



# Clinical outcomes of diode laser as an adjunct to nonsurgical periodontal therapy for residual periodontal pockets in mandibular second molars—a randomized controlled clinical trial

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## Abstract

**Objectives** The aim of this study was to evaluate the clinical outcomes of diode laser as an adjunct to nonsurgical periodontal therapy (NSPT) for residual periodontal pockets in mandibular second molars.

**Materials and methods** Sixty-seven mandibular second molars (154 residual periodontal pockets) were recruited into the study and randomly assigned to the Laser + NSPT group and the NSPT group. The Laser + NSPT group underwent NSPT adjunct with diode laser radiation (wavelength: 810 nm, power: 1.5 W, 40 s maximum), while the NSPT group underwent nonsurgical periodontal therapy alone. Clinical parameters were measured at baseline (T0) and 4(T1), 12(T2), and 24(T3), weeks after treatment.

**Results** Periodontal pocket depth (PPD), clinical attachment loss (CAL), and bleeding on probing (BOP) in both groups showed significant improvements at the end of study compared to baseline. The reductions of PPD, CAL, and BOP in the Laser + NSPT group were significantly greater than NSPT group. At T3, the Laser + NSPT group had a mean PPD of  $3.06 \pm 0.86$  mm, CAL of  $2.58 \pm 0.94$  mm and BOP of 15.49%, while the NSPT group had a mean PPD of  $4.46 \pm 1.57$  mm, CAL of  $3.03 \pm 1.25$  mm and BOP of 64.29%.

**Conclusions** The diode laser as an adjunct to nonsurgical periodontal therapy may contribute to clinical outcomes for residual periodontal pockets. However, the approach may cause reduction of keratinized tissue width.

**Trial registration number** This study was registered in the Chinese Clinical Trial Registry ChiCTR2200061194.

**Clinical relevance** Diode laser as an adjunct to nonsurgical periodontal therapy may contribute to the clinical outcomes for residual periodontal pockets in mandibular second molars.

**Keywords** Laser therapy · Diode laser · Periodontitis · Nonsurgical periodontal therapy

## Introduction

The success of periodontal treatment depends primarily on the effective removal of the pathogenic substances, such as supra- and subgingival pathogens and their endotoxins [1].

Removal of these pathogenic substances ensures biocompatibility between the root surface and the connective tissue attachment after treatment [2]. Nonsurgical periodontal therapy (NSPT) is mostly accomplished by manual instruments and ultrasonic scalers. Nevertheless, it is difficult to thoroughly disinfect deep periodontal pockets and sites that are hard to access with these instruments [3]. These sites often include periodontal pockets with periodontal probing depth (PPD)  $\geq 5$  mm, root furcation, and root concavities [4]. The second mandibular molars are one of these challenging NSPT sites. Also, due to the potential existence of impacted mandibular third molars, mandibular second molars are prone to the recurrence of deep periodontal pockets [5]. Although there are several periodontal surgical approaches for this issue, these procedures have the same challenges as nonsurgical therapy.

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Deep residual periodontal pockets may provide an environment for periodontal pathogens to colonize [6], leading to persistent or recurrent infections [7]. Ultimately, patients may have to undergo repeated mechanical treatment. However, such a protocol could not be ideal because it may lead to excessive removal of the dentin and cementum tissue. Similarly, frequent topical or systemic antibiotic use is not a viable choice since antibiotic usage can lead to complications such as bacterial resistance [8]. As a result of these limitations, a therapy that is both effective for the residual pockets and safe for the underlying tissue is required.

Diode laser is promising for applications in periodontal pocket disinfection due to its suitable wavelength for soft tissues, less thermal damage, and ease of use [9]. However, several past studies have reported contradictory results for the clinical outcomes of diode laser. Randomized controlled trials have found that diode laser as an adjunct for NSPT may have no or only minimal beneficial effects on periodontal healing [10, 11]. Conclusive recommendations from meta-analyses are also absent due to the heterogeneity of the studies or the limited sample size and disease severity descriptions [12, 13]. Nevertheless, a few recent studies have demonstrated that diode laser with NSPT produces promising results in patients who do not respond well to NSPT alone, such as those with deep periodontal pockets (PPD  $\geq 6$  mm), periodontitis patients with type 2 diabetes mellitus [14, 15], and aggressive periodontitis [16, 17]. There are also studies showing that diode laser with NSPT significantly improved the clinical outcomes of residual periodontal pockets in the maintenance phase [18]. Nd:YAG laser (wavelength: 1064 nm), which has a similar wavelength as the diode laser, has shown a beneficial PPD reducing effect [19]. Based on the above studies, the clinical outcomes of the diode laser as an adjunct to NSPT on residual periodontal pockets need to be evaluated further. The purpose of this study is to assess the clinical outcomes of using a diode laser as an adjunct to NSPT to treat residual periodontal pockets in mandibular second molars.

## Materials and methods

### Subject selection and study design

This study was a single-blind, randomized, controlled clinical trial. Subjects were patients who visited the Department of Periodontics, Stomatological Hospital of Tongji University, from August 2021 to August 2022. The study was conducted in accordance with the Declaration of Helsinki, which was enacted in 1975 and revised in 2000. The study protocol was approved by the Ethics Committee of the Affiliated Stomatology Hospital of Tongji University, Shanghai, China ([2022]-SR-069) and was registered in the Chinese

Clinical Trial Registry (ChiCTR2200061194). All enrolled patients were thoroughly informed of the nature, potential risks, and benefits of their participation in the study and signed an informed consent form before participation.

The sample size was estimated using software PASS version11 (NCSS, LLC, UT, USA). The primary outcome “change of PPD after 6 months” was used to determine the sample size. A statistical power of 80% was used to detect a significant difference of 1.0 mm for PPD ( $\alpha$  of 0.05, standard deviation [SD] of 1.5 mm) [18]. Based on this information, 24 patients were required in each group to have a power of 80%. To account for possible dropouts, at least 30 subjects should be recruited for each group.

Randomization was performed using a computer-generated random number table method (Microsoft Office Excel, Microsoft Corp., WA, USA). The randomization process was performed by an independent operator who was not subsequently involved in this study. The allocation sequence was concealed in opaque sealed envelopes, and the details of the series were unknown to the patients and the clinical parameters examiner. The NSPT and laser treatment were performed by an experienced periodontist. Patients were provided with opaque glasses during treatment, regardless of their allocation, to guarantee that they were unaware of their group. The examination and recording of clinical parameters were performed by another calibrated periodontist who was unaware of the treatment procedure and patient allocation at the first visit and the later follow-up visits.

The inclusion criteria were as follows: (1) residual periodontal pockets with probing depths  $\geq 5$  mm in the mandibular second molars after four weeks of NSPT; (2) mandibular third molars extracted for more than six months or congenitally absent; (3) less than 3 degrees of tooth movement; (4) no periodontal surgical treatment, antibacterial medication, or anti-inflammatory medication was administered in the past 6 months; and (5) no systemic disease related to the treatment. Exclusion criteria were (1) presence of caries, pulpal disease, and restorations in the mandibular second molar; (2) mandibular second molar inclination  $> 30^\circ$  or severe malocclusion; (4) pregnant or lactating women; (5) ongoing orthodontic treatment or recent need for orthodontic treatment; and (6) smoking  $> 5$  cigarettes/day.

### Treatment protocols

At the first visit, the patients were given careful oral hygiene instructions (OHIs), which were repeated at every subsequent visit. Panoramic radiographs were taken to confirm that the mandibular second and third molars met the criteria. At the first three visits, supra- and subgingival scaling was accomplished using an ultrasonic device and manual instruments. All patients were re-evaluated four weeks after the completion of the initial therapy, and those who met the

inclusion criteria were recruited for the study. As a baseline (T0), clinical parameters of the recruited residual pockets were recorded. After randomization, patients were assigned to the Laser + NSPT group or the NSPT group.

For the Laser + NSPT group, residual periodontal pockets were treated with laser as an adjunct to NSPT at T0. Laser therapy was performed by a diode laser device (Pioneer Pro Diode Laser, CAO Group, Inc., UT, USA). The laser parameters were set as follows: wavelength was 810 nm, power was 1.5 W, and radiation mode was continuous mode. During irradiation, the laser fiber was positioned parallel to the root surface and inserted into the periodontal pocket in contact with the soft tissue wall. The fiber was moved gently in a sweeping manner. The total irradiation time for each tooth did not exceed 40 s. Carbonized granulation tissue entangled around the fiber was promptly cleaned off using wet gauze containing 0.9% saline, and periodontal pockets were continuously rinsed with saline. The NSPT group underwent saline irrigation of the periodontal pockets. No sham laser irradiation was performed on the NSPT group to avoid unnecessary invasion of periodontal tissue, which might interrupt the healing of periodontal pocket.

### Clinical measurements and outcomes

Clinical parameters were measured and recorded at baseline (T0) and at 4, 12, and 24 weeks after treatment (T1, T2, T3). A UNC-15 periodontal probe (Hu-Friedy, IL, USA) was used to record including PPD, clinical attachment loss (CAL), bleeding on probing (BOP), plaque index (PLI). These parameters were collected at six sites of the mandibular second molar: mesiobuccal, mesiolingual, buccal, lingual, distobuccal, and distolingual. Keratinized tissue width (KTW), tooth movement (TM) and furcation involvement of the buccal sites (BFI) and lingual sites (LFI) were also examined. The mucogingival junction was localized by direct visual inspection of the color and movability of the soft tissues, Keratinized tissue width was measured from the mucogingival junction to the gingival margin with a UNC-15 periodontal probe, at the mesiobuccal, buccal and distobuccal sites, and the mean values were used to evaluate the KTW of the teeth. Furcation involvement was defined and graded by Hamp's index [20].

The primary outcome of this study was changes in PPD. The secondary outcomes were changes in CAL, KTW, TM, BFI, LFI, and percentage of sites with BOP and PLI.

### Examiner calibration

A calibrated examiner who was uninformed of the patient's grouping performed all measurements. Five patients were recruited for examiner calibration. At two separate sessions 48 h apart, duplicate measurements of PPD, KTW and CAL

were obtained at the same tooth. Calibration was accepted if the percentage agreement between measurements was more than 90%. The procedure was repeated every month throughout the period of the study.

### Statistical analysis

The statistical analysis of this study was performed using SPSS version 27.0, (IBM, IL, USA). The significance level  $\alpha$  was set at 0.05. Normality of the data was tested using the Shapiro–Wilk test. Clinical parameters were analyzed using the generalized estimating equations method (GEE), and post hoc comparisons were made using least significant differences (LSD). Continuous variables are expressed as the mean  $\pm$  SD, while categorical variables are expressed as percentages.

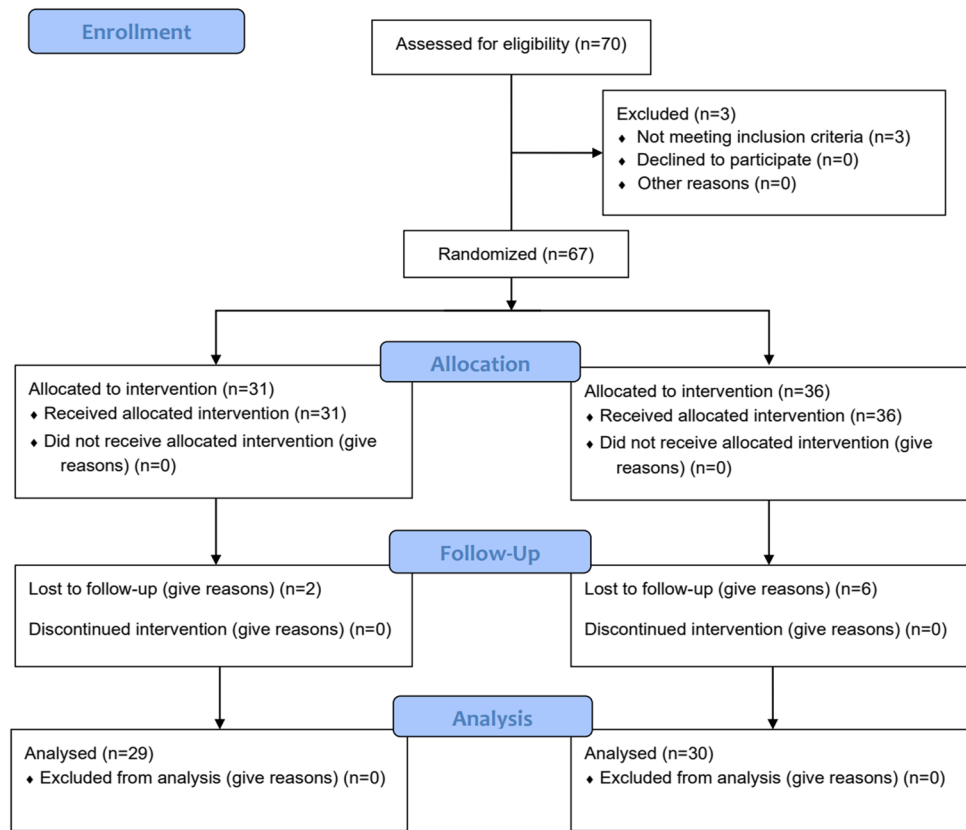
## Results

### General information

A total of 70 mandibular second molars were examined and received initial therapy during the first three visits. 3 teeth were excluded for not meeting inclusion criteria. Sixty-seven teeth were randomized and allocated to Laser + NSPT group or NSPT group. Four teeth at T1 (6 sites) and 4 teeth at T2 (7 sites) were lost to follow-up due to personal or schedule issues. A total of 59 teeth (141 sites) eventually completed the study, including 29 teeth (71 sites) in the Laser + NSPT group and 30 teeth (70 sites) in the NSPT group (Fig. 1). There was no significant difference in age, gender, number of smokers, or sites distribution between the two groups. PPD and BOP showed no significant differences between two groups at baseline, while CAL and KTW were significant greater in the Laser + NSPT group than in the NSPT group.

### Clinical outcomes

The PD, CAL, BOP, PLI, and KTW for the Laser + NSPT group and the NSPT group are shown in Table 1. In the intragroup comparison, all sites, regardless of grouping, showed significant improvements in PPD, CAL, and BOP at T1, T2, and T3 compared with T0. The primary outcome PPD in the Laser + NSPT group was  $3.06 \pm 0.86$  mm at T3, which was significantly better than the previous follow-up (T1 or T2). PPD in the NSPT group was  $4.46 \pm 1.76$  mm at T3, which was not significantly different with T1 or T2. Both the Laser + NSPT and NSPT groups showed a significant reduction in CAL at T3 compared to T1 and T2. The BOP was 15.49% in the Laser + NSPT group and 64.29% in the NSPT group. When compared to T0, the BOP of the

**Fig. 1** Flowchart of the randomized controlled trial design**Table 1** Patient characteristics at baseline (T0)

Patient characteristics		Laser+NSPT (n=29)	NSPT (n=30)	P-value
Age(years)	Mean	38	38	
	Range	24–47	26–52	0.920
Gender (n)	Male	14	11	
	Female	15	19	0.627
Smoking(n)	Smokers	2	2	
	Nonsmokers	27	28	0.980
Teeth(n)	Total	29	30	
	Left mandibular second molars	15	17	
	Right mandibular second molars	14	13	
Sites(n)	Total	71	70	
	MB	4	4	
	B	9	6	
	DB	23	22	
	ML	11	6	
	L	6	6	
PPD(mm)	Baseline	5.77 ± 1.04	5.67 ± 1.09	1.000
	Baseline	4.46 ± 1.32	3.91 ± 1.29	0.012*
BOP(%)	Baseline	88.73%	80.00%	0.151
KTW(mm)	Baseline	5.07 ± 0.91	4.17 ± 1.14	0.001*

NSPT, nonsurgical periodontal therapy; PPD, periodontal pocket depth; CAL, clinical attachment loss; BOP, bleeding on probing; KTW, keratinized tissue width; MB, mesiobuccal; B, buccal; DB, distobuccal; ML, mesiolingual; L, lingual; DL, distolingual; \*, significant difference between groups ( $P < 0.05$ )

laser + NSPT group significantly improved at T1, and it further significantly decreased at T3. The BOP of NSPT group also significantly improved at T1 compared to T0, but there was no subsequent improvement. The KTW of laser + NSPT group significantly reduced at T3 compared to T0, while the NSPT group showed no significant change in KTW over the trial. Statistical analysis did not reveal significant differences in PLI, TM, BFI and LFI between follow-ups.

In the intergroup comparison, the Laser + NSPT groups showed significantly better clinical outcomes at T1, T2, and T3 for PPD, CAL, and BOP than the NSPT group. KTW at T0 was significantly wider in the Laser + NSPT group ( $5.07 \pm 0.91$  mm) than in the NSPT group ( $4.17 \pm 1.14$  mm). At T3, the Laser + NSPT group was  $4.32 \pm 1.06$  mm, whereas the NSPT group measured  $3.99 \pm 0.99$  mm, with no significant difference between the two groups. At all follow-ups, PLI, TM, BFI and LFI were not significantly different between the two groups.

## Discussion

The mandibular second molar is susceptible to developing deep residual periodontal pockets due to impacted third molars or poor plaque management [21]. Several approaches, including repeated mechanical therapy and topical or systemic antibiotics, have been proposed for the treatment of residual periodontal pockets in patients. However, studies demonstrated that repeated scaling and root planing during the maintenance phase did not improve the effectiveness of subgingival debridement of periodontal pockets that had been treated during initial periodontal therapy [22].

The applications of laser in the treatment of periodontitis or peri-implantitis are quite extensive, including laser treatment alone, laser as an adjunct to NSPT [23], photodynamic therapy [24] and photothermal therapy with outside irradiation [23]. Because of the variety of laser devices and the diversity in application and treatment protocols, an effective standard treatment protocol has been absent thus far. As a result, the outcomes of laser treatment reported in meta-analyses remain controversial [25]. However, a recent meta-analysis reported beneficial outcomes of diode laser as an adjunct to the treatment of deep periodontal pockets and recommended it as a first-line adjunct for clinical use [26]. The present study investigated the clinical benefits of the diode laser as an adjunct to nonsurgical therapy for residual periodontal pockets of mandibular second molars, with the hope of providing evidence of additional nonsurgical treatment approaches in such challenging sites for conventional nonsurgical therapy.

The laser parameters adopted in this study were 1.5 W and continuous mode, which remained consistent with most laser experiments [13]. However, timing of laser irradiation

was performed four weeks after NSPT rather than immediately. The rationale for this was to give the periodontal soft tissue sufficient healing time after NSPT to reduce bleeding during laser irradiation. Energy of the diode laser is much readily and selectively absorbed by blood components [24]. It is assumed that if periodontal pockets are still bleeding during the irradiation, it would result in an excessive amount of energy being absorbed by the blood, not pockets, diminishing its disinfection effect on the soft tissues of the periodontal pocket wall. Additionally, it would cause unwanted thermal side effects and discomfort. Although bleeding during laser irradiation of inflaming periodontal pockets is inevitable, the accumulation of blood in the pockets can be reduced by continuous saline irrigation. Some former studies also recommend delayed laser irradiation and rinsing with saline during irradiation to flush away blood in the periodontal pocket [27, 28].

Table 2 shows the changes of clinical parameters at every visit. In our study, despite a considerable reduction in PPD at T1, T2, and T3 compared to T0, many patients still have periodontal pockets ( $PPD \geq 4$  mm), indicating that repeated nonsurgical therapy was less effective for residual periodontal pockets. PPD in the Laser + NSPT group reduce to  $3.85 \pm 1.34$  mm at the first month follow-up, and further to  $3.06 \pm 0.86$  mm at T3. Figure 2 shows the changes of PPD, CAL, BOP, and KTW during the study. The PPD reduction of Laser + NSPT group was significantly greater than that of the NSPT group throughout the study (Fig. 2). This may suggest that laser as an adjunct to NSPT, performing with the protocol described above, may be an effective approach for reducing PPD for the residual periodontal pockets.

As the Laser + NSPT group had a greater CAL than the NSPT group at baseline, the comparability of the control group was undermined. However, the following clinical results demonstrated a significant reduction in CAL in the Laser + NSPT group since T1 and showed consistent improvement in CAL during follow-ups. The outcome of CAL reduction in the Laser + NSPT group was significantly greater than the NSPT group at the end of the study (Fig. 2). CAL in the NSPT group also improved significantly after treatment but is still approximately 3 mm at T3. The mean value for the Laser + NSPT group was  $2.58 \pm 0.94$  mm, about 1.5 mm reduction from baseline, indicating greater attachment gain, which improves long-term tooth retention.

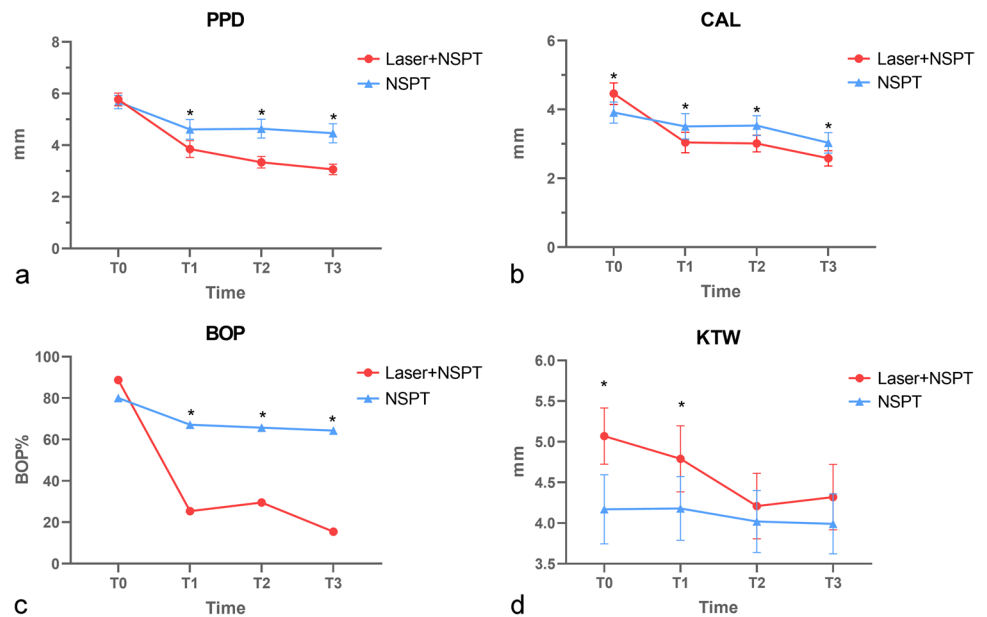
BOP is one of the most key parameters of ongoing inflammation in gingival tissue. The major cause of persistent BOP is the existence of bacterial infections in residual periodontal pockets. According to our findings, NSPT significantly decreased BOP, but was still detected in 64.29% of sites at T3, suggesting that the gingival tissue was still in an inflammatory condition at the end of the study. This also implies, as the results above, that NSPT was less effective in removing the bacterial biofilm of the residual periodontal pocket,

**Table 2** Clinical parameters at every visit

Clinical parameters	Sites/Teeth	Group	Time				<i>P</i> -value	
			T0	T1	T2	T3		
primary outcome								
PPD/mm	71	Laser+NSPT	5.77 ± 1.04	3.85 ± 1.34*	3.34 ± 0.96 <sup>a</sup>	3.06 ± 0.86 <sup>ab</sup>	Group	<0.001
	70	NSPT	5.67 ± 1.09	4.61 ± 1.61*	4.64 ± 1.54*	4.46 ± 1.57*	Time	<0.001
		Intergroup comparison	0.563	0.002	<0.001	<0.001	Group×Time	<0.001
secondary outcome								
CAL/mm	71	Laser+NSPT	4.46 ± 1.32	3.04 ± 1.26*	3.01 ± 1.04*	2.58 ± 0.94 <sup>ab</sup>	Group	0.170
	70	NSPT	3.91 ± 1.29	3.51 ± 1.55*	3.53 ± 1.21*	3.03 ± 1.25 <sup>ab</sup>	Time	<0.001
		Intergroup comparison	0.012	0.046	0.006	0.015	Group×Time	<0.001
BOP/%	71	Laser+NSPT	88.73%	25.35%*	29.58%*	15.49% <sup>b</sup>	Group	<0.001
	70	NSPT	80.00%	67.14%*	65.71%*	64.29%*	Time	<0.001
		Intergroup comparison	0.151	<0.001	<0.001	<0.001	Group×Time	<0.001
KTW/mm	29	Laser+NSPT	5.07 ± 0.91	4.79 ± 1.07	4.21 ± 1.06 <sup>a</sup>	4.32 ± 1.06 <sup>a</sup>	Group	0.006
	30	NSPT	4.17 ± 1.14	4.18 ± 1.05	4.02 ± 1.02	3.99 ± 0.99	Time	0.005
		Intergroup comparison	0.001	0.023	0.486	0.204	Group×Time	0.151

NSPT, nonsurgical periodontal therapy; PPD, periodontal pocket depth; CAL, clinical attachment loss; BOP, bleeding on probing; KTW, keratinized tissue width; \*, significant difference with T0 ( $P < 0.05$ ); <sup>a</sup>, significant difference with T1 ( $P < 0.05$ ); <sup>b</sup>, significant difference with T2 ( $P < 0.05$ )

**Fig. 2** Mean of PPD (a), CAL (b), BOP (c) and KTW (d) at baseline (T0) and T1, T2, and T3 between the Laser + NSPT group and NSPT group. \*Significant differences between two groups ( $P < 0.05$ ). Red dot: Laser + NSPT group, blue triangle: NSPT group



which is consistent with earlier studies [22]. As an adjunctive treatment, the laser was proven to be beneficial in reducing BOP within the present study. At T1, the BOP of the Laser + NSPT group had already decreased to below 30%. At T3, the BOP was 15.49%, representing a stable clinical condition (Fig. 2).

It is controversial whether laser as an adjunctive treatment has significant clinical benefits. Almost all previous studies [14, 16–19, 27–30] reported significant intra-group improvements in clinical parameters at the end of

treatment compared to baseline, both in the experimental groups and control groups. However, when it comes to intergroup comparison, some studies [29, 30] reported that laser as an adjunct had no beneficial effects compared to NSPT. Nevertheless, Saglam et al. [27] reported a significant beneficial effect of laser as an adjunct in PD, CAL, and BOP reduction, using a similar laser setting to the present study, and with saline rinses applied during laser irradiation. Kamma et al. [16] and Matarese et al. [17] reported significant reduction of PD, CAL with laser as an

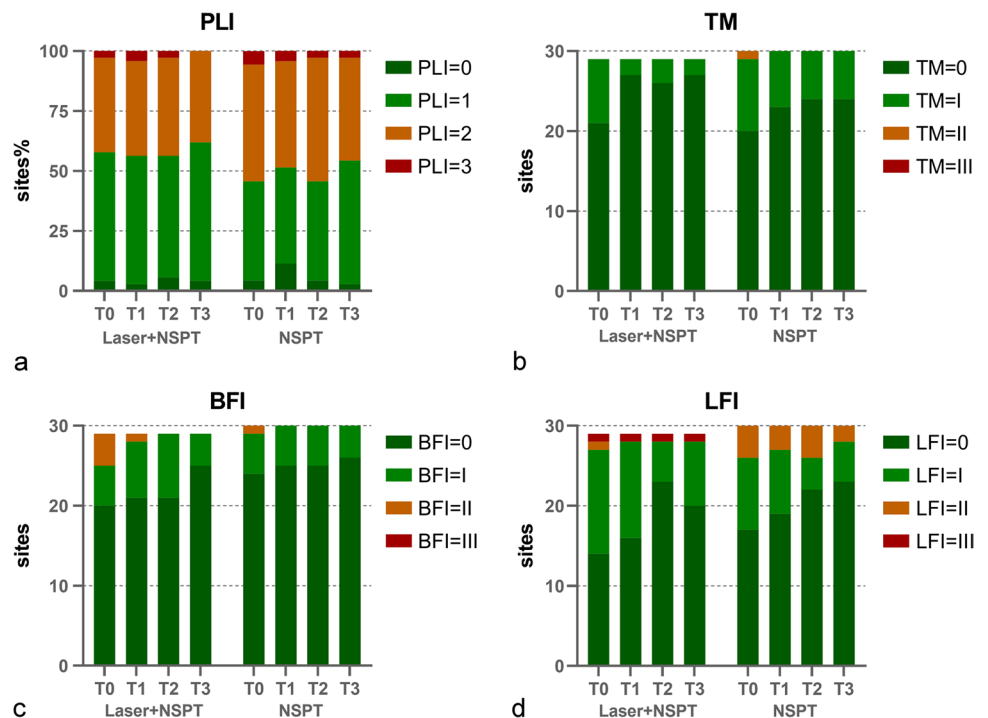
adjunct on aggressive periodontitis but no differences were detected for BOP. Studies [14, 15] of chronic periodontitis in patients with type 2 diabetes mellitus also reported that laser as an adjunct could significantly reduce PD and CAL and found that the NSPT with laser has better outcomes in deep periodontal pockets. Tabari et al. [18] also applied the laser to recurrent periodontal pockets during maintenance phase and reported that the laser as an adjunct significantly enhanced PD, CAL, and bleeding index reduction in the short term, but only enhanced bleeding index reduction in the long term. Dortaj et al. [19] reported better PD reduction and better attachment gain in NSPT with laser but concluded that the PPD reduction was more from gingival recession. Different allocations, treatment protocols, and study populations may have contributed to the discrepancies in these studies.

Beyond these potential causes, it is also possible that, for the majority of mild periodontitis, NSPT alone already provides significant clinical improvement and therefore shows no additional effect by laser as an adjunct. When NSPT alone fails to achieve favorable clinical improvement, the clinical benefits of the laser as an adjunct are shown. Based on the results of the present study, for sites such as residual periodontal pockets in mandibular second molars, NSPT is less effective but Laser+NSPT may significantly improve clinical outcomes that last for six months of follow up. This may reduce the need for further surgical treatment for patients with residual periodontal pockets, offering it a more efficient and acceptable approach both for practitioner and patient.

At T0, KTW was significantly wider in the Laser+NSPT group than in the NSPT group. However, there was no longer a significant difference between the two groups since T2 (Fig. 2). The KTW of the Laser+NSPT group was reduced by about 1 mm at T3 compared to T0. No significant KTW reduction was found in the NSPT group throughout treatment. A recent study, using Nd:YAG laser with a similar wavelength, also found a reduction in KTW when applying laser as an adjunct [19]. Nevertheless, the mean KTW of Laser+NSPT group was  $4.32 \pm 1.06$  mm at the end of the study, which was adequate for long-term periodontal health. Yet, caution should be maintained when considering lasers as an adjunct for teeth with narrow KTW ( $\leq 2$  mm).

Figure 3 and Supplementary Table S1 show changes in PLI, TM, and furcation involvement (BFI and LFI) at each follow-up. Although there were consistent improvements in these parameters over the study (Fig. 3), statistical analysis did not reveal significant differences in these parameters between follow-up visits or groups. Due to the anatomy and position, it is challenging to achieve thorough and lasting plaque control for the mandibular second molar. The present study demonstrated that despite careful and repeated OHIs were exerted at each visit, approximately half of the sites still had poor plaque control ( $PLI > 2$ ) at the end of trial (Fig. 3). There was no significant difference between the groups, implying that patients still generally struggle to maintain long-term plaque control in the mandibular second molar when relying simply on OHIs. Regular mechanical plaque removal treatment is recommended in some cases when long-term good plaque control is indispensable.

**Fig. 3** Clinical changes in PLI (a) as percentage of sites, clinical changes in TM (b), BFI (c) and LFI (d) at T0 (baseline) and T1, T2, and T3 between the Laser+NSPT group and NSPT group. NSPT, nonsurgical periodontal therapy; PLI, plaque index; TM, tooth movement; BFI, buccal furcation involvement; LFI, lingual furcation involvement



There are still some limitations in this study. First, there was a significant difference in CAL and KTW between the two groups at baseline, which may cause bias and led to poor comparability of the two groups. However, the primary outcome PPD showed no significant difference at baseline, limiting the bias induced by baseline comparison. Moreover, CAL was worse in the trial group than in the control group at baseline, yet the trial group still had a better outcome. Second, a small percentage of teeth (approximately 8% of sites) were dropped during follow-ups. Although telephone review shows that these patients stopped follow-up due to personal and scheduling problems, it is also possible that they may have stopped since their self-consciousness symptoms had improved. Third, the maximum follow-up was set at six months, and further long-term (> 12 months) follow-up studies may be necessary to observe longer-term clinical outcomes.

## Conclusion

NSPT alone is less effective in maintaining the long-term periodontal health of periodontally compromised mandibular second molars. Diode laser as an adjunct to NSPT may contribute to clinical outcomes for residual periodontal pockets and maintain for 6 months. The approach could, however, result in KTW reduction.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s00784-023-05071-6>.

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**Author contribution** All authors have made substantial contributions to conception and design of the study. Jia-wei Lu, Shi-hui Huang, Li-jun Luo have been involved in data analysis, data interpretation, drafting the manuscript and revising it critically. Jia-wei Lu have been involved in treatment performing. Shi-hui Huang, Xiao-xiao Lei have been involved in data collection and statistical analysis, Li Deng have been involved in randomization and all authors have given final approval of the version to be published.

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**Data Availability** The data are available from the corresponding author on reasonable request.

## Declarations

**Competing interests** The authors declare no competing interests.

**Ethics approval and consent to participate** The study was conducted in accordance with the Declaration of Helsinki, which was enacted in 1975 and revised in 2000. The study protocol was approved by the Ethics Committee of the Affiliated Stomatology Hospital of Tongji

University, Shanghai, China ([2022]-SR-069) and was registered in the Chinese Clinical Trial Registry (ChiCTR2200061194). All enrolled patients were thoroughly informed of the nature, potential risks, and benefits of their participation in the study and signed an informed consent form before participation.

**Conflict of interest** The authors declare no competing interests.

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