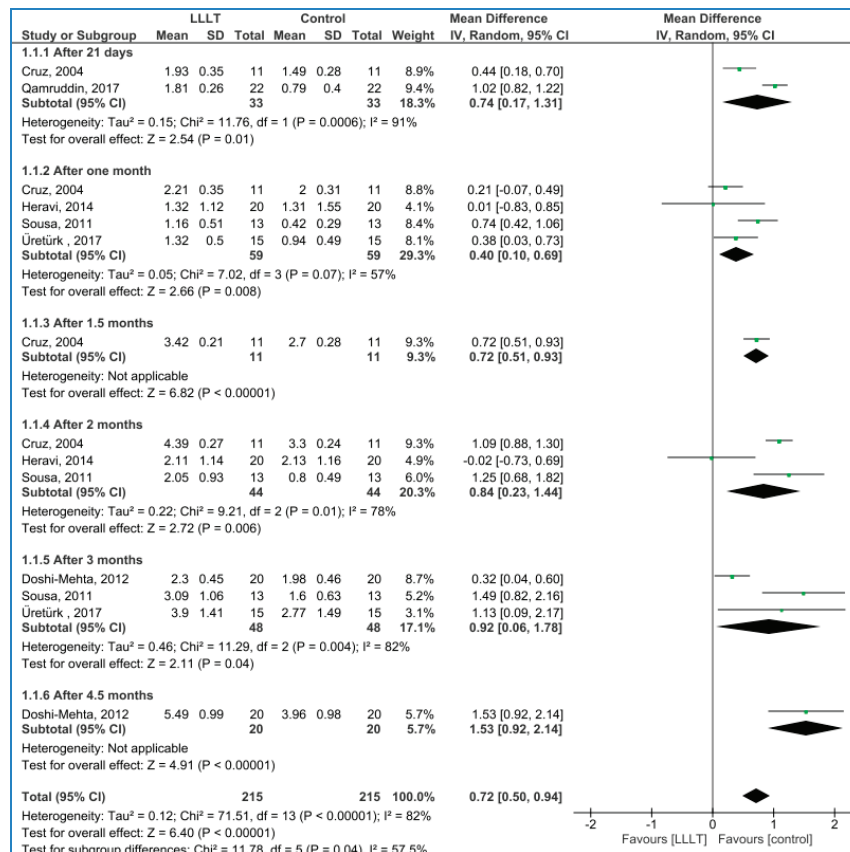

Figure 3. Risk of bias graph.

Figure 4. Forest plot of the random-effects of orthodontic tooth movement of canine in different times in the patients undergoing low-level laser therapy (LLLT) compared with the controls (follow-ups: 21 days, 1, 2, 3, and 4.5 months)

tied to determine the laser wavelength, full delivery energy, pulse repetition rate, dose, and the optical properties of the irradiated tissues to increase the rate of tooth movement (16, 27). There were three significant limitations in this meta-analysis, including low number of studies, different characteristics of used laser such as power, wavelength, frequency, and energy density, and low number of teeth examined in the studies.

5. CONCLUSIONS

Based on the findings, LLLT can increase the rate of orthodontic movement of human canine and consequently decrease the treatment time. Therefore, LLLT represents an appropriate adjuvant therapy for orthodontic treatment. However, more studies with a focus on the characteristics of used laser on a high number of teeth are necessary to confirm the results of this meta-analysis.

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REFERENCES

1. Qamruddin I, Alam MK, Khamis MF, Husein A. Minimally invasive techniques to accelerate the orthodontic tooth movement: a systematic review of animal studies. Biomed Res Int 2015;2015:608530.

2. Doshi-Mehta G, Bhad-Patil WA. Efficacy of low-intensity laser therapy in reducing treatment time and orthodontic pain: a clinical investigation. Am J Orthod Dentofacial Orthop 2012;141:289-297.

3. Seifi M, Eslami B, Saffar AS. The effect of prostaglandin E2 and calcium gluconate on orthodontic tooth movement and root resorption in rats. Eur J Orthod 2003;25:199-204.

4. Yoshida T, Yamaguchi M, Utsunomiya T, et al. Low-energy laser irradiation accelerates the velocity of tooth movement via stimulation of the alveolar bone remodeling. Orthod Craniofac Res 2009;12:289-298.

5. Segal GR, Schiffman PH, Tuncay OC. Meta-analysis of the treatment-related factors of external apical root resorption. Orthod Craniofac Res 2004;7:71–78.

6. Salehi P, Torkan S, Gavareshki SR. Evaluating the effect of low energy laser irradiation on the rate of mandibular molar protraction in orthodontic patients. J Res Med Den Sci 2016;4:228-232.

7. Lim HM, Lew KK, Tay DK. A clinical investigation of the efficacy of low level laser therapy in reducing orthodontic postadjustment pain. Am J Orthod Dentofacial Orthop 1995;108:614-622.

8. Cruz DR, Kohara EK, Ribeiro MS, Wetter NU. Effects of low-intensity laser therapy on the orthodontic movement velocity of human teeth: a preliminary study. Lasers Surg Med 2004;35:117-120.

9. Zahra SE, Elkasi AA, Eldin MS, Vandevska-Radunovic V. The effect of low level laser therapy (LLLT) on bone remodelling after median diastema closure: a one year and half follow-up study. Orthod Waves 2009;68:116-122.

10. Kawasaki K, Shimizu N. Effects of low-energy laser irradiation on bone remodeling during experimental tooth movement in rats. Lasers Surg Med 2000;26:282-291.

11. Mozzati M, Martinasso G, Cocero N, et al. Influence of superpulsed laser therapy on healing processes following tooth extraction. Photomed Laser Surg 2011;29:565-571.

12. Abtahi SM, Mousavi SA, Shafaee H, Tanbakuchi B. Effect of low-level laser therapy on dental pain induced by separator force in orthodontic treatment. Den Res J 2013;10:647-651.

13. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097.

14. Oremus M, Wolfson C, Perrault A, Demers L, Momoli F, Moride Y. Interrater reliability of the modified Jadad quality scale for systematic reviews of Alzheimer's disease drug trials. Dement Geriatr Cogn Disord 2001;12:232–236.

15. Sousa MV, Scanavini MA, Sannomiya EK, Velasco LG, Angelieri F. Influence of low-level laser on the speed of orthodontic movement. Photomed Laser Surg 2011;29:191-196.

16. Heravi F, Moradi A, Ahrari F. The effect of low level laser therapy on the rate of tooth movement and pain perception during canine retraction. Oral Health Dent Manag 2014;13:183-188.

17. Qamruddin I, Alam MK, Mahroof V, Fida M, Khamis MF, Husein A. Effects of low-level laser irradiation on the rate of orthodontic tooth movement and associated pain with self-ligating brackets. Am J Orthod Dentofacial Orthop 2017;152(5):622-630.

18. Üretürk SE, Saraç M, Fıratlı S, Can ŞB, Güven Y, Fıratlı E. The effect of low-level laser therapy on tooth movement during canine distalization. Lasers Med Sci 2017;32:757-764.

19. Altan BA, Sokucu O, Ozkut MM, Inan S. Metrical and histological investigation of the effects of low-level laser therapy on orthodontic tooth movement. Lasers Med Sci 2012;27:131-140.

20. Kawasaki K, Shimizu N. Effects of low-energy laser irradiation on bone remodeling during experimental tooth movement in rats. Lasers Surg Med 2000;26:282-291.

21. Yamaguchi M, Hayashi M, Fujita S, Yoshida T, Utsunomiya T, Yamamoto H, et al. Low-energy laser irradiation facilitates the velocity of tooth movement and the expressions of matrix metalloproteinase-9, cathepsin K, and alpha(v) beta(3) integrin in rats. Eur J Orthod 2010;32:131-139.

22. Duan J, Na Y, Liu Y, Zhang Y. Effects of the pulse frequency of low-level laser therapy on the tooth movement speed of rat molars. Photomed Laser Surg 2012;30(11):663-7.

23. Shirazi M, Ahmad Akhoundi MS, Javadi E, et al. The effects of diode laser (660 nm) on the rate of tooth movements: an animal study. Lasers Med Sci 2015;30:713-718.

24. Ge M, He WL, Chen J, et al. Efficacy of low level laser therapy for accelerating tooth movement during orthodontic treatment: a systematic review and meta-analysis. Lasers Med Sci 2015;30:1609-1618.

25. Saito S, Shimizu N. Stimulatory effects of low-power laser irradiation on bone regeneration in midpalatal suture during expansion in the rat. Am J Orthod Dentofacial Orthop 1997;111:525–532.

26. Qamruddin I, Alam MK, Mahroof V, Fida M, Khamis MF, Husein A. Effects of low-level laser irradiation on the rate of orthodontic tooth movement and associated pain with self-ligating brackets. Am J Orthod Dentofacial Orthop 2017;152:622-630.

27. Carvalho-Lobato P, Garcia VJ, Kasem K, Ustrell-Torrent JM, Tallón-Walton V, Manzanares-Céspedes MC. Tooth movement in orthodontic treatment with low-level laser therapy: a systematic review of human and animal studies. Photomed Laser Surg 2014;32:302-309.

28. Goulart CS, Nouer PRA, Mouramartins R, Garbin IU, Lizarelli RZ. Photoradiation and orthodontic movement: Experimental study with canines. Photomed Laser Surg 2006;24:192–196.

29. Seifi M, Shafeei HA, Daneshdoost S, Mir M. Effects of two types of low-level laser wave legiths (850 and 630 nm) on the orthodontic tooth movements in rabbits. Lasers Med Sci 2007;22:261–264.

30. Limpanichkul W, Godfrey K, Srisuk N, Rattanayatikul C. Effects of low-level laser therapy on the rate of orthodontic tooth movement. Orthod Craniofac Res 2006;9:38–43.

31. Kim SJ, Moon SU, Kang SG, Park YG. Effects of low-level laser therapy after Corticision on tooth movement and paradental remodeling. Lasers Surg Med 2009;41:524-533.

32. Youssef M, Ashkar S, Hamade E, Gutknecht N, Lampert F, Mir M. The effect of low-level laser therapy during orthodontic movement: a preliminary study. Lasers Med Sci 2008;23:27-33.