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Significance of photobiomodulation therapy in increasing stability of orthodontic mini-implants: a systematic review and meta-analysis

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Abstract

Background and aim. Although OMIs made a huge progress in orthodontic treatment, occasional failures such as looseness of OMIs during treatment have not been avoided. Lately studies on photobiomodulation therapy (PBMT) showed its positive impact on stability of OMIs. The aim of this systematic review and meta-analysis was to estimate the impact of PBMT on the stability of OMIs.

Materials and methods. Electronic data base search was carried out according to PRISMA principles. PubMed, Research Gate, The Cochrane Library and Wiley Online Library were used to browse the literature. Statistical analysis was conducted with the Review Manager 5.4.1. A meta-analysis was performed by using Standartized mean difference and random effect. Heterogeneity of the studies was assessed using Cochran's Q and I2 tests.

Results. After full-text analysis, 7 articles were included. All 7 studies were pooled into meta-analysis and quantitative synthesis was performed. Meta-analysis revealed that PBMT statistically increases OMI stability 1 and 2 months after OMIs were placed. No significant heterogeneity was found between respective studies.

Conclusion. Based on present meta-analysis, LLLT irradiation on OMIs increases their secondary stability and, therefore, could be implemented clinically as adjunctive therapy to promote secondary OMI stability. However, future randomly controlled studies with larger study groups are needed to further confirm the study results.

Keywords: "Laser therapy", "Orthodontic anchorage", "Mini-implants".

INTRODUCTION

Anchorage control in modern day orthodontics has become highly demanding as the traditional treatment modalities were commonly associated with anchorage loss, for instance, mesial migration of the posterior dental anchorage units [1]. Even though extraoral appliances in theory are somewhat efficient in anchorage control, this way of treatment is highly dependent on patients' compliance and a desirable tooth movement is not always accomplished [2]. Therefore, an introduction of orthodontic mini-implants (OMIs) as temporary orthodontic anchorage devices has become an essential part of orthodontic treatment [3, 4]. To this day, OMIs are considered as the most effective way to improve anchorage control [5]. OMIs are also praised for not only being compliance-free, but also provides the convenience of placement and removal, are low invasive and low cost [6].

Nevertheless, even though OMIs have made a huge progress in orthodontic treatment, occasional failures, such as looseness of OMIs during orthodontic treatment have been reported [7]. This is a result of an absence of mechanical stability, in other words, loss of primary or secondary stability. OMI stability depends on numerous contributing aspects, such as bone density and thickness, OMI type and size parameters, surgical technique, and patient's medical history [8]. In the current literature, one way of improving OMI stability is photobiomodulation therapy (PBMT). PBMT is the term used to describe the mechanistic/scientific basis for this photonic specialty and PBMT as the term for its therapeutic application [9]. Recent studies with animals have proven, that PBMT has a promising impact on the stability of OMIs [10]. Therefore, the aim of this meta-analysis was to estimate the impact of PBMT on the stability of orthodontic mini-implants.

METHODS

Search strategy

Electronic data base search was carried out according to PRISMA principles [11]. PubMed, Research Gate, The Cochrane Library and Wiley Online Library were used to browse the literature with the following keywords: "Laser therapy", "Orthodontic anchorage", "Mini-implants".

Inclusion and exclusion criteria

Inclusion and exclusion criteria are displayed in Table 1.

Table 1. Inclusion/exclusion criteria

Inclusion	Exclusion
RCT studies	Retrospective studies, case reports, literature reviews, meta-analysis
Published less than 5 years ago	Published more than 5 years ago
Written in English	Written in other language than English
Human subject	Animal studies, in vitro studies
Patients whose treatment required as a direct anchorage device for distalization	Patients with previous orthodontic treatment
Follow-up at least of 2 months	Follow-up less than 2 months

Quality assessment

RoB2 tool was used to assess risk of bias and general quality of included studies [12]. Following aspects were assessed: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, other bias.

Statistical analysis

Statistical analysis was conducted with the Review Manager 5.4.1. A meta-analysis was performed by using Standartized mean difference and random effect. Heterogeneity of the studies was assessed using Cochran's Q and I2 tests.

RESULTS

1. Search results

The search process was depicted in Figure 1. After an initial search in electronic databases, 194 articles were displayed. Then, after checking the titles and abstracts for their relevancy, 26 articles were selected for full-text analysis. Lastly, after full-texts, 7 articles were included into meta-analysis. [13-19] 6 of the included studies were randomly controlled trials and 1 [16] was quasi-experimental design study.

2. Characteristics of included studies

Characteristics of all 7 included studies are described in Table 2 and Table 3. In total, 115 patients received a total number of 230. Mean age of the patients in the included studies ranged from 16.77 to 31.7 years. In 3 of the studies resonance frequency analysis was used to determine OMI stability, while in 4 of the studies PerioTest was used. Follow-up in the included studies ranged from 2 months to 3 months. In the included studies, wavelength of the lasers ranged from 618nm up to 940nm. Power of lasers ranged from 100mw to 1700mw, while density ranged from 20 to 360 mw/cm^2. Number of sessions ranged from 4 to 21.

3. Quality assessment

By ROBINS-I tool, all three publications had a low risk of incomplete outcome data and selective reporting bias. Only one study had high risk of random sequence generation bias. Risk of allocation concealment bias was high in four studies. In two studies risk of blinding of participants and personnel bias was unclear and in one was high. Risk of blinding of outcome assessment was not clear in three out of seven publications. All studies had low risk of other bias. Overall, three studies had low, two publications had moderate and two had high risk of bias. Process of study quality assessment is showed in table 3.

4. Quantitative synthesis of results

The meta-analysis indicated no significant difference in OMI stability between PBMT and control group at the baseline (SMD (standardized mean difference)=0,09, 95% CI=-0,18, 0,37; p=0,51) and after 6-7 days post-insertion (SMD=-0,01, 95% CI=-0,32, 0,29; p=0,93). Yet, meta-analysis revealed that PBMT statistically increases OMI stability one month (SMD=0,63, 95% CI=0,35, 0,92; p<0,0001) and two months (SMD=0,98, 95% CI=0,71, 1,26; p<0,00001) after OMIs were placed. No significant heterogeneity (I2=0%, p>0,05) was found between respective studies. Forest plots are depicted in figure 2.

Table 2. Characteristics of included studies

Author, year	Study type	Sample size (patiens, implants)	Age (years)	Implantation site	Implant stability evaluation method	Follow-up time
Abohabib, 2018	randomized clinical trial	15,	20.9 ±3.4	between the roots of first permanent molar and second premolar	resonance frequency analysis	10 weeks
Ekizer, 2016	randomized clinical trial	20 (13 females, 7 males)	16.77 (±1.41)	between the roots of maxillary first molars and second premolars	resonance frequency analysis	3 months

Flieger, 2019	randomized clinical trial	20 (13 females 7 males)	32.5 (±6.1)	gingiva between the second premolar and first molar teeth	Periotest	60 days
Matys, 2020	randomized clinical trial	22 (14 females, 8 males), 44 MIs	31.7 (±9.7)	distal region of the maxilla	Periotest	60 days
Matys, 2020	randomized clinical trial	15 (10 females, 5 males), 30 MIs	36.3 (±7.4)	among teeth 13 and 14, 2 mm below the mucogingival junction.	Periotest	60 days
Osman, 2017	randomized clinical trial	12 (6 females, 6 males), 24 MIs	18	between the second premolar and first molar	Periotest	60 days
Marañón-Vásquez, 2019	quasi-experimental	19 (), 35 MIS	17.3 (±7.05)	N/M	resonance frequency analysis	3 months

Table 3. PBMT characteristics of included studies

Author, year	**Photobiomodulation type device**	**Wavelength nm**	**Power mw**	**Energy density J/cm2**	**Application time per session**	**Number of sessions**
Abohabib, 2018	Biolase (Epic 10 Console) diode laser	940 nm	1.7 W	36 J/cm2	60 s	4
Ekizer, 2016	OsseoPulse1 LED device	618 nm	N/M	20 mW/cm2	20 minutes	21
Flieger, 2019	Red diode laser (SmartM, Lasotronix)	635 nm	20 J	20 J/cm2	100 s	7

Matys, 2020	Diode laser (SmartM PRO, Lasotronix)	808 nm	100 mW	200 mW/cm2	40 s ×2	7
Matys, 2020	Diode laser (SmartM PRO; Lasotronix)	635 nm	100 mW	200 mW/cm2	40 s ×2	7
Osman, 2017	Diode laser (Biolase Technology)	910 nm	0,7 W	N/M	60 s	5
Marañón-Vásquez, 2019	Diode (GaAlAs) laser equipment (Therapy XT, DCM)	808 nm	0,1 W	4 J/cm2 (day 0), 8 J/cm2	20 s (day 0), 40s	7

Table 4. Quality assessment of included studies

Study, year of publication	**Random sequence generation**	**Allocation concealment**	**Blinding of participants and personnel**	**Blinding of outcome assessment**	**Incomplete outcome data**	**Selective reporting**	**Other bias**
Abohabib, 2018	Low	Low	Low	Low	Low	Low	Low
Ekizer, 2016	Low	Low	Low	Low	Low	Low	Low
Flieger, 2019	Low	High	Not clear	Not clear	Low	Low	Low
Matys, 2020	Low	High	Not clear	Not clear	Low	Low	Low
Matys, 2020	Low	High	High	Low	Low	Low	Low
Osman, 2017	Low	Low	Low	Not clear	Low	Low	Low
Marañón-Vásquez, 2019	High	High	Low	Low	Low	Low	Low

Figure 1. Detailed search process

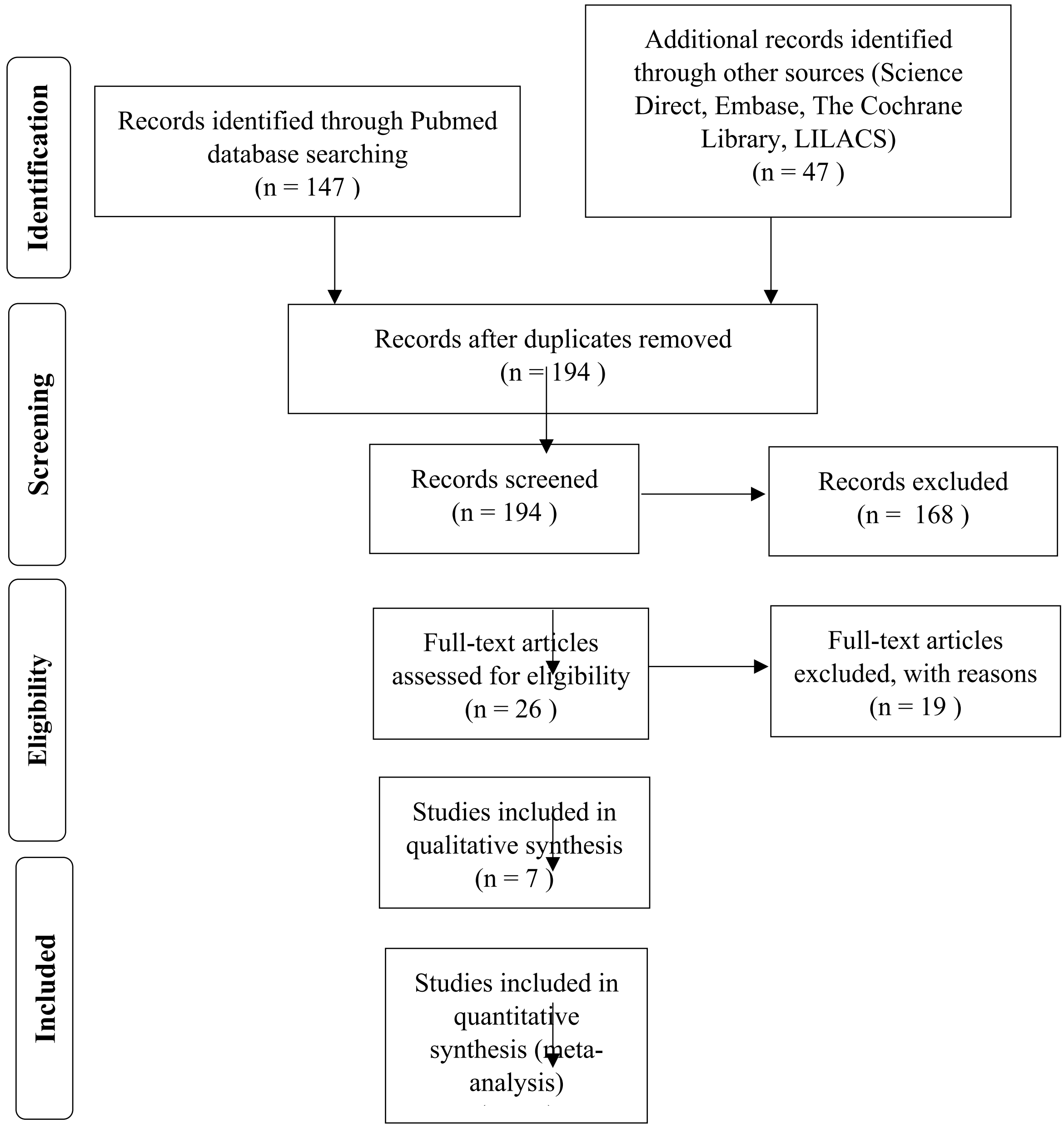
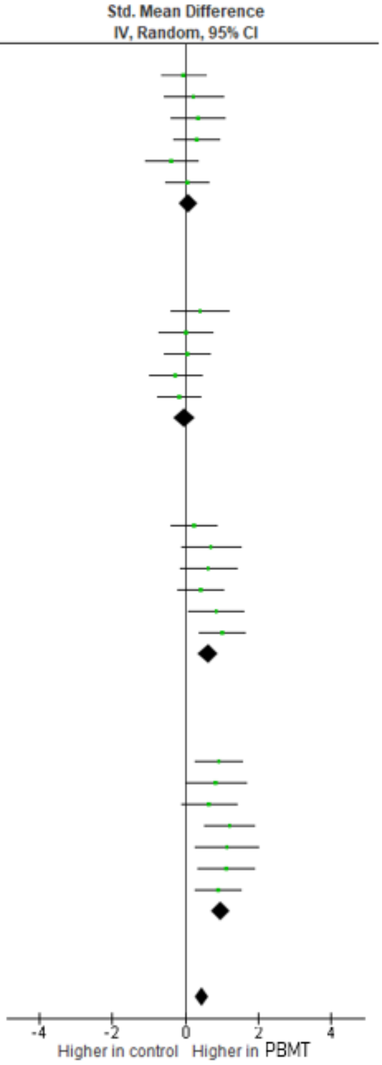


Figure 2. Comparison of OMI stability between PBMT and control groups, depicted using Forest plots.

Study or Subgroup	PBMT Mean	PBMT SD	PBMT Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI	Year
1.1.1 Baseline									
Ekizer 2016	69.05	5.19	20	69.21	4.21	20	4.8%	-0.03 [-0.65, 0.59]	2016
Osman 2017	-1.26	3.98	12	-2.27	4.23	12	3.6%	0.24 [-0.57, 1.04]	2017
Abohabib 2018	5,188.8	339.3	14	5,050	422	14	3.9%	0.35 [-0.40, 1.10]	2018
Flieger 2019	2.74	0.7	20	2.53	0.58	20	4.7%	0.32 [-0.30, 0.94]	2019
Matys (1) 2020	0.44	1.67	15	1.25	2.48	15	4.0%	-0.37 [-1.10, 0.35]	2020
Matys (2) 2020	1.25	2.65	22	1.08	2.34	22	5.0%	0.07 [-0.52, 0.66]	2020
Subtotal (95% CI)			**103**			**103**	**26.0%**	**0.09 [-0.18, 0.37]**	
Heterogeneity: Tau² = 0.00; Chi² = 2.86, df = 5 (P = 0.72); I² = 0%									
Test for overall effect: Z = 0.65 (P = 0.51)									
1.1.2 After 6-7 d.									
Osman 2017	-1.68	3.57	12	-3.32	4.15	12	3.5%	0.41 [-0.40, 1.22]	2017
Abohabib 2018	5,003.8	569.7	14	4,995	433.3	14	3.9%	0.02 [-0.72, 0.76]	2018
Flieger 2019	2.71	0.12	20	2.6	2.79	20	4.8%	0.05 [-0.57, 0.67]	2019
Matys (1) 2020	0.82	1.51	15	1.34	2.29	15	4.1%	-0.26 [-0.98, 0.46]	2020
Matys (2) 2020	0.54	2.71	22	0.94	2.41	22	5.0%	-0.15 [-0.75, 0.44]	2020
Subtotal (95% CI)			**83**			**83**	**21.3%**	**-0.01 [-0.32, 0.29]**	
Heterogeneity: Tau² = 0.00; Chi² = 1.77, df = 4 (P = 0.78); I² = 0%									
Test for overall effect: Z = 0.09 (P = 0.93)									
1.1.3 After 1 month									
Ekizer 2016	69.7	4.31	20	68.6	4.44	20	4.7%	0.25 [-0.38, 0.87]	2016
Osman 2017	-2.6	1.9	12	-4.32	2.65	12	3.4%	0.72 [-0.11, 1.55]	2017
Abohabib 2018	4,417.5	565.4	14	3,980	743.4	14	3.8%	0.64 [-0.12, 1.41]	2018
Flieger 2019	-6.18	5.3	20	-9.17	8.25	20	4.7%	0.42 [-0.20, 1.05]	2019
Matys (1) 2020	-6.12	4.78	15	-10.88	5.89	15	3.9%	0.86 [0.11, 1.62]	2020
Matys (2) 2020	-6.32	3.62	22	-11.34	5.76	22	4.7%	1.02 [0.39, 1.66]	2020
Subtotal (95% CI)			**103**			**103**	**25.2%**	**0.63 [0.35, 0.92]**	
Heterogeneity: Tau² = 0.00; Chi² = 3.79, df = 5 (P = 0.58); I² = 0%									
Test for overall effect: Z = 4.40 (P < 0.0001)									
1.1.4 After 2nd month									
Ekizer 2016	71.75	4.55	20	68.35	2.2	20	4.5%	0.93 [0.28, 1.59]	2016
Osman 2017	-2.02	2.6	12	-4.29	2.57	12	3.4%	0.85 [0.01, 1.69]	2017
Abohabib 2018	4,411.3	645.3	14	3,912.5	799.2	14	3.8%	0.67 [-0.10, 1.43]	2018
Flieger 2019	-1.51	2.25	20	-5	3.24	20	4.3%	1.23 [0.55, 1.91]	2019
Vasquez 2019	-7.8	0.8	12	-8.7	0.7	12	3.2%	1.16 [0.28, 2.03]	2019
Matys (1) 2020	-5.7	3.39	15	-10.55	4.81	15	3.7%	1.13 [0.35, 1.91]	2020
Matys (2) 2020	-6.55	4.66	22	-10.95	4.77	22	4.7%	0.92 [0.29, 1.54]	2020
Subtotal (95% CI)			**115**			**115**	**27.6%**	**0.98 [0.71, 1.26]**	
Heterogeneity: Tau² = 0.00; Chi² = 1.61, df = 6 (P = 0.95); I² = 0%									
Test for overall effect: Z = 6.97 (P < 0.00001)									
Total (95% CI)			**404**			**404**	**100.0%**	**0.46 [0.26, 0.65]**	
Heterogeneity: Tau² = 0.10; Chi² = 41.27, df = 23 (P = 0.01); I² = 44%									
Test for overall effect: Z = 4.67 (P < 0.00001)									
Test for subgroup differences: Chi² = 31.25, df = 3 (P < 0.00001), I² = 90.4%									



DISCUSSION

The aim of this meta-analysis was to evaluate PBMT influence on OMI stability. Overall, 11 micro-implants were lost in all seven studies. According to Abohabib et al, there were six failed mini-implants, three in each group and their failures were mainly detected during the first 6 weeks. [13] As for mini-implant stability, significant difference in values was observed from week 3 to 10. During this period the low-intensity laser sides presented significantly increased mean resonance frequency values compared to control sides. Results of this study demonstrated some minor favourable changes in resonance frequency scores using low-intensity laser therapy although MI stability was not clinically affected. Ekizer et al and Osman at al found no statistically significant differences in MI stability between irradiated and control groups, although according to Osman et al, the mean mobility measures in the experimental sides was less than the control sides both at baseline and during the whole observation period. [14, 19] Flieger et al reported higher secondary stability of MI that were irradiated with low level laser after 30 and 60 days of follow ups and higher primary stability in test group three days after the insertion of MI. [15] Two different wave lengths of the same laser diode were used in two studies carried out by Matys et al and better stability results were achieved while using 635 nm Red Laser Light, although 30 days after LLLT with 808 nm wavelength laser diode trial group has also showed a higher rate of stability compared to control group. [17, 18] Vasquez et al compared not only irradiated and non-irradiated Mis but also immediate and delayed loading protocols. [16] After comparison of all four regimens, authors have discovered that group where both LLLT and delayed loading was performed showed the lowest loss of stability, that was statistically significantly different from non-irradiated groups.

Regarding limitations of this meta-analysis, there were few. Firstly, the characteristic of PBMT modalities had a bit of differences. Therefore, it could have influenced the overall homogeneity of the included studies, making some of them slightly heterogeneous. Also, more RCT are needed to determine, whether any particular PBMT modality characteristics, for instance wavelength or power output, have any influence on OMI stability. Thus, no exact treatment protocol using PBMT could be done up to this day. Secondly, implant stability is greatly influenced by a patient's oral health [20]. Therefore, future studies should update their methodology by considering patient's oral health condition. And lastly, OMI insertion site should be a question of concern in the included studies, since the bone type, thickness, and density vary from site to site [21, 22].

In conclusion, based on present meta-analysis, low-level laser therapy on orthodontic mini-implants increase their secondary stability and, therefore, could be implemented clinically as adjunctive procedure. However, future randomly controlled studies with larger samples are needed to confirm the study results.

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