Effects of low-level laser therapy and mechanical vibration on orthodontic pain caused by initial archwire

Fatih Celebi,[a] Tamer Turk,[b] and Ali Altug Bicakci[a]
Tokat and Samsun, Turkey

Introduction: The aim of this study was to evaluate the effects of mechanical vibration and low-level laser therapy on orthodontic pain after placement of the initial archwire. **Methods:** Sixty subjects with 3-6 mm maxillary dental crowding, a nonextraction fixed treatment plan, and no medical history were included in this study. The subjects were randomly divided into 3 groups, equally distributed by sex. In each subject, preadjusted edgewise appliances were placed in the maxillary arch from the left first molar to the right first molar, and a 0.014-inch round nickel-titanium archwire was fully engaged with elastomeric ties and cut at the end of first molar bondable tube. In group 1 (mean age 13.98 ± 2.68 y), mechanical vibration was performed 3 times: immediately, 24 hours, and 48 hours after engagement of the initial archwire. In group 2 (mean age 14.86 ± 2.06 y), low-level laser therapy was applied once: immediately after the insertion of the initial archwire. Group 3 (mean age 14.41 ± 1.78 y) served as the control group. Pain scores were determined with the use of a visual analog scale (VAS). **Results:** Although no statistically significant differences were found among the groups ($P > 0.05$), the mean VAS scores for the mechanical vibration group were consistently lower than those of the control and low-level laser therapy groups at all measured time points. **Conclusions:** The mechanical vibration group had lower, though nonsignificant, VAS scores for all measured time points. Additional clinical trials are recommended for more definitive conclusions. (Am J Orthod Dentofacial Orthop 2019;156:87-93)

Pain is among the frequently encountered adverse effects of orthodontic treatment. Orthodontic applications such as separator placement, fixed orthodontic appliances, and the debonding procedure can cause discomfort and pain.[1-3] Studies investigating the nature of orthodontic pain have shown that 80%-95% of patients experience pain during the treatment process.[1,4,5] Pain that appears within 2 hours after the application of initial archwire gradually increases over the next 24-36 hours, starts to decrease on the third day and disappears within 6-7 days in the fixed orthodontic treatment.[1] There are various opinions about the existence mechanism of pain. It can be summarized briefly as follows: Orthodontic tooth movement causes hyperalgesic response and releases algogens, such as substance P, histamine, enkephalin, dopamine, serotonin, glycine, glutamate gamma-amino butyric acid, prostaglandin Es, leukotrienes, and cytokines, at the site of periodontal ligament.[3] This triggers a pain response when orthodontic force is applied. It was stated that individual variability such as age, sex, pain threshold, magnitude of the applied force, emotional status, cultural differences, and previous pain experiences can be determinant factors on pain perception.[2,6-9]

Orthodontic pain can be detrimental for the daily life quality of the patient as well as the future of treatment. It has been reported that pain is the most disliked aspect of orthodontic treatment and ranked fourth among the major fears and apprehensions before treatment.[10] Patients who suffer from pain can restrain masticatory function. It has been demonstrated in a study examining the influence of fixed orthodontic treatment on dietary intake and behavior in adolescent patients that a majority of patients prefer a soft diet because of the pain.[11] Furthermore, this situation can be so disturbing that patients have to take medication. A survey indicated that the rate of taking medications increased from

[a]Department of Orthodontics, Faculty of Dentistry, Gaziosmanpasa University, Tokat, Turkey.
[b]Department of Orthodontics, Faculty of Dentistry, Ondokuz Mayıs University, Samsun, Turkey.
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Address correspondence to: Fatih Celebi, Department of Orthodontics, Faculty of Dentistry, Gaziosmanpasa University, 60100 Tokat, Turkey; e-mail, fatihcelebi5860@gmail.com.
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7.1% at the fourth hour to 16.2% at the 24th hour and decreased down to 13% at the 48th hour and 4.2% or less on the third day, and no patients reported taking any medication on the seventh day.[8] In addition, there are publications indicating that pain is a major reason for discontinuing treatment.[7,12] A total of 8% of patients chose to discontinue the treatment due to pain.[13]

The method that is most frequently used to alleviate orthodontic pain is nonsteroidal antiinflammatory drugs (NSAIDs). The functions of these drugs, such as aspirin, ibuprofen, flurbiprofen, and naproxen sodium, can be indicated as inhibition of prostaglandin synthesis in the process of inflammation.[14,15] Although NSAID consumption is the most commonly used method, it has some undesirable side-effects. It has been reported that inhibition of prostaglandin synthesis to alleviate pain can cause detrimental effects on the whole body, such as allergy, bleeding disorders, gastric or duodenal ulceration, renal insufficiency, asthma, congestive heart problems, hypertension, and atherosclerosis.[16] Furthermore, tooth movement can be interrupted, because it requires the inflammation process, including prostaglandin synthesis.[17-19] Therefore, it is required to focus on new methods for managing the orthodontic pain.

Low-level laser therapy (LLLT) is described as a laser treatment that will not cause the body temperature to rise above 36.5°C.[20] When the energy output is low enough to maintain the normal body temperature (36.5°C), the potency of laser are arisen as biostimulation effects including reducing pain,[21] accelerating tooth movement,[22] stimulating bone regeneration in the midpalatal suture area after rapid maxillary expansion,[23] and enhancing the stability of orthodontic miniscrews.[24] The analgesic efficacy of LLLT has been investigated and some opinions have been suggested, including increased local circulation,[25] impeded production of inflammatory factors, stimulated lymphocytes, nerve cell respiration, and the release of neurotransmitters in the inflammatory tissue.[26-28] However, there is no consensus in the literature about the pain alleviation mechanism of LLLT.

Mechanical vibration was introduced as an alternate method to manage orthodontic pain.[29] It was thought that temporary displacement of teeth could loosen the compressed periodontal area including nerve fibers and occluded blood vessels, thus enabling the blood to flow more easily. In this way, biochemical agents that could lead to the pain process could be prevented from acting at the site.[30,31] Various methods based on this perspective have been suggested for relieving orthodontic pain, such as using a viscoelastic bite wafer, chewing gum,[32,33] and mechanical vibration of the teeth.[29] It was claimed that chewing gum or plastic wafers could reduce orthodontic discomfort and pain during the first 8 hours after appliance activation.[34] In fact, mechanical vibration is not a new method for relieving pain that is arises from the dental and musculoskeletal system.[35,36] However, there is a scarcity of publications on the effectiveness of this method for relieving orthodontic pain in literature.[29,37]

Table I. Inclusion and exclusion criteria

Inclusion criteria
Nonextraction fixed treatment modality
3-6 mm maxillary dental crowding
Permanent dentition
Healthy teeth and gum
Exclusion criteria
Chronic usage of analgesic drugs
Unerupted tooth
Medical history
Using transpalatal arch, miniscrew, or headgear as a component of treatment

The objective of the present study was to investigate the effects of LLLT and mechanical vibration on orthodontic pain caused by initial archwire during the first week and to compare the results with those of a control group.

MATERIAL AND METHODS

This study was approved by the Clinical Research Ethics Committee of Gaziosmanpasa University, Tokat, Turkey. Patients who applied for orthodontic treatment to the Department of Orthodontics Gaziosmanpasa University were selected according to the inclusion and exclusion criteria (Table I). Informed consent forms were given to both patients and their parents. Patients and their parents who agreed to take part in the study signed the forms.

A total of 60 patients (30 male, 30 female) aged 11-23 years took part in this study. Subjects were classified randomly as laser (10 male and 10 female), mechanical vibration (10 male and 10 female), and control (10 male and 10 female) groups. Randomization was performed with the help of 2 different colored raffle boxes. Male subjects used a blue raffle box and female subjects used a red raffle box, so the groups were equal in terms of sex. In addition, the pressure pain thresholds were measured with the use of a pressure algometer device (JTECH Medical). This device documents pain threshold by quantifying the levels of tenderness of muscle, joints, tendons, and ligaments. The measurement is performed by applying continuous pressure at a constant rate on the patient's skin.

A preadjusted edgewise appliance with slot dimensions of 0.018 × 0.025 inch with Roth prescription (Mini Master, American Orthodontics, Sheboygan, Wis) was placed only on the maxillary arch from the left first molar to the right first molar. A 0.014-inch round nickel-titanium archwire (TP Orthodontics, La Porte, Ind) as initial archwire was fully engaged with elastomeric ties and cut at the end of first molar bondable tube. Additional appliances that could be unpredictable pain sources, such as molar band, transpalatal arch, headgear, and miniscrew, were not used. Instructions on oral hygiene were provided and the patients were recommended to refrain from taking analgesic drugs during the study.

Mechanical vibration was applied 3 times in the vibration group: immediately, 24 hours, and 48 hours after placement of the initial archwire. The duration for each application was 20 minutes for a total duration per patient of 60 minutes. The vibration device, operated with a battery-powered motor, was applied with parameters of 111 Hz and 0.06 N.

LLLT application was carried out immediately after placement of the fixed orthodontic appliances in the laser group. A GaAlAs diode laser with a wavelength of 820 nm (CTL-1106MX; Doris, Warsaw, Poland) was used. Applications were performed on both buccal and palatal mucosa covering the root from the upper left first molar to the right first molar, including a total of 12 teeth. Three different areas were irradiated on both sides: distal aspect of the cervical third, midsection of the middle third, and mesial aspect of the apical third. Six different areas per tooth were thus irradiated. For each application, the mucosa was irradiated with a power output of 50 mW, energy dose 0.8 J, exposure duration 16 seconds, focal spot area 0.453 cm^2, power density 110.3 mW/cm^2, and energy density 1.76 J/cm^2. Average duration to complete the LLLT application per patient was ~25 minutes.

There was no additional implementation in the control group aside from the routine orthodontic procedure.

Pain perception was measured with the use of a 10-cm visual analog scale (VAS). Participants were instructed to complete a VAS diary containing 6 forms for 6 different times: second hour, sixth hour, 24th hour, second day, third day, and seventh day after start of the fixed orthodontic treatment. Subjects were instructed to tap their teeth 10 times and apply pressure by thumb, then indicate the pain level on the 10-cm VAS forms, with 0 indicating no pain and 10 indicating intolerable pain.

Statistical analysis was performed with the use of the Statistical Package for the Social Science (SPSS for Windows, version 16.0; SPSS, Chicago, Ill). Kruskal-Wallis test was carried out for intergroup comparisons of ages and pressure pain threshold measurements. Kruskal-Wallis and Mann-Whitney *U* with Bonferroni correction tests were applied where appropriate for comparing the VAS scores. Friedman and Wilcoxon signed rank with Bonferroni correction tests were used for intragroup comparisons to evaluate the VAS scores.

Table II. Comparison of pain threshold and age among the control, mechanical vibration, and LLLT groups

Variable	χ^2	P
Pain threshold	1.186	0.553
Age	3.053	0.217

Table III. Evaluation of the pain scores among the control, mechanical vibration, and LLLT groups

Time	χ^2	P
2nd h	0.417	0.812
6th h	6.680	0.035*
1st d	3.066	0.216
2nd d	2.949	0.229
3rd d	1.071	0.585
7th d	1.717	0.424

*Significant at $P < 0.05$ (Kruskal-Wallis test).

RESULTS

There were no statistically significant differences in ages and pressure pain threshold measurements between the groups (Table II). The mean ages for the participants were 14.41 ± 1.78 years (control group), 13.98 ± 2.68 years (mechanical vibration group), and 14.86 ± 2.06 years (LLLT group). The mean pressure pain threshold measurements for the patients were 15.64 ± 5.60 kg/cm^2 (control group), 14.09 ± 4.61 kg/cm^2 (mechanical vibration group) and 13.84 ± 4.64 kg/cm^2 (LLLT group).

Among the groups, there were no statistically significant differences at the second hour ($P = 0.812$), first day ($P = 0.216$), second day ($P = 0.229$), third day ($P = 0.585$), or seventh day ($P = 0.424$) (Table III). A statistically significant difference was detected at the sixth hour among the groups (Kruskal-Wallis; $P = 0.035$). When statistical analysis was performed to find out which groups are different, it was revealed that there was no statistically significant difference among the groups (Mann-Whitney *U* with Bonferroni correction; control–mechanical vibration: $P = 0.033$; control–LLLT: $P = 0.935$; mechanical vibration–LLLT: $P = 0.020$; Table IV).

Statistically significant differences were observed for the intragroup comparisons for VAS scores at different

Table IV. Evaluation of the pain scores between groups at the 6th hour

Groups	*U*	P
Control–mechanical vibration	121.0	0.033
Control–LLLT	197.0	0.935
Mechanical vibration–LLLT	114.5	0.020

times for all 3 groups. According to the tests' results, pain that appeared at 2 hours rose gradually until the first day, then mean VAS scores decreased gradually toward the seventh day. The highest mean pain intensity for all 3 groups was observed on the first day, with the control group recording 5.18 cm, the mechanical vibration group recording 3.91 cm, and the LLLT group recording 4.96 cm. Mean VAS scores of the mechanical vibration group were lower than those of the other groups at all times, albeit with statistically insignificant results (Fig).

DISCUSSION

Pain due to orthodontic treatment has adverse impacts on the daily life of the patients, and it can be seen as a major cause of treatment discontinuation.[7] Even though the percentage of patients who suffer from pain varies, it has been indicated that from 80%-95% of patients suffer from pain.[1,4,5] One survey that rated the fears and apprehensions before orthodontic treatment showed that pain was the most disliked situation during treatment.[10]

Surprisingly, despite the fact that orthodontic pain is one of the major concerns about treatment, this issue has hitherto been neglected in terms of clinical applications. Clinicians usually assume that pain is a natural outcome of the orthodontic treatment process and that it is negligible compared with other significant orthodontic problems, such as root resorption, prolonged treatment time, and periodontal problems. Clinicians must be aware that pain is not an unavoidable outcome of the orthodontic treatment and that precautions should be taken for providing a more comfortable treatment process. Researchers must help clinicians in offering effective and safe pain relief methods. The present study was designed to investigate the efficiency of 2 different pain relief methods.

Pain is a subjective phenomenon and therefore extremely difficult to measure objectively. Subjective measurement methods were used in previous studies investigating the nature of the pain.[1,4,6,8] VAS is a widely accepted method for measuring the degree of pain, and it has been defined as a sensitive and reliable method compared with others. In addition, VAS is suitable for children.[38,39] Therefore, VAS was preferred for measuring the degree of pain.

Biochemical substances in gingival crevicular fluid could have been analyzed at different times in the present study. However, there is no consensus on the relationship between pain and biochemical substances in gingival crevicular fluid. There are conflicting results in the literature, with studies stating both correlation and noncorrelation between pain and substances.[21,40,41] Therefore, biochemical measurement methods for gingival crevicular fluid were not preferred.

In the literature, there is no clear consensus about how mechanical vibration must be applied. Marie et al instructed their patients to use the vibratory device just 1 time, for 15 minutes, immediately after archwire placement.[29] Miles et al used the vibration device for 20 minutes per day during the 10-week study period.[37] We supposed that multiple applications could be more effective in pain management compared with a single application because it does not seem likely that a single application immediately after archwire placement, before algogens are released, can alleviate the orthodontic pain. We also thought that it would be unnecessary to intervene for alleviating pain after the third day because orthodontic pain after the second day has a notable decreasing trend even if not intervened for.[6,8] Consequently, we preferred 3 times for application: immediately, 24 hours, and 48 hours after placement of the initial archwire. Miles et al investigated the effects of vibration on not only patient discomfort but also tooth movement, which was probably the main reason for their longer application period. Both previous studies used the same device, with the same parameters of 111 Hz and 0.06 N, used in the present study.

Patients were instructed to perform the measurements after tapping the teeth 10 times and applying pressure by thumb. We have clinically observed that patients suffer from orthodontic pain especially during chewing rather than spontaneously. Through these exercises before the measurements, we aimed to provoke and stimulate the orthodontic pain.

Previous studies stated that pain began quickly with starting orthodontic treatment, and after the peak at the 24th hour, pain intensity decreased steadily toward the seventh day.[6,8] The data acquired in this study confirmed these findings: Pain was detected at the second hour, it reached the highest point at the 24th hour, and pain intensity decreased gradually toward the seventh day (Fig).

The results of this study indicate that the use of LLLT with the parameters used in this study was not effective for relieving orthodontic pain, because there were no

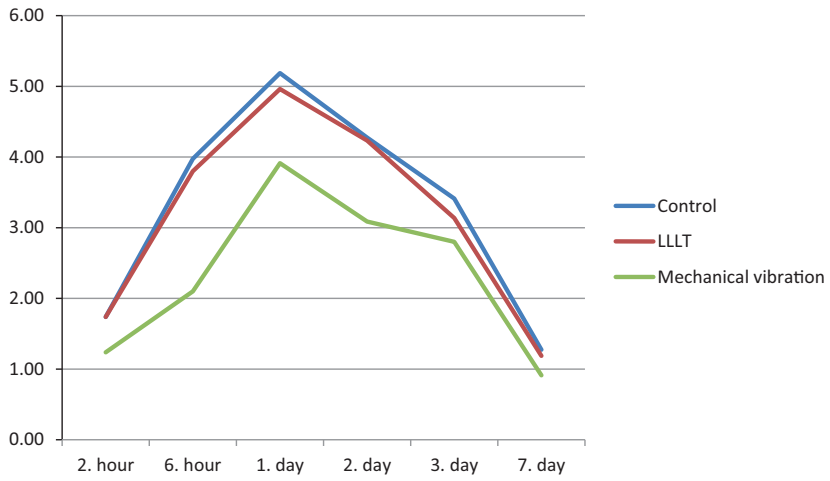

Fig. Pain courses of the groups.

Table V. Comparison of the LLLT technical specifications between the present and previous studies

Study	*Wavelength*	*Power output*	*Power density*	*Energy dose*	*Energy density*	*Focal spot area*
Artés-Ribas[43]	830 nm	100 mW	250 mW/cm^2	2 J	5 J/cm^2	0.4 cm^2
Bicakci[21]	820 nm	50 mW	1592 mW/cm^2	0.25 J	7.96 J/cm^2	0.0314 cm^2
Doshi-Mehta[22]	800 nm	0.7 mW	0.175 mW/mm^2	–	–	0.04 cm^2
Lim[20]	830 nm	30 mW	59.7 mW/cm^2	–	–	0.50 cm^2
Present study	820 nm	50 mW	110.3 mW/cm^2	0.8 J	1.76 J/cm^2	0.453 cm^2

statistically significant differences between the VAS scores of the LLLT and control groups at any time. There are conflicting results in the literature regarding the efficacy of LLLT for orthodontic pain.[20-22] There may be some reasons causing these conflicting results. First, studies that evaluated the effectiveness of LLLT for orthodontic pain used different parameters, including technical specifications and application modes. It has been stated that not just a few parameters, but a number of parameters, such as wavelength, power output, energy dose, exposure duration, focal spot area, power density, energy density, and frequency of treatment, are responsible for optimal LLLT effectiveness.[42] In this regard, even just 1 parameter may have influenced the efficacy of LLLT on orthodontic pain. When considering the parameters used in previous studies, it can be seen that the parameters used in the present study were reasonable (Table V). Further studies that define the optimal laser parameters are needed for using from LLLT in clinical usage.

Second, results of the studies depend strictly on the participants' individual variability such as age, sex, pain threshold, magnitude of the applied force, emotional status, cultural differences, and previous pain experiences.[2,6-9] Therefore, differences between the groups in terms of individual variability could lead to false conclusions. A limitation of past studies in the orthodontic literature is that individual variability was neglected when forming the groups. Therefore, in this study we tried to form equal groups in terms of individual variability. Groups consisted of equal numbers of male and female subjects. Furthermore, we evaluated the participants' pressure pain threshold, and statistical analysis showed that there were no statistical differences between the groups in pressure pain threshold and age. It was stated that pressure pain threshold, which is measured with the use of an algometer, is a reliable indicator for skin and other soft tissue tenderness.[43] This quantification concept was put out in 1930s, and it has been widely used in clinical practice since the 1980s.[44] Studies have reported lower pain thresholds in female than in male subjects.[45] However, we had already designed our study so that the groups had equal sex distribution. It has also been stated that measurements taken by a single examiner, as we did, increases the reliability of the method.[43]

There was no study in the literature that took into account the fact that the pain thresholds of the participants may affect the results. In addition, patients with a 3-6 mm maxillary dental crowding and nonextraction treatment modality were chosen. Furthermore, the same sizes of brackets and wires were used because it

has been indicated that there is a relationship between the amount of force and the amount of associated pain.[34]

Third, the majority of previous studies in this field used elastomeric separators as a source of force.[20,21,46] We think that studies using elastomeric separators as a source of force may lead to false conclusions because the nature of pain caused by the separator may have different characteristic compared with pain caused by fixed orthodontic treatment. Therefore, the present study was carried out on patients who were treated with the use of fixed orthodontic mechanics.

The results indicated that there were no statistically significant differences between the mechanical vibration and control groups in VAS scores at any time according to the Mann-Whitney *U* test with Bonferroni correction. There is a scarcity of studies about mechanical vibration in the literature. Marie et al claimed that mechanical vibration might be a useful method in relieving pain.[29] On the other hand, Miles et al stated that using this method for alleviation of pain has no advantage.[37] Publications about viscoelastic bite wafer and chewing gum in the literature demonstrated that temporary displacement of teeth could help to relieve orthodontic pain.[32-34]

It was interesting to notice in the present study that the mean VAS scores of the mechanical vibration group were lower than the mean VAS scores of the other groups despite the fact that no statistically significant difference was detected. We think that we could have detected statistically significant differences between the mechanical vibration and control groups if the groups comprised a greater number of subjects.

It may be concluded when considering lower VAS scores in mechanical vibration, albeit statistically insignificant results, that mechanical vibration can be a useful method for alleviating pain.

In recent years, there has been an increasing demand for orthodontic treatment among adults.[47] Along with this increasing demand, it is clear that the issue of outcomes of orthodontic treatments, including pain, on adults should be clarified. In the literature, the general opinion is that adults perceive pain more than young patients.[3] However, this opinion can be misleading. It should be remembered that different orthodontic appliances are used in different age groups and their potentials for pain generation may be different. Therefore, well structured studies are needed to compare age groups.

CONCLUSIONS

It was demonstrated as a result of the present study that pain perception detected at the second hour reached the highest intensity at the 24th hour. LLLT did not affect the intensity and course of pain perception compared with the control group. However, VAS scores of the mechanical vibration group were lower in comparison with those of other groups, albeit with statistically insignificant results. These results encourage us about clinical utilization of mechanical vibration. Nevertheless, further studies should be carried out to investigate the effectiveness of mechanical vibration and reach more definitive conclusions.

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