Original Article

Effect of low-level laser therapy on the time needed for leveling and alignment of mandibular anterior crowding: *A randomized controlled clinical trial*

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ABSTRACT

Objectives: To assess the effect of low-level laser therapy (LLLT) on overall leveling and alignment time of mandibular anterior crowding and associated pain after initial archwire placement.

Materials and Methods: Thirty-two females (18-25 years) with mandibular anterior crowding were randomly allocated into laser and control groups. Eligibility criteria included Angle Class I molar relationship and Little's irregularity index (LII) from 4 to 10 mm. Randomization was accomplished with a computer-generated random list. A 0.014-inch copper-nickel-titanium (Cu-NiTi) wire was inserted immediately after bonding of 0.022-inch Roth brackets followed by 0.016-inch Cu-NiTi, 0.016 $\times$ 0.022-inch NiTi then 0.017 $\times$ 0.025-inch stainless steel wire after completion of alignment. In-Ga-As laser was applied to the mandibular anterior segment in the laser group on days 3, 7, and 14, then at 1 month followed by every 2 weeks until completion of leveling and alignment. Visual analogue scale questionnaires were completed by each patient over 7 days from initial archwire placement. Digital models were used to monitor changes in the irregularity index. Blinding was applicable for outcome assessors only.

Results: The mean time for leveling and alignment was significantly lower in the laser compared to the control group (68.2 $\pm$ 28.7 and 109.5 $\pm$ 34.7 days, respectively). The laser group displayed a significantly higher mean alignment improvement percentage as well as lower pain scores compared to the control group.

Conclusions: Within the constraints of the current study, LLLT has a potential for acceleration of anterior segment alignment as well as reduction of the pain associated with placement of initial archwires. (*Angle Orthod.* 2022;92:478–486.)

KEY WORDS: Acceleration; LLLT; Alignment; Tooth movement; Pain; Irregularity index

INTRODUCTION

The increasing demand, especially among adults, to attain a pleasing smile through orthodontic treatment is usually challenged by its long duration and possible associated discomfort. The last decade has witnessed a persistent quest for a reliable, practical, and minimally invasive approach for acceleration of orthodontic tooth movement (OTM).[1,2] Leveling and alignment is usually the first step in a treatment sequence[3] that could take, according to the severity of incisor irregularity, up to 8 months.[4]

Reduction of leveling and alignment time via acceleration of OTM has been successfully attempted through approaches including surgical interventions such as corticotomy, corticision, piezocision,[5] and micro-osteoperforation.[6] Nevertheless, these techniques were quite invasive as perceived by orthodontists and patients. This, in turn, has led to the advocacy of other less invasive maneuvers, including the local or systemic administration of pharmacological agents[7] or device-assisted therapies such as photobiomodulation with light-emitting diodes[8,9] or laser therapy, with the

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latter being the most investigated thanks to its promising results and noninvasive nature.[10–12] The increase in the rate of orthodontic tooth movement associated with application of LLLT was related to stimulation of bone remodeling subsequent to increased expression of RANK/RANKL from precursor cells, therefore increasing the number of osteoclasts and osteoblasts and reinforcing their functions.[10]

Attempts to evaluate the outcome of photodynamic therapy on leveling and alignment of the mandibular anterior segment revealed contradictory results. El Shehawy et al.[13] failed to find any effect of LLLT, compared to AlSayed Hasan et al.[14] and Caccianiga et al.,[15] who demonstrated a significant reduction in orthodontic leveling and alignment time (OLAT) by 26% and 25%, respectively. Additionally, a number of studies have confirmed the palliative effects of LLLT through its inhibition of the release of arachidonic acid metabolites, particularly prostaglandin E2,[16] and stimulation of induction of endogenous opioids that encouraged potent analgesic effects.[17] Nevertheless, other studies failed to corroborate those findings.[18]

Specific Objectives and Hypotheses

The primary outcome for this study was to evaluate the effects of LLLT on the OLAT of the crowded mandibular anterior segment. Alignment improvement percentage and the associated pain experience during the first 7 days of initial archwire placement were also evaluated as secondary outcomes. The null hypothesis was that LLLT would have no effect on the OLAT of anterior crowding as well as the associated pain.

MATERIAL AND METHODS

Trial Design and any Changes After Trial Commencement

This study was a two-arm parallel randomized clinical trial with an allocation ratio of 1:1. The CONSORT statement reporting guidelines were followed (Figure 1). The study methodology was approved by the Ethical Committee review board at the Faculty of Dentistry, Ain Shams University (FDASU-RecM071403). There were no changes to the methodology after the commencement of the trial.

Participants, Eligibility Criteria, and Settings

Forty-six patients were screened at the outpatient clinic of the Orthodontic Department, Faculty of Dentistry, Ain-Shams University. Thirty-two participants were recruited according to the eligibility criteria presented in Table 1. Patients were asked to sign informed consent after careful explanation of the study design and any possible drawbacks.

Interventions

Standard pretreatment records were taken for each patient. Bonding of 0.022-inch Roth Mini Diamond brackets (Ormco, Pomona, California, USA) was accomplished. In both groups, an initial archwire of 0.014-inch copper-nickel-titanium (Cu-NiTi) (Ormco) was inserted immediately after bonding. Proceeding to 0.016-inch Cu-NiTi then 0.016×0.022-inch NiTi wire was carried out when 50% and 80% reduction in Little's irregularity index (LII) was achieved, respectively. Finally, on completion of alignment (LII < 0.25), a 0.017×0.025-inch stainless steel wire was inserted.

For pain assessment after initial archwire placement, patients in both groups received a printed questionnaire with a visual analogue scale (VAS). The patients were asked to fill in the questionnaire over a 7-day period starting from the day of wire insertion.

For the laser group, leveling and alignment was commenced with the application of LLLT (Epic 10 diode laser machine, BIOLASE, Foothill Ranch, California, USA) following the protocol and parameters illustrated in Table 2 and Figure 2. All safety and infection control measures for laser application were strictly followed. Subjects in both groups were recalled for follow-up and laser application on days 3, 7, and 14, then at 1 month, followed by every 2 weeks until alignment completion. An alginate impression was obtained of the lower arch of each subject at each follow-up visit.

Measurements

Alginate impressions for each subject were poured to fabricate stone models that were scanned using a 3Shape R-750 desktop scanner (3Shape, Copenhagen, Denmark) to obtain digital models that were used to measure the irregularity index (LII) using 3Shape Ortho-Analyzer software (3Shape). The linear measurements were performed with the digital caliper function tool to measure LII, which reflected the degree of malalignment[19] (Figure 3). Leveling and alignment improvement percentage (LAIP) was calculated by dividing the amount of change in the LII value at a specific time point by the LII value just before initial wire placement (T0) and multiplying by 100. The change at any specific time point was calculated by subtracting the LII value at that time point from the LII value at T0. The digital model measurements were assessed by the same assessor (GY) twice, 2 weeks apart, and by another assessor (NI) once to validate measurement reliability.

Evaluation of pain related to initial archwire placement was performed by instructing each patient to record her level of pain each day for the first week after initial archwire placement using a VAS. There were

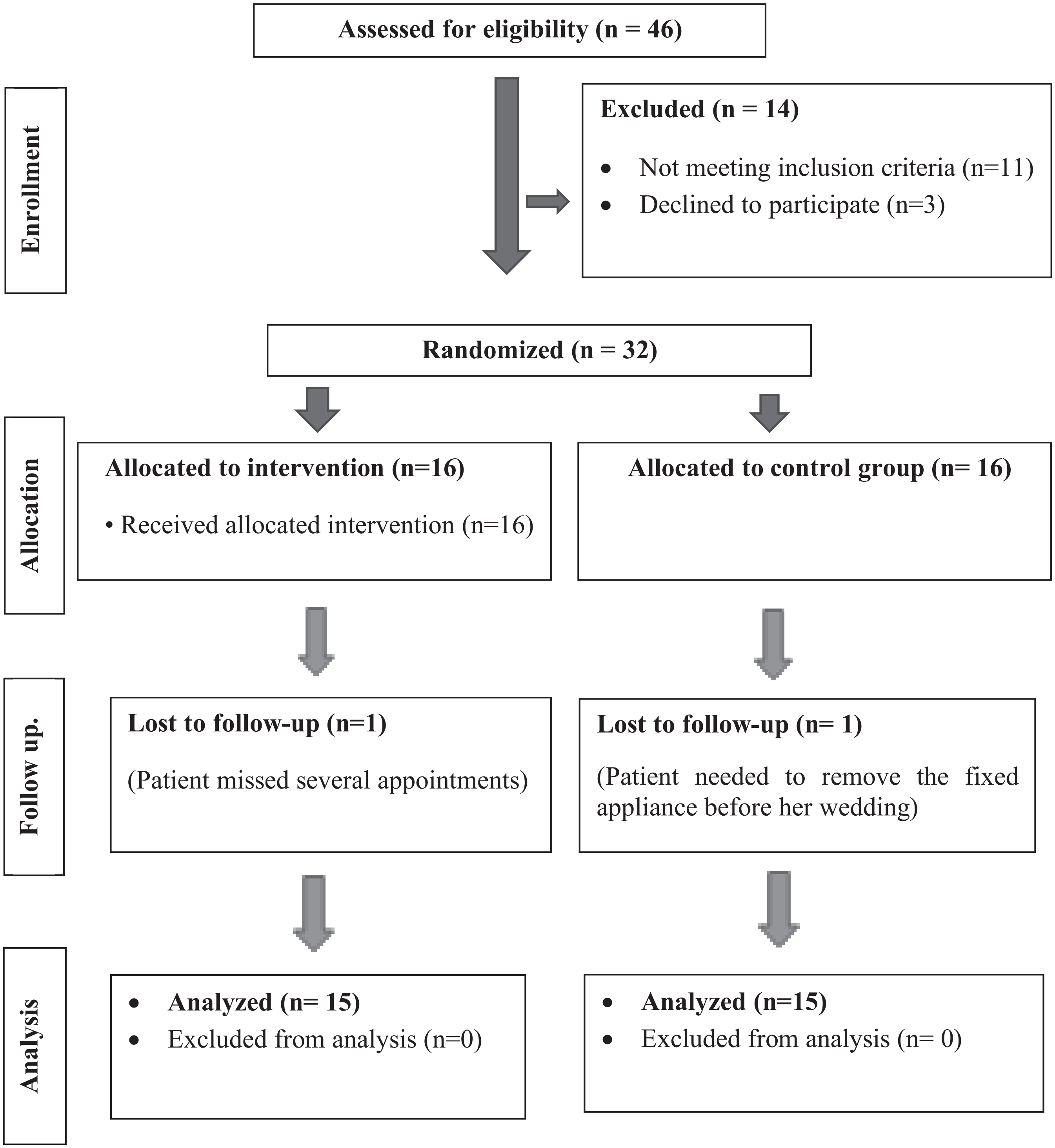

Figure 1. CONSORT flowchart.

anchors at each end of the line that read (0) for "no pain" and (10) for "horrible pain."

Sample Size Calculation

Sample size calculation was based on a study by AlSayed Hasan et al.[14] in which the estimated time for alleviation of crowding of the mandibular anterior teeth was 81.23 ± 15.29 days. In that study, a clinically significant difference with 26% reduction in treatment time in the experimental group was reported. Sample size calculation was performed with G*Power software version 3.1.3 (Universität Kiel, Kiel, Germany). The

Table 1. Eligibility Criteria for Study Participants

Inclusion Criteria	Exclusion Criteria
Females	Pregnancy, systemic diseases, or syndromes
Age 18–25 y of age	Medication interfering with tooth movement
Angle Class I malocclusion	Skeletal discrepancy in any of three planes
Fully erupted permanent dentition	Extracted, missing, or badly decayed permanent teeth (not including third molars)
Good oral and general health	History of orthodontic treatment
Mandibular anterior irregularity index ranging from 4 to 10 mm	Treatment plan involving mandibular extractions
	Spacing in the mandibular arch
	Impediment to bracket placement on the mandibular anterior teeth

power analysis yielded a total sample size estimate of 26 participants when using a two-sample *t*-test at a conventional alpha-level ($P = 0.05$) and desired power of 80%, thus yielding 13 patients per group. To account for dropouts, six more patients were added to the estimated sample.

Randomization and Blinding

A generated randomization sequence was prepared using Microsoft Excel software (Redmond, Washington, USA). The first 16 random numbers were assigned to the intervention group while the others were assigned to the control. Each number was placed in a sealed opaque envelope. Envelopes and the generated sequence were held by the department secretary.

Blinding of the patient and operator was not applicable due to the nature of this study. However, the outcome assessors were blinded through data concealment during assessment.

Statistical Analysis

Statistical analysis was performed with IBM SPSS Statistics Version 20 (SPSS Inc., Chicago, Ill) for Windows. Numerical data were explored for normality by checking the data distribution and implementing Kolmogorov-Smirnov and Shapiro-Wilk tests. All data showed nonparametric distributions. Mann-Whitney *U*-test was used to compare between the groups. Friedman's test was used to study the changes by time within each group. Dunn's test was used for pairwise comparisons when Friedman's test was significant. Intra- and interobserver reliability were assessed using Cronbach's alpha reliability coefficient and intraclass correlation coefficient (ICC). The significance level was set at $P \leq .05$.

Table 2. Laser Parameters and Application Zones

Medium	In-Ga-As Semiconductor Diode
Power Mode	Continuous
Wavelength	940 ± 10 nm
Energy density	25.7 J/cm^2 per application
Power output	2.5W
Application tool	Tooth-whitening handpiece (35 mm $\times$ 8 mm) $=$ (2.8 cm^2)
Application zones and time	Labially at the vestibule for 30 s.
Laser treatment intervals	At (d 0, 3, 7, 14, 30 and then repeated every 2 wk)

RESULTS

Participant Flow

Forty-six female patients (mean age: 21.5 ± 3.5 years) were assessed for eligibility; of those, 14 did not meet inclusion criteria. Thirty-two patients were randomized in a 1:1 ratio to laser or control groups. Two patients were lost to follow-up, one in each group (Figure 1).

Baseline Characteristics and Outcomes

All recruited patients were adult females with Angle Class I molar relationships. Pretreatment LII value comparison between laser and control groups showed no statistically significant difference with a preoperative

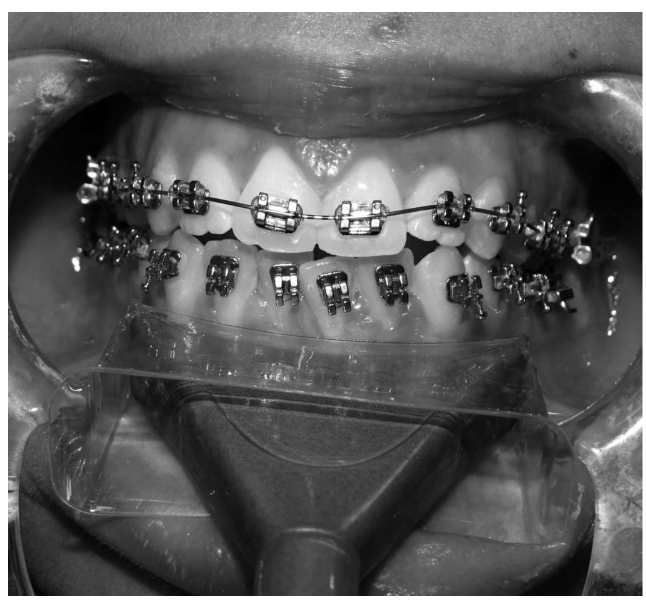

Figure 2. Whitening tip used for laser application.

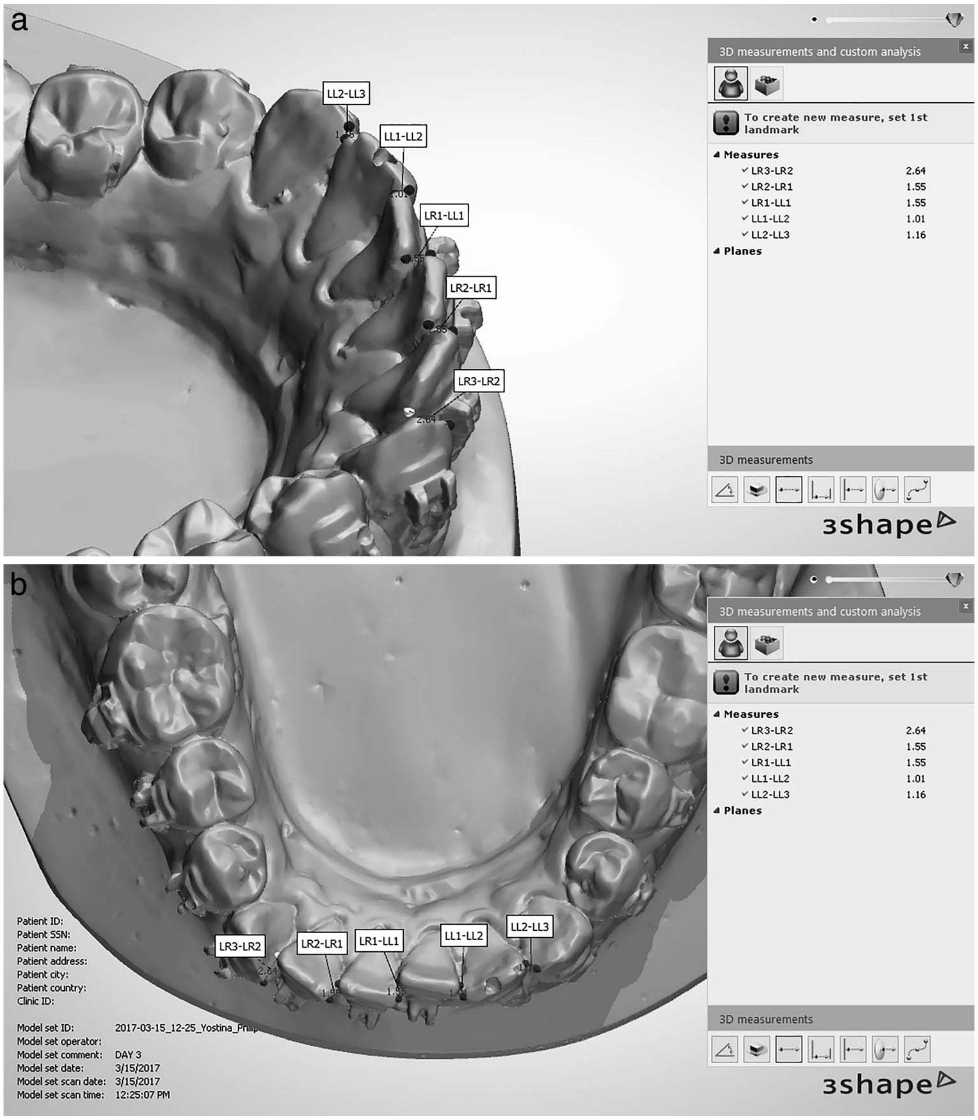

Figure 3. Little's irregularity index measured on digital models using Ortho Analyzer software (3Shape, Holmens Kanal, Copenhagen, Denmark). (a) side view; (b) occlusal view.

LII mean of 5.85 ± 1.75 mm and 6.4 ± 2.7 mm for the experimental and the control groups, respectively (Table 3).

The laser group showed a statistically significantly lower mean OLAT of 68.2 ± 28.7 days compared to 109.5 ± 34.7 days for the control group ($P \leq .05$) (Table 4). When LAIP was evaluated after 3, 7, and 14 days, as well as 4 and 6 weeks, the results showed no statistically significant difference between both groups. However, after 8, 10, 12, and 14 weeks, the laser group displayed a statistically significantly higher mean LAIP than the control group with 86.2%, 98.2%, 99.7%, and 100% compared to 69.8%, 78.9%, 86.1%, and 92%, respectively ($P \leq .05$) (Table 5).

VAS scores for pain perception by the patients showed no statistically significant differences in the

Table 3. Mean, SD, Median, IQR, 95% CI for the Mean Difference Values and Results of Mann-Whitney *U*-Test for Comparison of Little's Irregularity Index on Preoperative Models Between the Two Groups[a]

	Laser Group				Control Group					
Time	Mean (mm)	SD	Median	IQR	Mean (mm)	SD	Median	IQR	95% CI for Mean Difference	*P* Value
Preoperative	5.85	1.75	5.65	4.2–7.6	6.40	2.77	4.9	4.8-7.3	−4.05 to 2.95	.606

* Significant at $P \leq .05$.
[a] CI indicates confidence interval; IQR, interquartile range; SD, standard deviation.

Table 4. Mean, SD, Median, IQR, 95% CI for Mean Difference Values and Results of Mann-Whitney *U*-Test for Comparison of Overall Time for Leveling and Alignment Between the Two Groups[a]

Laser Group				Control Group				95% CI for Mean Difference	*P* Value
Mean, Days	SD	Median	IQR	Mean, Days	SD	Median	IQR		
68.2	28.7	75	45–75	109.5	34.7	105	86.3–135	−70.3 to -12.3	.008*

* Significant at $P \leq .05$.
[a] CI indicates confidence interval; IQR, interquartile range; SD, standard deviation.

Table 5. Mean, SD, Median, IQR, 95% CI for Mean Difference Values and Results of Mann-Whitney *U*-Test for Comparison of Leveling and Alignment Improvement Percentage (LAIP) Between the Two Groups[a]

	Laser Group				Control Group					
Time	Mean	SD	Median	IQR	Mean	SD	Median	IQR	95% CI for Mean Difference	*P* Value
Day 3	9.8	8.3	7.4	5.6–18.9	4.1	2.6	3.2	2.4–6.7	−0.2 to 11.4	.060
1 week	29.6	19.5	31.9	18.8–46.8	14.9	9.6	13.9	5.8–23.6	−0.05 to 29.3	.102
2nd week	39.8	25.7	52.7	25.4–67.5	27.6	14.4	29.3	11.3–42.3	−7.1 to 31.5	.290
4th week	52.3	28.1	63.8	31.8–85	41.4	17.9	40.4	27.9–56.6	−11 to 32.6	.398
6th week	74.0	24.2	89.7	61.1–100	58.8	19.6	57.5	45.7–76.7	−4.9 to 35.5	.158
8th week	86.2	17.1	100	85.1–100	69.8	19.6	68.7	58.8–87.6	0.3 to 33.2	.050*
10th week	98.2	4.4	100	96–100	78.9	19.2	82	66.6–94	6.9 to 31.7	.002*
12th week	99.7	1.2	100	100–100	86.1	17.7	89.4	78.8–100	2.3 to 24.7	.009*
14th week	100.0	0.0	100	100–100	92.0	15.3	100	89–100	1.6 to 17.6	.024*

* Significant at $P \leq .05$.
[a] CI indicates confidence interval; IQR, interquartile range; SD, standard deviation.

Table 6. Mean, SD, Median, IQR, 95% CI for Mean Difference Values and Results of Mann-Whitney *U*-Test for Comparison of Pain Scores Between the Two Groups[a]

	Laser Group				Control Group					
Time	Mean	SD	Median	IQR	Mean	SD	Median	IQR	95% CI for Mean Difference	*P* Value
Day 1	3.0	2.0	1.5	1.5–3.5	2.0	0.9	1.5	1.5–3.5	−0.5 to 2.3	.280
Day 2	3.9	2.0	3.5	1.5–5.5	3.0	1.6	3.5	1.5–3.5	−0.7 to 2.5	.266
Day 3	3.6	2.4	3.5	1.5–5.5	4.3	1.7	5.5	5.5–5.5	−2.5 to 1.2	.421
Day 4	1.7	2.0	1.5	0–3.5	3.6	2.2	3.5	1.5–5.5	−3.7 to 0.01	.052
Day 5	0.9	1.4	0	0–1.5	2.5	1.9	1.5	1.5–3.5	−3.1 to −0.1	.035*
Day 6	0.6	1.4	0	0–0	1.4	1.8	1.5	0–1.5	−2.1 to 0.7	.146
Day 7	0.6	1.4	0	0–0	0.7	1.1	0	0–1.5	−1.2 to 1.1	.502

* Significant at $P \leq .05$.
[a] CI indicates confidence interval; IQR, interquartile range; SD, standard deviation.

two groups after 4 days of initial archwire placement. However, the laser group reported statistically significant lower mean pain scores than the control group at the fifth day (0.9 vs 2.5, respectively; $P \leq .05$). Remarkably, no statistically significant difference in pain scores between the groups were reported on the sixth and 7th days of initial archwire placement (Table 6).

The ICC ranged from 0.825 to 0.924 and from 0.806 to 0.914 for intra- and interexaminer agreements, respectively, reflecting strong reliability of the measurements. No serious harm was observed other than gingivitis associated with plaque accumulation.

DISCUSSION

A noticeable trend toward nonextraction orthodontic treatment has been advocated during the past two decades.[20] The leveling and alignment stage constitutes a major phase of nonextraction treatment. The average time needed to complete leveling and alignment varied between 104 and 284.1 days as reported by Shaughnessy et al.[9] and Caccianiga et al.,[15] respectively. Results of the current study showed OLAT of 109.5 ± 34.7 days for the control group that was comparable to that reported by AlSayed Hasan et al.[14] (109.23 ± 14.18 days). This variation among previous studies in the OLAT could be related to the

Table 7. Clinical Studies Evaluating Effects of LLLT on Leveling and Alignment of Crowded Mandibular Anterior Segments

Study	Sample/n	Degree of Crowding at Baseline, mm	OLAT, d	Arch-Wire Sequence	Active Medium	Emission Type
AlSayed Hasan et al., 2017	Control/13 LLLT/13	LII = 10.8 ± 2.29 LII = 8.91 ± 1.57	109.23 ± 14.18 81.23 ± 15.29	0.014-inch NiTi/0.016 × 0.016-inch/0.017 × 0.025-inch NiTi/finally 0.019 × 0.025-inch stainless steel	Ga-Al-As	Continuous
Caccianiga et al., 2017	Control/18 LLLT/18	8.86 ± 1.51 9.08 ± 1.26	284.1 211.8	0.014-inch thermal NiTi/ 0.016 × 0.022 and 0.017 × 0.025 thermal NiTi	Diode laser	Continuous
El Shehawy et al., 2020	Control/15 LLLT/15	LII = 6.84 ± 1.83 LII = 6.95 ± 1.91	104 48	0.012/0.014 and 0.016-inch NiTi	Ga-Al-As	Continuous

[a] Ga-Al-As indicates gallium-aluminum-arsenate; LII, Little's irregularity index; LLLT, low-level laser therapy; n, number; NiTi, nickel-titanium; NS, nonsignificant; OLAT, orthodontic leveling and alignment time; S, significant; TLA, overall time for leveling and alignment.

differences in LII at the baseline, which ranged between 5.8 ± 1.6 mm[9] up to 10.8 ± 2.29 mm.[14]

Effectiveness of LLLT for acceleration of tooth movement and relieving associated pain has been widely investigated.[1,10,11,21–23] Nevertheless, results are still inconclusive and cannot be generalized due to the heterogeneity of laser parameters (wavelength, power output, energy density, duration time, and mode of application), as well as sample standardization and type of mechanics employed.

The calculated energy density in the present study was 25.7 J/cm^2 per application (12 J per tooth), which corresponded to those implemented by AlSayed Hasan et al.[14] and Caccianiga et al.[15] with reported significant effects of LLLT. Ge et al.[11] advocated lower energy densities of 2.5–8 J/cm^2 than higher ones (20 and 25 J/cm^2 or more) for acceleration of tooth movement. Yet, they emphasized the ambiguity of optimal dose. On the other hand, El Shehawy et al.[13] applied 2 J per tooth with a total energy of 12 J per session; though, a negligible effect of LLLT on alignment was reported. Unexpectedly, findings of the present study were not in agreement with the study of Limpanichkul et al.[24] that used the same energy density and concluded that 25 J/cm^2 energy density of LLLT was probably too low to express either stimulatory or inhibitory effects on the OTM rate.

The laser whitening tip used in this study was considered ideal for allowing greater area of exposure compared to the regular optical fiber tip reported in other studies targeting a single tooth rather than the whole anterior segment. Caccianiga et al.[15] reported mandibular arch segmentation into four segments that were consecutively irradiated from the labial side only. On the other hand, AlSayed Hasan et al.[14] used four application points for each tooth (two at buccal and two at palatal side at the center of the cervical and apical haves of the roots). Likewise, facial and lingual application at 10 points per tooth were reported by El Shehawy et al.[13]

The reported laser-assisted OLAT in previous studies ranged between 48 and 211.8 days.[13,15] Again, OLAT for the laser group in the current study was comparable to that reported by AlSayed Hasan et al.[14] with 26% time reduction in that study, compared to 40% in the current study. Inconsistency of the results among studies could again be related to differences in the implemented laser parameters and intervention schedule, together with variability in the employed archwire sequence (Table 7).

Comparison between alignment improvement percentage (LAIP) in the two study groups (Table 5) revealed a significant alignment improvement in the laser group starting from the second month. Those results were confirmed by the findings of Ge et al.,[11] who emphasized a cumulative effect of LLLT, particularly from the third month. They elaborated that a promotion in speed of orthodontic movement after the use of laser irradiation could be observed as being a result of increased osteoclast number and/or activity in the laser-treated area via stimulation of the RANK/ RANKL/ OPG system, essential for bone remodeling.

Several studies have reported use of LLLT to promote analgesia. Consistent with other studies,[25] both groups in the present study showed no statistically significant difference in pain scores taken at the first, second, third, and fourth days after initial archwire placement. However, at the fifth day, the laser group showed statistically significant lower mean pain scores than the control group. Matys et al.[26] evaluated pain levels at different assessment times and showed that the highest numeric rating score was 24 hours after orthodontic treatment initiation. Hence, they suggested that laser irradiation should be used mainly in the first 24-hours postorthodontic appliance installation. The significant difference in pain scores at the fifth day in the present study could have been related to the cumulative effect of LLLT described by Ge et al.[11]

Despite reported potential of LLLT in reducing OLAT and its associated pain, any advantages of the

Table 7. Extended

Wavelength, nm	Dose of Irradiation	Exposure Time/Point, s	Output	Laser Sessions	% of Time Reduction	Alignment Rate (mm/mo)	Effects of LLLT
830	2.25 J/cm²	15	150 mW (d 0, 3, 7, 14); then every 15 d	Optical fiber tip	26	*Not specified*	S
980	1 J/cm²/s	32	1W every 4 wk	Optical fiber tip	25	*Not specified*	S
635	6.5 J/ cm²	10	20 mW (d 0, 3, 7, 14); then repeated for additional 2 ms	Optical fiber tip	54	1.96 ± 0.47 0.64 2.04 ± 0.65	NS

decreased treatment interval may be diminished by the number of recall visits needed for laser application. Hence, further studies are encouraged to refine laser application protocols.

Limitations and Generalizability

Despite helping validate the comparison, restriction of gender to females and focusing on one jaw (ie, mandible) have limited generalizability of the results. Additionally, the operator and patients could not be blinded; however, data concealment and blinding of the outcome assessor and the statistician were established to minimize possible risk of bias. Furthermore, diversity in the reported laser parameters for acceleration of tooth movement has limited application of the current results to the laser protocol that has been implemented. Hence, more studies on different populations, malocclusions, and laser protocols should be carried out to aid evidence-based decision-making regarding effectiveness of LLLT in acceleration of tooth movement.

CONCLUSIONS

- Within the limits of the current study, administration of LLLT can efficiently reduce the OLAT as well as the pain perception associated with initial arch wire placement.

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