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EFFECT OF LOW LEVEL LASER THERAPY ON RATE OF ORTHODONTIC TOOTH MOVEMENT

[1]Gayatri Ganesh, Tulika Tripathi[2]*, Priyank Rai[3] and Anup Kanase[4]

[1]Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Maulana Azad Institute of Dental Sciences, Bahadur Shah Zafar Marg, New Delhi-110002, India.

[2]Senior Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Maulana Azad Institute of Dental Sciences, Bahadur Shah Zafar Marg, New Delhi-110002, India.

[3,4]Professor, Department of Orthodontics and Dentofacial Orthopaedics, Maulana Azad Institute of Dental Sciences Bahadur Shah Zafar Marg, New Delhi-110002, India.

***Corresponding Author: Dr. Tulika Tripathi**
Senior Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Maulana Azad Institute of Dental Sciences, Bahadur Shah Zafar Marg, New Delhi-110002, India.

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ABSTRACT

Background: Pain and long treatment duration are two of the majors concerns associated with fixed orthodontic treatment. Low level laser therapy (LLLT) as a non-surgical approach has been reported to challenge both the concerns. The aim of the present study was to assess the effect of low level laser therapy on rate of orthodontic tooth movement during canine retraction and its subsequent association with gender and age. **Methodology:** A split mouth single blind interventional study was carried on 40 sites (18 patients) of both genders in the age group of 13 to 20 years requiring fixed orthodontic treatment with extraction of the first premolars in both or either arch. Segmental canine retraction was carried out using a nickel-titanium closed-coil spring. The laser side received low level laser application and simulations were given on the opposite side on days 0, 3,7,11,15,28,31,35,39,43 and 56 post commencement of canine retraction. Tooth movement was measured on study models RESULT: A difference in the rate of tooth movement was observed to be 0.02 mm/day between the two groups with the laser side showing faster movement. The association between age and rate of movement in the laser group was negative i.e. the amount of tooth movement decreases with age. CONCLUSION: Low level laser therapy is effective in accelerating orthodontic tooth movement thus reducing the treatment duration with no association with age.

KEYWORDS: Low level laser therapy, Orthodontics, Tooth movement, Canine retraction, Coil springs.

INTRODUCTION

The long treatment period of 2-3 years associated with fixed orthodontic treatment is often a major patient concern.[1] However, this duration is influenced by various factors such as case severity, extraction versus non-extraction therapy etc and is indirectly associated with an increased risk of root resorption, gingival inflammation and dental caries making it an equally important concern for the orthodontist.[1,2,3]

Orthodontic tooth movement arises when externally applied forces produce an injury to the periodontal ligament causing inflammation leading to both pathological and physiological responses.[4,5] An entire series of events subsequently follows leading to bone resorption and apposition through modelling–remodelling producing tooth movement.[6] The amount of tooth movement in response to the applied force is influenced by several factors such as gender, status of periodontal ligament (PDL), the type of tooth movement and the magnitude of the applied force.[7]

So far, a lot of surgical and non-surgical attempts have been made to find approaches for enhancing orthodontic tooth movement. The surgical category includes alveolar decortication, corticotomy, distraction of the periodontal ligament or the dento-alveolus,[8] while injections of prostaglandins[9,10], active form of vitamin D.[9,11] and osteocalcin[10,11] around the alveolar socket, resonance vibration[12] and ultrasound waves[13] are few amongst the non-surgical ones. Though these substances stimulate the rate of tooth movement, they also have the undesirable side effects of local pain and discomfort during the injections.[14]

Low level laser therapy (LLLT) or photobiomodulation, came into use in its modern form in 1971 and subsequently has been used in orthodontics for reduction of post-adjustment pain[15], bone regeneration in midpalatal suture area after rapid maxillary expansion[16] and accelerating tooth movement.[1,7]

Over the last decade, many histologic studies have attempted to determine the effect of LLLT on the rate of orthodontic tooth movement.[17] However the results of these studies on the rate of tooth movement are controversial as some report a significant acceleration of tooth movement in the laser group compared to the placebo application while others report no difference or even indicated the inhibitory effect.[18]

Hence the aim of the present study was to determine the effect of LLLT on tooth movement and establish a protocol to improve the patient's comfort, compliance as well as possibly shorten the treatment time.

MATERIALS AND METHODOLOGY

This study was a split mouth single blind interventional study carried out in the Department of Orthodontics and Dentofacial Orthopaedics at Maulana Azad Institute of Dental Sciences, New Delhi over a period of 12 months. The sample size was determined as 40 sites (18 patients) at a confidence level of 95%. These patients aged between 13 to 20 years comprised of 16 females & 2 males who required fixed orthodontic treatment with extraction of the first premolars in both or either arch.

All subjects fulfilling the inclusion criteria were included and patients with unerupted or impacted second molars/second premolars, decreased levels of alveolar bone, any history of prior systemic disease or long term medications were excluded in the study. A written consent was obtained from all the subjects prior to the commencement of the study.

The study design was approved by the ethics committee of Maulana Azad Institute of Dental Sciences, New Delhi, India. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The selected patients were bonded with 0.022 in slot McLaughlin Bennett Trevisi brackets and alignment and levelling of teeth were carried out using subsequent NiTi and stainless steel wires. After the completion of alignment and leveling, a final working wire 0.019" x 0.025" stainless steel was placed and individual canine retraction was started with a 9 mm nickel-titanium closed-coil spring (Optima^R, Desire orthodontics) placed from the hook of the molar tube to the hook of the canine bracket.

Standardized anchorage control protocol using a Nance palatal arch and second molar banding was followed in all the cases. The incisors and molars were consolidated using a figure of eight with 0.009 inch stainless steel ligature wire. A force of 75 g measure by a Dontrix gauge was used for individual canine retraction. Patients were asked to report immediately if the spring dislodged or broke; it was then replaced.

Following the placement of the coil springs, all the patients were randomly allocated into two groups – Laser Group (LG) and the Placebo group (PG). Each group consisted of an upper or lower canine of an arch with the contralateral canine placed in the remaining group. The laser probe (Photon plus diode laser®, Zolar Technology & Mfg. Co.Inc. Canada, Gallium Aluminium Arsenic based diode laser 980 nm, 100mW, continuous wave mode) was placed in contact with the mucosa and aimed at 5 points buccally and palatally around the canine i.e. two in the cervical third, two in the middle third and one at the apex of the root. The laser was applied on 0, 3,7,11,15,28,31,35,39,43 and 56th day which amounted to a total dose of 10 J (10 x 10 s x 100 mW) per application. The placebo group consisting of the contralateral canine of the same arch received no laser; only simulations. The laser and the placebo application were done by a single operator.

Alginate impressions were taken before starting canine retraction (T_{00}), at days 28 (T_{28}) and 56 (T_{56}). The amount of tooth movement in millimeters was prompted by measuring the distance between the tip of the mesial cusp of the first molar and the tip of the canine cusp and the distal surface of lateral incisor bracket slot and mesial surface of the canine bracket slot. Tooth movement was measured using the study models with a digital vernier caliper using standard landmarks at day zero, day 28 and day 56.

All data was tabulated and analyzed using the statistical software program (SPSS Inc, Chicago, Ill). The descriptive statistics of mean differences, standard deviations and standard errors were calculated for all variables and the results were calculated using independent *t* test. A p value of <0.05 was considered significant.

RESULTS

The sample of 18 patients comprised of 2 males and 18 females in the age group of 13- 20 years with a mean age of 16 years.

Table 1 depicts the mean distances and changes in the mean distances measured in the respective groups, LG2 and PG2 at the three time intervals. Figure 1 shows a pictorial representation of the same.

Independent T test done for comparison change in the mean distance at the three time intervals; T_{00}, T_{28} and T_{56} between the two groups revealed significant differences between the change in mean movement of the two groups at T_{00} - T_{28} and T_{00}-T_{56}. However, when T_{28}-T_{56} was compared, the change was not significant (Table 2). Table 3 depicts the rate of tooth movement of the LG2 and PG2 measured over a period of 56 days. The difference of 0.02 mm/day between the laser and the placebo group is represented in Graph 2 signifying that the rate of tooth movement increases with the application of low level laser therapy.

Association between age and rate of movement can be seen in Table 4 where the correlation coefficient depicts a negative association between age and tooth movement i.e. the amount of tooth movement decreases with age in LG2. However the PG2 does not show any significant association.

Table 1: Mean Distances between the canine cusp tip and mesiobuccal cusp tip of the molar (mm) and the lateral incisor and canine.

GROUPS	**N**	T_{00}	T_{28}	T_{56}
Mean distance between the canine cusp tip and mesiobuccal cusp tip of the molar (mm)				
LG2	20	19.95 ± 1.46	17.72 ± 1.53	16.54 ± 1.60
PG2	20	19.26 ± 1.70	17.72 ± 1.41	16.83 ± 1.42
Changes in the mean distance between the canine cusp tip and mesiobuccal cusp tip of the molar (mm)				
GROUPS	**N**	T_{00} - T_{28}	T_{00} - T_{56}	$T_{28} – T_{56}$
LG2	20	2.23 ± 0.97	3.41 ± 1.46	1.18 ± 0.73
PG2	20	1.53 ± 1.13	2.42 ± 1.37	0.89 ± 0.55
Changes in the mean distance between the distal surface of the lateral incisor and mesial surface of the canine bracket (mm)				
GROUPS	**N**	T_{28} -T_{00}	$T_{56} – T_{00}$	$T_{56} – T_{28}$
LG2	20	1.92 ± 0.86	3.14 ± 1.30	1.47 ± 0.73
PG2	20	0.96 ± 0.63	1.89 ± 0.71	0.93 ± 0.57

LG2: Laser Group
PG2: Placebo group
T_{00}: Start of canine retraction at Day 0
T_{28}: At Day 28
T_{56}: At Day 56

Table 2: Intergroup comparison of the change in the amount of tooth movement using an independent t- test.

t – test for Equality of Means					
	t	**df**	**Sig. (2-tailed)**	**95% Confidence Interval of the Difference**	
				Lower	**Upper**
Changes in the mean distance between the canine cusp tip and mesiobuccal cusp tip of the molar (mm)					
T_{00} - T_{28}	2.08	38	**0.04***	0.018	1.37
T_0 - T_{56}	2.20	38	**0.03***	0.08	1.89
$T_{28} – T_{56}$	1.43	38	0.16 (NS)	0.12	0.71
Changes in the mean distance between the distal surface of the lateral incisor and mesial surface of the canine bracket (mm)					
T_{28} -T_{00}	4.00	38	**0.0001***	0.47	1.44
$T_{56} – T_{00}$	4.51	38	**0.0001***	0.83	2.17
$T_{56} – T_{28}$	2.60	38	**0.01***	0.12	0.96

* Level of significance < 0.05
NS: Level of significance is not significant

Table 3: Comparison of the rates of tooth movement.

Groups	**Mean rate of tooth movement (mm/day)**
LG2	0.06
PG2	0.04

Table 4: Correlation between age and the amount of tooth movement.

Group	**N= 20**	**Age**	**Changes in the mean distance between the canine and the molar (mm)**		
			T_{00} - T_{28}	T_0 - T_{56}	$T_{28} – T_{56}$
LG2	Correlation	1	-0.51	-0.48	-0.27
	p value		**0.01***	**0.03***	0.24 (NS)
PG2	Correlation	1	-0.41	-0.38	-0.10
	p value		0.06 (NS)	0.09 (NS)	0.65 (NS)

* Level of significance < 0.05
NS: Level of significance is not significant

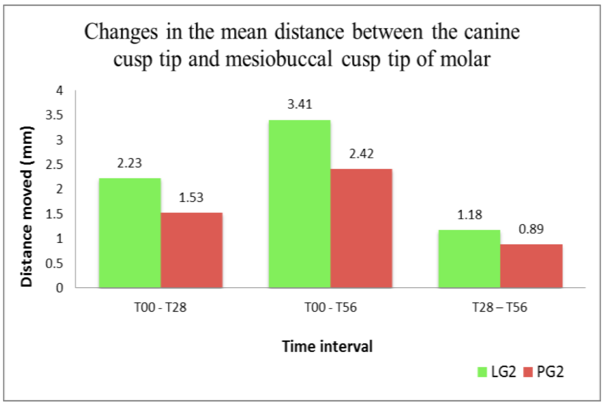

Figure 1: Changes in the mean distance between the canine cusp tip and mesiobuccal cusp tip of the molar at the three time intervals.

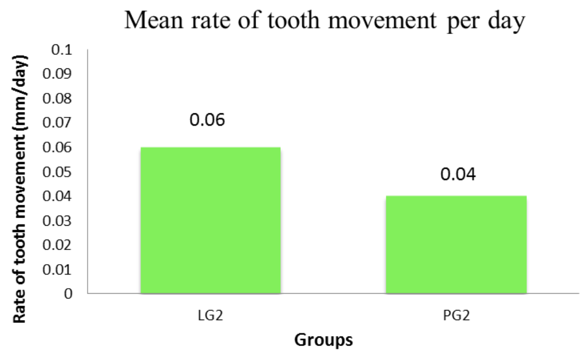

Figure 2: Mean rate of tooth movement per day.

DISCUSSION

With increasing awareness about orthodontic treatment, patients have realized that the benefits of orthodontic treatment go beyond the obvious physical changes and prove to be a great way to improve their self-image. Thus, the field of orthodontics is constantly undergoing advances for discovery of new methods to improve patient compliance.

The aim of the present study was to evaluate the effectiveness of low level laser therapy in tooth movement and establishment of a protocol possibly to reduce the treatment time.

The external forces responsible for orthodontic tooth movement result in remodeling changes in the bone adjacent to the periodontal ligament (PDL) of the tooth where the force has been applied. The PDL cells secrete bone-resorbing cytokines to stimulate osteoclast formation and bone resorption in the direction of orthodontic force vector.[19] To measure the activity of the osteoclasts responsible for bone resorption, RANKL (Receptor Activator for Nuclear Factor κ B Ligand) an osteoclast differentiation factor and its inhibitor osteoprotegerin (OPG) levels are evaluated.[20] However, the bone remodeling is subject to a number of external factors such as nutrition, age and medications[21] and internal factors such as prostaglandins (especially PGE_2)[22,23], interleukin-1β[24] and cytokines[25]

Accelerated orthodontics has been attempted by both surgical and non-surgical techniques. One of the non-surgical methods, low level laser therapy has proven to be non-invasive, easy to use without requirements of any special technique for its operations.[26,27]

Cruz et al[28] conducted a two month study on 11 patients to assess the rate of tooth movement and showed significantly higher acceleration of canine retraction in laser treated group than in the control group. Limpanichkul et al[1] studied maxillary canine retraction in 12 young adult patients and found no significant difference in the rate of tooth movement over a three month period.

In the present study, the probe was place in contact with the mucosa and aimed at 5 points buccally and palatally around the canine i.e. two in the cervical third, two in the middle third and one at the apex of the root to cover the entire periodontal fibers and alveolar process around the canine. The laser was applied on 0, 3,7,11,15,28,31,35,39,43 and 56th day. The laser regimen was applied on days 0, 3, 7, and 14 in the first month. Thereafter, irradiations were done on every 15th day until complete canine retraction on the experimental side amounting to a total dose of 10 J per application (10×10 s×100 mW) which was well within the range required for biostimulation. Youssef et al[7] also applied a total dose of 8J distributed over three points in the lingual and buccal PDL of the canines i.e. cervical, middle and apical on 0, 3, 7 and 14-day intervals after every activation.

According to Dominguez et al[17], the levels of RANKL in GCF peaked at 48 hours in both groups but higher levels were observed in the laser group. The ratio of RANKL/OPG also peaked at 48 hours in both groups with higher concentrations in the laser group. Hence to maintain the peak RANKL and RANKL/OPG levels, laser irradiations were given every 48 hours for the first two weeks in the laser group. Applications for every 48 hours over the first two weeks after the activation of the spring were required in order to maintain any biomodulation effect of LLLT on the periodontium.[18] Post 28 days, when the records were taken and the spring was activated again to maintain a constant force, the same protocol was followed till the end of the study at day 56.

Several hypotheses have been proposed for the mechanism by which LLLT accelerates tooth movement. Four main mechanisms have been described by which LLLT reduces pain i.e. the first where low level laser therapy causes increase in the RANKL levels in the periodontal ligament[29], second where it acts by increasing osteoblastic cell proliferation leading to stimulation of osteogenesis and increase in bone density on the traction side[30] and the third described by Kim et al[31] where low level laser therapy facilitates the increased turnover of connective tissue. Lastly, Yamaguchi et al[32] studied that low level laser therapy can increase macrophage-colony stimulating factor (M-CSF) on the compressed side which may also increase osteoclastogenesis leading to tooth movement.

The present study measured the distance between the canine cusp tip and the mesiobuccal cusp tip of the molar along with the distance between the distal edge of the lateral incisor bracket and the mesial edge of the canine bracket molar. Changes in the distance between the lateral incisor and canine were similar to the change between the canine and the molar thus overcoming the errors in previous studies.

This study reported an increase in the rate of tooth movement in the laser Group (LG2) as compared to the (PG2) measured over a period of 56 days unlike studies by Limpanichkul et al[1], Kansal et al[33] and Hosseini et al[34] who reported no significant differences in the rate of tooth movement.. The mean rate of tooth movement achieved was 0.06 mm/day in LG2 as compared 0.04 mm/day in PG2. Significant differences were obtained in the change in the mean distance between the two groups at T_{00}- T_{28} and T_{00}- T_{56}. However, the change in the mean distance between T_{28} and T_{56} was not significant. Thus, LLLT appears to have a positive effect on the rate of tooth movement.

The correlation between age and the rate of tooth movement in the two respective groups depicted that the age and the amount of tooth movement were negatively correlated i.e. with an increase in age the amount of tooth movement decreased with significant changes in the laser group at T_{00}- T_{28} and T_{00}- $T_{56.}$ Beckwith et al[35] reported that a decreased rate of tooth movement was observed in adult patients because of decreased vascularity and cellularity of tissues.

Hence, based on these findings it can be said with increase in age as the amount of tooth movement decreases, it would be highly beneficial to use LLLT as a tool to accelerate the tooth movement especially in such patients as not only does it increase the rate of movement without any side effects, but it also has an additional effect of increasing the vascularity and cellularity of tissues.[36,37,38]

CONCLUSION

- The rate of orthodontic tooth movement determined in the study for the laser group was 0.06 mm per day compared to 0.04 mm per day in the placebo group, thus concluding that low level laser therapy accelerated the rate of orthodontic tooth movement.

With increase in age as the amount of tooth movement decreases.

REFERENCES

1. Limpanichkul W, Godfrey K, Srisuk N & Rattanayatikul C.Effects of low-level laser therapy on the rate oforthodontic tooth movement. Orthod Craniofacial Res., 2006; 9: 38–43.
2. Mavreas D & Athanasiou AE. Factors affecting the duration of orthodontic treatment: a systematic review. European Journal of Orthodontics, 2008; 30: 386–95.
3. Fisher MA, Wenger RM & Hans MG. Pretreatment characteristics associated with orthodontic treatment duration. American Journal of Orthodontics and Dentofacial Orthopedics, 2010; 137: 178–86.
4. Wise GE & King GJ Mechanisms of tooth eruption and orthodontic tooth movement. J Dent Res., 2008; 87: 414–34.
5. Bruno MB et al. A double blind, randomized clinical trial assessing the effects of a single dose of preemptive anti-inflammatory treatment in orthodontic pain. Prog Orthod, 2011; 12(1): 2-7
6. Yamaguchi M. RANK/RANKL/OPG during orthodontic tooth movement. Orthodontics and Craniofacial Research, 2009; 12: 113–19.
7. Youssef et al. The effect of low-level laser therapy during orthodontic movement: a preliminary study. Lasers Med Sci., 2008; 23: 27–33.
8. Uzuner FD & Darendeliler N. Dentoalveolar surgery techniques combined with orthodontic treatment: a literature review. European Journal of Dentistry, 2013; 7: 257–65.
9. Kale S, Kocadereli I, Atilla P & Asan E. Comparison of the effects of 1,25 dihydroxycholecalciferol and prostaglandin E2 on orthodontic tooth movement. American Journal of Orthodontics and Dentofacial Orthopedics, 2004; 125: 607-14.
10. Seifi M, Eslami B & Saffar AS. The effect of prostaglandin E2 and calcium gluconate on orthodontic tooth movement and root resorption in rats. European Journal of Orthodontics, 2003; 25: 199-04.
11. Collins MK & Sinclair PM. The local use of vitamin D to increase the rate of orthodontic tooth movement. Am J Orthod Dentofacial Orthop, 1988; 94: 278-84.
12. Kobayashi Y et al. Effects of local administration of osteocalcin on experimental tooth movement. Angle Orthodontist, 1998; 68: 259-66.
13. Davidovitch Z et al. Electric currents, bone remodeling, and orthodontic tooth movement.; I. The effect of electric currents on periodontal cyclic nucleotides. Am J Orthod Dentofacial Orthop, 1980; 77: 14-32.
14. 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: 289–97.
15. Turhani D, Scheriau M, Kapral D, Benesch T, Jonke E & Bantleon HP. Pain relief by single low-level laser irradiation in orthodontic patients undergoing

fixed appliance therapy. Am J Orthod Dentofacial Orthop, 2006; 130(3): 371–377.
16. 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: 525-32.
17. Domínguez A, Gómez C & Palma JC. Effects of low-level laser therapy on orthodontics: rate of tooth movement, pain, and release of RANKL and OPG in GCF; Lasers Med Sci., 2015; 30: 915–923.
18. 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; OHDM, 2014; 13(2): 183-88.
19. Sandy JR, Farndale RW & Meikle MC. Recent advances in understanding mechanically induced bone remodeling and their relevance to orthodontic theory and practice. Am J Orthod Dentofacial Orthop, 1993; 103: 212–22.
20. Altan B, Sokucu O, Ozkut M & Inan. Metrical and histological investigation of the effects of low-level laser therapy on orthodontic tooth movement. Lasers Med Sci., 2012; 27: 131–40.
21. Cağlaroğlu M & Erdem A. Histopathologic investigation of the effects of prostaglandin E2 administered by different methods on tooth movement and bone metabolism. Korean J Orthod, Jun, 2012; 42(3): 118-28.
22. Yamasaki K, Shibata Y & Fukuhara T. The effect of prostaglandins on experimental tooth movement in monkeys (Macaca fuscata). J Dent Res., Dec, 1982; 61(12): 1444-6.
23. Yamasaki K et al. Clinical application of prostaglandin E1 (PGE1) upon orthodontic tooth movement. Am J Orthod, Jun, 1984; 85(6): 508-18.
24. Saito M, Saito S, Ngan PW, Shanfeld J & Davidovitch Z. Interleukin 1 beta and prostaglandin E are involved in the response of periodontal cells to mechanical stress in vivo and in vitro. Am J Orthod Dentofacial Orthop, Mar, 1991; 99(3): 226-40.
25. Krishnan V & Davidovitch Z. On a path to unfolding the biological mechanisms of orthodontic tooth movement. Journal of Dental Research, 2009; 88: 597–08.
26. 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: 117–20.
27. Kawasaki K & Shimizu N. Effects of low- energy laser irradiation on bone remodeling during experimental tooth movement in rats. Lasers Surg Med., 2000; 26(3): 282-91.
28. Xiaoting L, Yin T and Yangxi C. Interventions for pain during fixed orthodontic appliance therapy. Angle Orthod, 2010; 80: 925–32.
29. Kapila YL, Lancero H & Johnson PW. The response of periodontal ligament cells to fi- bronectin. J Periodontol, Sep, 1998; 69(9): 1008-19.
30. Ozawa Y, Shimizu N, Kariya G & Abiko Y. Low-energy laser irradiation stimulates bone nodule formation at early stages of cell culture in rat calvarial cells. Bone, Apr, 1998; 22(4): 347-54.
31. Kim SJ, Moon SU, Kang SG & Park YG. Effects of low-level laser therapy after Corti- cision on tooth movement and paradental remodeling. Lasers Surg Med., Sep, 2009; 41(7): 524-33.
32. Yamaguchi M et al. Low-energy laser irradiation stimulates the tooth movement velocity via expression of M- CSF and c-fms. Ortho Waves, 2007; 66(4): 139-48.
33. Dalaie K, Hamedi R, Kharazifard MJ, Mahdian M & Bayat M. Effect of Low-Level Laser Therapy on Orthodontic Tooth Movement: A Clinical Investigation. Journal of Dentistry, 2015; 12(4): 249-56.
34. Hosseini MH, Kamali A & Mahmoodzadeh M. Effect of low level laser therapy on orthodontic tooth movement in human. J Dent Med., 2011; 24: 156–64
35. Beckwith FR, Ackerman RJ, Cobb CM & Tira DE. An evaluation of factors affecting duration of orthodontic treatment. Am J Orthod Dentofacial Orthop, 1999; 115: 439-47.
36. Ozawa Y, Shimizu N, Kariya G, Abiko Y. Low-energy laser irradiation stimulates bone nodule formation at early stages of cell culture in rat calvarial cells. Bone, Apr, 1998; 22(4): 347–54.
37. Khadra M, Kasem N, Haanaes HR, Ellingsen JE, Lyngstadaas SP. Enhancement of bone formation in rat calvarial bone defects using low-level laser therapy. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, Jun, 2004; 97(6): 693–700.
38. Schindl A, Schindl M, Schindl L, Jurecka W, Hönigsmann H, Breier F. Increased dermal angiogenesis after low-intensity laser therapy for a chronic radiation ulcer determined by a video measuring system. J Am Acad Dermatol, Mar, 1999; 40(3): 481–4.