Photobiomodulation, Photomedicine, and Laser Surgery
Volume 40, Number 6, 2022

Pp. 1–7
DOI: 10.1089/photob.2021.0126

Original Research

Femtosecond Laser for Cavity Preparation in Enamel and Dentin: Axial Wall Taper Related Factors

Xiao Zong, BDS,[1,2] Yong Wang, MS,[1,2] Yuchun Sun, DDS, PhD,[1,2] and Hu Chen, DDS[1,2]

Abstract

Background and objective: Femtosecond laser (fs-laser) is a novel tooth preparation tool. After cavities were prepared by fs-laser, their axial-wall taper is closely related to the retention force and success of restorations, while the taper after preparation by fs-laser is not clear yet. This study aimed to explore the value of the taper after fs-laser tooth preparation and the effect of laser fluence, scanning line spacing, and scanning layers on taper.
Materials and methods: Twenty cavities with a width of 0.5 mm were prepared by an fs-laser both in enamel and dentin to obtain the axial-wall taper (No. PKUSSIRB-201949124). To study the effects of three parameters of fs-laser, five different laser fluence were set as 1.56, 3.13, 4.69, 6.25, and 7.81 J/cm^2 of five cavities. Scanning line spacing was set as 6, 12, 25, 30, 40, and 50 μm of six cavities and the scanning layers were 5, 10, 25, 50, 75, 100, 200, 300, and 400, respectively, of nine cavities. Laser pulses irradiated perpendicular to the tooth and the scanning path was controlled via a vibratory mirror. The taper was measured with a laser confocal microscope. Curves of the taper versus different parameters were drawn.
Results: There was a significant difference in taper between enamel and dentin. Overall, the taper decreased gradually with the increase of laser fluence. The optimal taper obtained was $20.53° \pm 0.28°$ in dentin and $38.71° \pm 0.46°$ in enamel when the corresponding fluence was 6.25 J/cm^2. In comparison, the scanning line spacing has little effect on the taper. The scanning layers significantly affect the taper, which decreased dramatically as scanning layers increased within 75 layers and does not change considerably as it was beyond 100 layers.
Conclusions: Reasonable selection of laser fluence, scanning line spacing, and the number of scanning layers can optimize the cavity taper by fs-laser.

Keywords: fs-laser, tooth preparation, inlay, taper, laser therapy

Introduction

Defected teeth caused by caries, trauma, abrasion, erosion, and developmental dysplasia require proper tooth preparation for clinical filling or restoration. In other words, tooth preparation is an essential step through oral treatment and restoration. At present, the preparation tool for clinical use is the dental turbine, of which the efficiency is relatively high. Still, it has a series of drawbacks.[1,2] For example, the effect of traditional tooth preparation depends on the doctor's experience and inevitably causes side effects such as micro cracks and thermal damage.[3] Among the restorations, inlay[4] is a dental restoration made outside of a tooth to correspond to the form of the prepared cavity, which is then luted into the tooth. The inlay is bonded by adhesive to the tooth. Therefore, the axial wall taper is an essential factor

---

[1] Center of Digital Dentistry, Department of Prosthodontics, Peking University School and Hospital of Stomatology, National Center of Stomatology, National Clinical Research Center for Oral Diseases, National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing Key Laboratory of Digital Stomatology, NHC Research Center of Engineering and Technology for Computerized Dentistry, Beijing, P.R. China.
[2] Shanxi Province Key Laboratory of Oral Diseases Prevention and New Materials, Taiyuan, P.R. China.

in the success of it.[5] The textbook states that the optimal taper of inlay is 6°,[6] but the previous study has shown that the taper prepared by clinical freehand is far more than the angle.[7]

Since the introduction of laser into dental cavity preparation, it has been a hot topic because of its comfort and safety.[8,9] The pulse width of a laser directly affects its thermal damage and preparation effect.[10] Because of its ultrashort pulse duration, the femtosecond laser (fs-laser) will take away the material as plasma when the heat has not yet spread around to achieve ''cold'' ablation, which is considered the safest laser and has attracted the attention of scholars.[11–13] The fs-laser tooth preparation has many advantages over the mechanical technique and techniques using other types of lasers. The mechanical instrumentation could cause irreversible damage to the tooth. In contrast, surfaces irradiated by the fs-laser show an entire lack of thermal or mechanical damage such as cracks, charring, or craters.

The fs-laser also allows greater control of the removal of material than that permitted by the smallest bur and realizes the machining with micron-level precision. Beyond that, irrigation is not required and the absence of noise lets the patient stress theoretically reduce and provides the dentists a clear view on performing the cavity.[3] However, the fs-laser beam follows the Gaussian distribution, of which the energy gradually reduces from the spot center to the surroundings. The profile after fs-laser ablation will therefore present a tapered cavity, of which the axial walls are not entirely vertical.[14,15] Scholars have explored the effect and influence factors of fs-laser dental ablation, such as the ablation efficiency[12,16–19] of fs-laser, morphological changes[3],[12,14,20–23] and parameter selection,[24,25] but the related factors of axial wall taper of the fs-laser cavity has not been investigated yet.

Loganathan et al.[25] used mathematical models and constructed the relationship between the depth and width of the cavity and the combination of laser parameters to predict the desired cavity contours in advance and choose the optimal parameters. However, these studies did not involve the taper of the cavity. There is also some literature focused on the selection of fs-laser parameters ablating dental tissue, while they mostly focused on the ablation efficiency, temperature changes after ablation, and morphologies changes they did not address the taper related factors.[3,12,14,20–23,26–31]

After the cavity is prepared, its axial wall taper is closely related to the retention force of the inlay and directly affects the success or failure of the restoration. The axial wall taper of the tooth after preparation is not clear. This study aimed to explore the exact value of the axial wall taper of the cavity prepared by the fs-laser and how different laser parameters affect the axial wall taper. To achieve this goal, we conducted the following experiments to study the effect of different parameters on the axial wall taper by adjusting the laser fluence, scanning line spacing, and the number of scanning layers. The clinical relevance is to provide valuable references of the choice of laser parameters for fs-laser tooth preparation in the future.

Materials and Methods

Sample preparation

The study was approved by the local Research Ethics Committee (PKUSSIRB-201949124). Several complete human third molars from stomatology hospital oral surgery outpatient clinics were collected and stored immediately into 0.01 wt% of the thymol solution for 2 weeks. The molars were cut perpendicular to the tooth's longitudinal axis twice into dentin blocks with a thickness of 2 mm by a wire cut machine. The upper surface exposed both the enamel and the dentin, as shown on the right side of the sample in Fig. 1. All tooth blocks were then polished to 3000-grit sandpaper with a water aid.

fs-laser platform construction

The solid state fs-laser used in the experiment (JenLas® D2.fs, Jena, Germany) has a wavelength of 1025 nm, a pulse width of 400 fs, a repeat frequency between 30 and 200 kHz, an output power between 0 and 4 W, and a spot diameter of 24 μm. The scanning path was controlled via a vibratory mirror (GO2-YAG-12-22-D; Beijing Golden Orange Technology Co., Ltd., China) by its control software (EasyCad V1; Beijing Golden Orange Technology Co., Ltd.).

The in vitro experiment process is shown in Fig. 1. The tooth sample was fixed with the left side blocked by a stainless steel metal plate. The laser beams were with vertical incidence and focused on the dental surface and were guided using a rectangular wave scanning ablation. This is a way in which a laser ablates the material surface by moving along a rectangular wave trajectory. The scanning line passed across the enamel and dentin boundary line, resulting in a rectangular cavity with a width of 0.5 mm. The spacing between adjacent scanning lines in rectangular wave scanning ablation is called scanning line spacing, as the P indicates in Fig. 1. The scanning layers are defined as the number of times the laser spot traverses the scanned area during rectangular wave scanning ablation.

The experiment explored the relationship between laser fluence, scanning line spacing, and the number of scanning

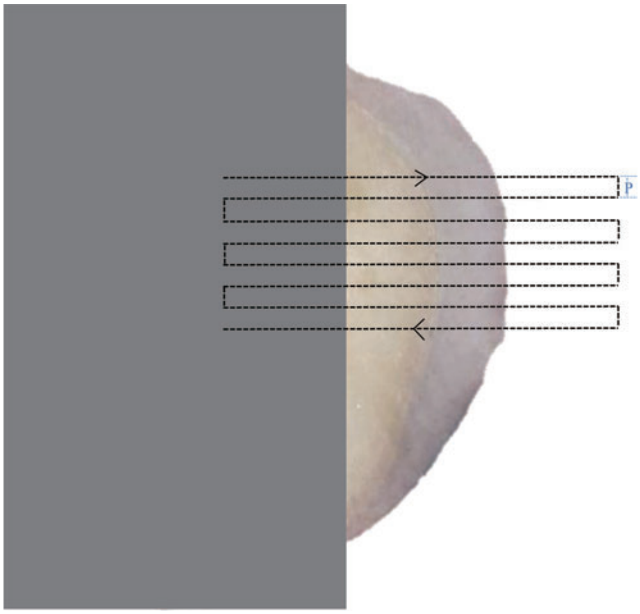


FIG. 1. Schematic diagram of the fs-laser scanning path. fs-laser, femtosecond laser.

layers and the axial wall taper of the cavity. The scanning speed is controlled at 720 mm/s, and other parameters were set as follows.

The effect of laser fluence on taper

Laser output power was set as 0.23, 0.46, 0.69, 0.92, and 1.15 W, and the corresponding laser fluence (F) is calculated using this formula,

$\mathrm{F} = \frac{2E_P}{\pi\omega_0^2}$ where E_P is the energy of a single laser pulse that equals laser power (P) divided by laser repetition frequency (R), and ω_0 represents waist diameter of laser focus spot. The corresponding laser fluence was calculated as 1.56, 3.13, 4.69, 6.25, and 7.81 J/cm^2. The line spacing was 24 μm, the frequency was 30 kHz, and the number of scanning layers was 800, 800, 400, 200, and 200, respectively, to avoid the cavity too deep to affect the results. The fs-laser output parameters were set as Supplementary Table S1.

The effect of scanning line spacing on taper

The scanning line spacing used was 6, 12, 25, 30, 40, and 50 μm. To keep the ablation time of each group as close as possible, the corresponding number of scanning layers was 100, 200, 400, 500, 600, and 800. The laser fluence was 4.69 J/cm^2. According to the results of the pre-experiment, under the limit of dentin thickness, a too deep cavity will let the laser defocus and the dentin penetrate. Meanwhile a too shallow one would make the depth difficult to be measured and affect the accuracy of the measurement. To confine the depth of cavities, scanning layers in this group were not set exactly the same but with a certain regularity. The fs-laser output parameters were set as Supplementary Table S2.

The effect of scanning layers on taper

To discover the effect of scanning layers on taper, the scanning layers were set as 5, 10, 25, 50, 75, 100, 200, 300, and 400 layers. The laser fluence was 4.69 J/cm^2. The scanning line spacing was set at 12 μm. The fs-laser output parameters were set as the Supplementary Table S3.

Measurements and calculation of taper

We measured five sites of the cavity of each group to obtain five samples in each group. Totally, 20 cavities were prepared and 100 samples were measured. Measured the axial wall taper of each sample using a laser confocal microscope (Keyence VK-X100/X200, Keyence, Japan). Draw five parallel lines evenly (as shown in Fig. 2) on each sample, and we can obtain five cross sections of the cavity. Choose the boundary of the surface and the bottom in the analysis software. The angle α could be automatically calculated and shown in the software in the red circle.

Since the shape of the cavity prepared by the fs-laser was irregular, the value of α indicated the angle between the bottom and the line connecting point A and B. The complement angle of α was then calculated and expressed as β. Measure and calculate β on both the left and right sides of each area separately, and then the angles were added together, and the sum was the taper. The average and standard deviation of the five measurement data for each sample were calculated.

Results

The effect of the laser fluence on taper

In five groups of laser fluence, only when the laser fluence exceeded 1.56 J/cm^2 in dentin, and 3.13 J/cm^2 in the enamel could fs-laser ablate a complete cavity. Otherwise, the surfaces only showed several shallow and narrow parallel scanning lines (Fig. 3a and b, the laser fluence was 1.56 J/cm^2). Changes in taper over fluence are presented in Fig. 4. As the figure indicated, the two curves showed a similar trend: as the laser fluence increased, the axial wall taper decreased gradually. When the laser fluence reached 6.25 and 7.81 J/cm^2, the taper was quite close. The taper reached 20.53° ± 0.28° to 20.81° ± 0.73° (Fig. 3c) in dentin and 38.71° ± 0.46° to 39.77° ± 1.11° (Fig. 3d) in enamel. There was a significant difference in taper between enamel and dentin.

The effect of scanning line spacing on taper

In six groups of scanning line spacing, when the line spacing of the experiment was between 6 and 25 μm, we obtained complete cavities. However, once the line spacing exceeded 30 μm, the bottom surface of the cavity began to appear uneven. When the line spacing was 40 μm, it was impossible to ablate an entire cavity but several shallow and narrow parallel scanning lines. When the line spacing was between 12 and 30 μm, the effect of the scanning line spacing on the taper was not obvious, changes are expressed in the curves of Fig. 5. The taper reached 37.03° ± 1.42° to 39.86° ± 1.62° in enamel and 20.22 ± 0.21 to 22.85 ± 0.20 in dentin.

The effect of scanning layers on taper

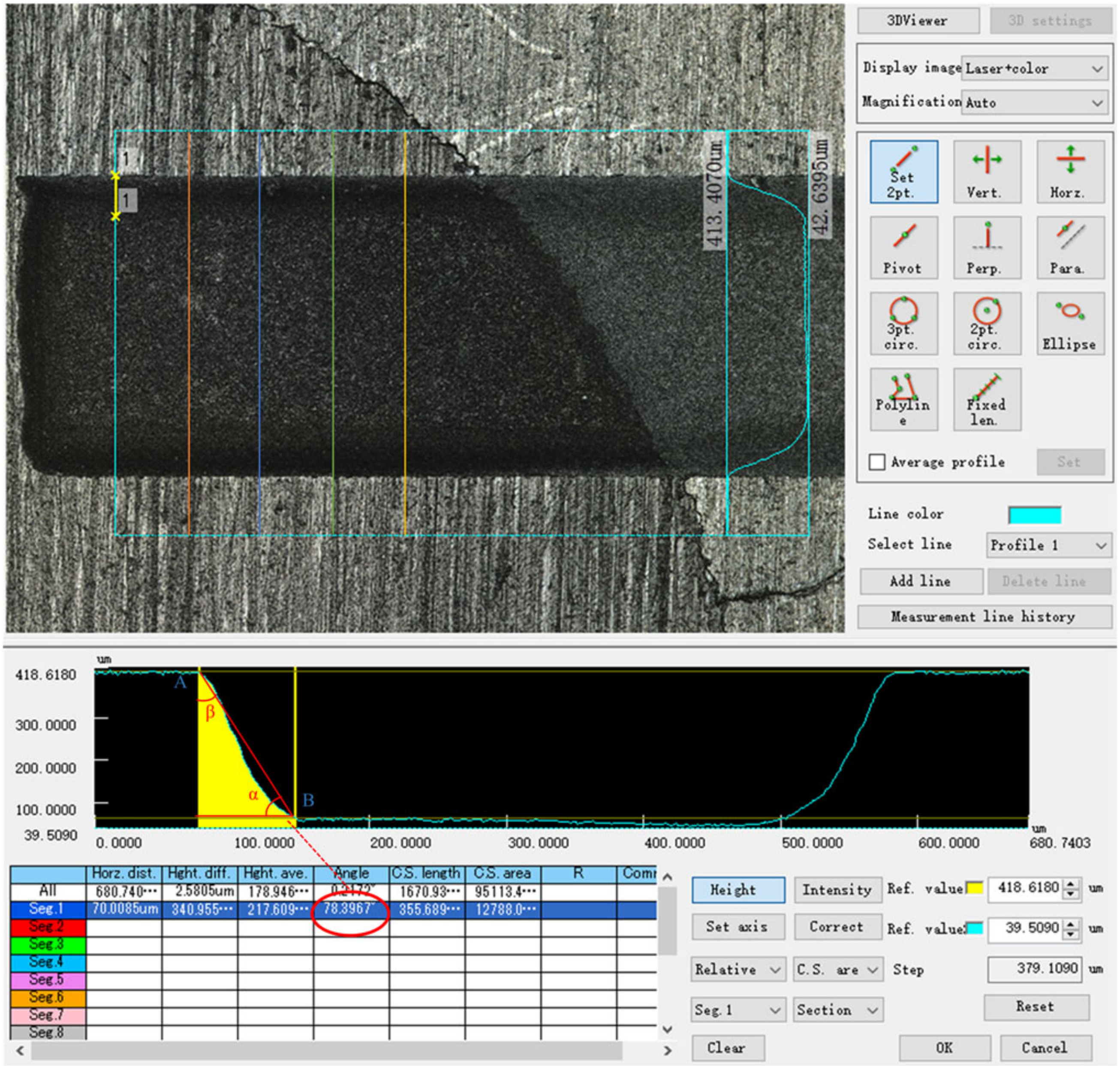
Variation of the depth of enamel and dentin with scanning layers is shown in Table 1. The depth increased with an increasing number of scanning layers. The taper decreased as the scanning layers increased, and the changing trend is expressed in the curves of Fig. 6. When the scanning layers increased from 5 to 75, the taper showed a rapid decline. When the number of layers increases from 75 to 400, the taper tended to plateau, and the optimal taper obtained was 300 layers. The taper was 23.12° ± 0.88° in dentin and 36.62° ± 0.73° in enamel.

Discussion

In this experiment, the effects of laser fluence, scanning line spacing, and the number of scanning layers on the axial wall taper of the cavity after fs-laser ablation were studied, and a preliminary trend was obtained. Further analysis results are as follows.

The effect of laser fluence on taper

The taper was significantly associated with laser fluence. It decreased with increasing laser fluence at first and tended to be smooth when the laser fluence exceeds 6.25 J/cm^2. The ablation threshold was 0.58–2.2 J/cm^2 in enamel and 0.3–1.4 J/cm^2 in dentin.[10,32–34] The possible reason may be that the beam of fs-laser obeys the Gaussian distribution, at the cavity edge, in a specific range of laser fluence, the greater the laser fluence around the beam, the easier of the bottom of the cavity edge dental tissue to be removed, so the formation of the axial cavity wall to be close to



Display image Laser+color
Magnification Auto
Select line Profile 1
413.4070um
42.6395um
Ref. value 418.6180 um
Ref. value 39.5090 um
Step 379.1090 um

	Horz. dist.	Hght. diff.	Hght. ave.	Angle	C.S. length	C.S. area	R	Comr
All	680.740···	2.5805um	178.946···	0.2172°	1670.93···	95113.4···		
Seg.1	70.0085um	340.955···	217.609···	78.3967°	355.689···	12788.0···		
Seg.2								
Seg.3								
Seg.4								
Seg.5								
Seg.6								
Seg.7								
Seg.8								

FIG. 2. The measurement of taper in software.

vertical. When the laser fluence is too high, it produces a weak plasma shielding effect,[34,35] which limits the ablation of the axial walls. It was suggested that to obtain a better axial wall taper, we should choose the appropriate laser fluence. Under the limits of this experimental condition, the laser fluence of the optimal axial wall taper is between 6.25 and 7.81 J/cm^2.

The effect of scanning line spacing on taper

Under these experimental conditions, the diameter of the spot of the fs-laser is 24 μm. The scanning line spacing used in this experiment spanned this diameter. It is found that although the laser fluence used is much higher than the ablation threshold of dentin and enamel when the scanning line spacing exceeds the diameter of the spot, it is impossible to make a complete cavity but a parallel line without overlap. This suggests that in future clinical applications, the spacing of the scanning line should be no larger than the spot diameter, even with high laser fluence. When the line spacing is less than 25 μm, the taper did not show significant differences. So it suggests that to improve ablation efficiency, we can choose the line spacing to let the spot overlap rate be zero.

The effect of scanning layers on taper

The effect of the number of scanning layers on the depth of ablation was approximately linear (Table 1). Within 75 layers, with the increase of layers, the taper was also linearly

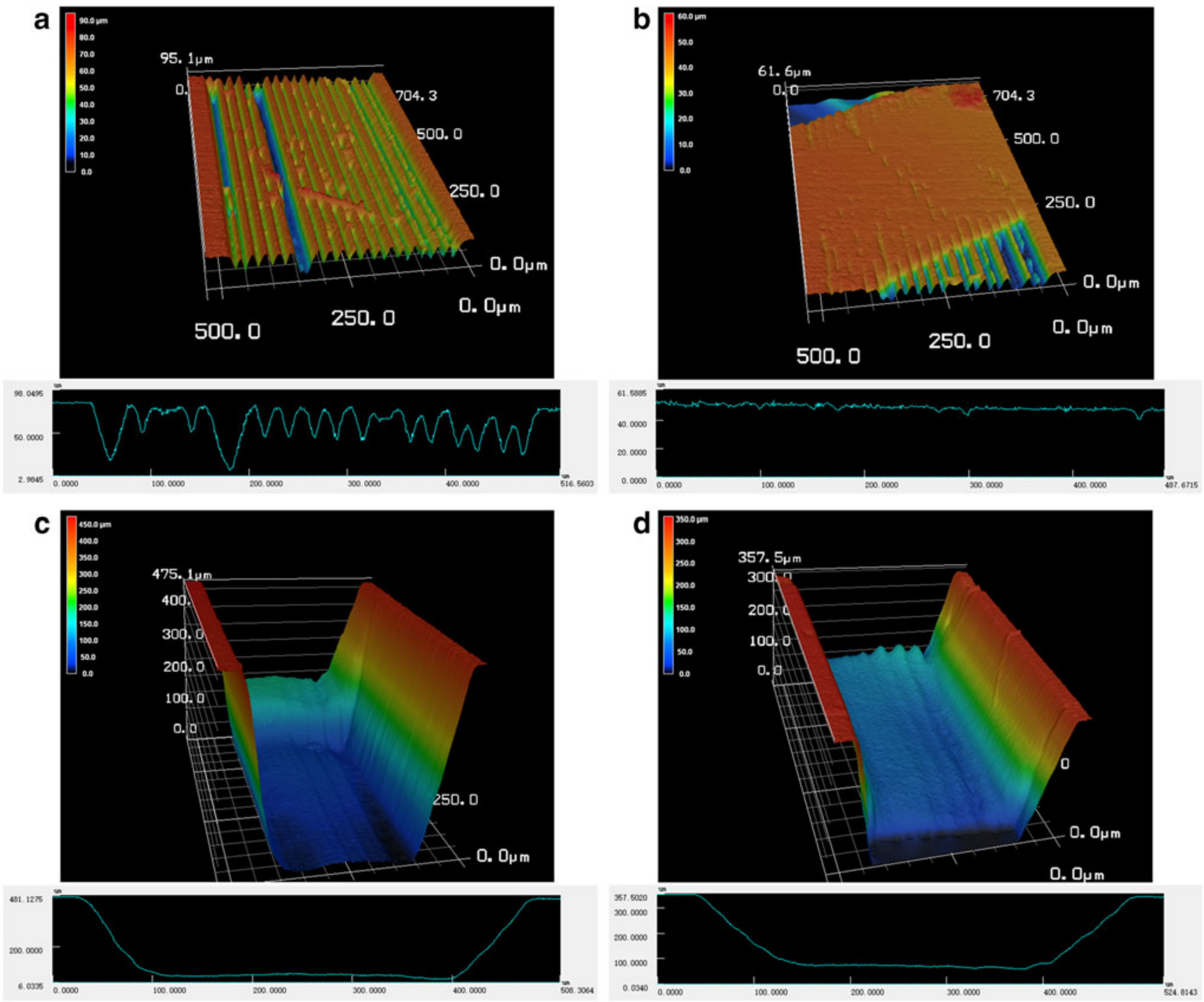


FIG. 3. The three-dimensional profile of different morphologies in dentin **(a, c)** and enamel **(b, d)**.

decreasing both on dentin and enamel. When the layers are more than 75, the depth of tooth enamel and dentin reached 86.54 ± 0.56 and 139.77 ± 6.44 μm, respectively, with its gradual increase, the taper gradually decreased. After that, with the rise in the number of layers, the change in taper was not noticeable. The possible reason was that, with the increase of layers, the axial wall material could be cut off again by the accumulated number of pulses so that it was closer to the vertical. When the cumulative pulse number reached a

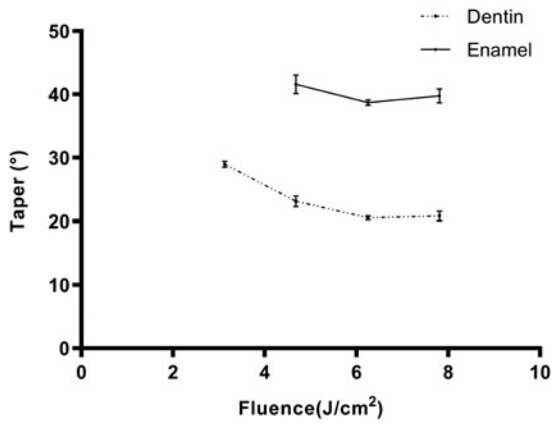


FIG. 4. Relationship between laser fluence and taper for enamel and dentin.

Table 1. Ablation Depth of Different Scanning Layers in Enamel and Dentin

	Ablation depth, mean ± SD (μm)	
No. of layers	*Enamel*	*Dentin*
5	6.38 ± 0.39	14.39 ± 2.40
10	11.64 ± 2.60	24.87 ± 1.45
25	27.65 ± 0.41	51.34 ± 1.54
50	60.19 ± 0.80	101.77 ± 7.61
75	86.54 ± 0.56	139.77 ± 6.44
100	115.17 ± 1.74	187.49 ± 7.10
200	218.86 ± 4.28	376.30 ± 18.89
300	331.90 ± 11.57	558.31 ± 36.85
400	438.50 ± 15.94	740.41 ± 44.49

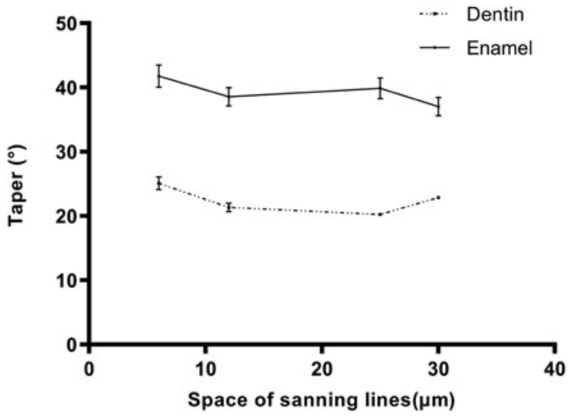


FIG. 5. Relationship between scanning line spacing and taper for enamel and dentin.

certain level, the cumulative effect did not increase. This suggests that the scanning layers should not be less than 75 layers in future clinical applications.

Although the textbook recommends that tooth preparation of the inlay needs to meet the requirements of a taper of less than 6° the studies found that it is unable to achieve in clinical operation. The study[7] found that the actual slightest taper is 17° or so and was dependent on the doctor's age and experience. Although the taper of fs-laser cavity preparation does not meet the requirements of textbooks, compared with the clinical practice reported in the literature, the optimal combination of parameters can still be close to the taper value of the dentist's actual operation.

Prospects

This experiment only explored the effect of different parameters on taper, while finding the optimal parameter combinations has not been involved. The maximum depth obtained in preparation and the clinical inlay preparation is required to have a thickness of 1.5–2 mm. Whether such a trend after the depth of 1.5–2 mm is still applicable is the point that needs further study in the future.

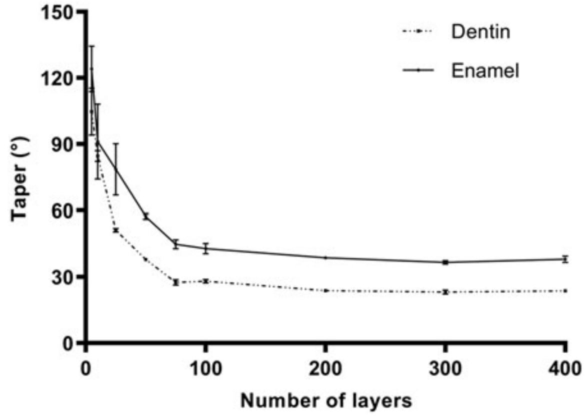


FIG. 6. Relationship between scanning layers and taper for enamel and dentin.

Author Disclosure Statement

No competing financial interests exist.

Funding Information

We are grateful for the financial support from National Key R&D Program of China (2019YFB1706900), PKU-Baidu Fund (2019BD021), Capital's Funds for Health Improvement and Research (2022-2Z-4106), and open fund of Shanxi Province Key Laboratory of Oral Diseases Prevention and New Materials (KF2020-04).

Supplementary Material

Supplementary Table S1
Supplementary Table S2
Supplementary Table S3

References

1. Muñoz MP, Luengo MCL, Llorente JMS, et al. Morphological alterations in dentine after mechanical treatment and ultrashort pulse laser irradiation. Lasers Med Sci 2012; 27:53–58.
2. Bergenholtz G. Pathogenic mechanisms in pulpal disease. J Endod 1990;16:98–101.
3. Luengo MCL, Portillo M, Sánchez JM, et al. Evaluation of micromorphological changes in tooth enamel after mechanical and ultrafast laser preparation of surface cavities. Lasers Med Sci 2013;28:267–273.
4. The glossary of prosthodontic terms: Ninth edition. J Prosthet Dent 2017;117:e1–e105.
5. Thompson MC, Thompson KM, Swain M. The all-ceramic, inlay supported fixed partial denture. Part 1. Ceramic inlay preparation design: a literature review. Aust Dent J 2010; 55:120–127.
6. Wilson Jr AH and Chan DC. The relationship between preparation convergence and retention of extracoronal retainers. J Prosthodont 1994;3:74–78.
7. Mack PJ. A theoretical and clinical investigation into the taper achieved on crown and inlay preparations. J Oral Rehabil 1980;7:255–265.
8. Deppe H, Horch HH. Laser applications in oral surgery and implant dentistry. Lasers Med Sci 2007;22:217–221.
9. Midda M, Renton-Harper P. Lasers in dentistry. Br Dent J 1991;170:343–346.
10. Serbin J, Bauer T, Fallnich C, et al. Femtosecond lasers as novel tool in dental surgery. Appl Surf Sci 2002;197–198: 737–740.
11. Gamaly EG, Rode AV, Luther-Davies B, Tikhonchuk VT. Ablation of solids by femtosecond lasers: ablation mechanism and ablation thresholds for metals and dielectrics. Phys Plasmas 2002;9:949–957.
12. Serafetinides AA, Khabbaz MG, Makropoulou MI, Kar AK. Picosecond laser ablation of dentine in endodontics. Lasers Med Sci 1999;14:168–174.
13. Stern D, Schoenlein RW, Puliafito CA, Dobi ET, Birngruber R, Fujimoto JG. Corneal ablation by nanosecond, picosecond, and femtosecond lasers at 532 and 625 nm. Arch Ophthalmol 1989;107:587–592.
14. Nicolodelli G, Lizarelli RdFZ, Bagnato VS. Influence of effective number of pulses on the morphological structure of teeth and bovine femur after femtosecond laser ablation. J Biomed Opt 2012;17:048001.

15. Dutra-Correa M, Nicolodelli G, Rodrigues JR, Kurachi C, Bagnato VS. Femtosecond laser ablation on dental hard tissues—analysis of ablated profile near an interface using local effective intensity. Laser Phys 2011;21:965–971.
16. Loganathan S, Santhanakrishnan S, Bathe R, Arunachalam M. Surface processing: an elegant way to enhance the femtosecond laser ablation rate and ablation efficiency on human teeth. Lasers Surg Med 2019;51:797–807.
17. Petrov T, Pecheva E, Walmsley AD, Dimov S. Femtosecond laser ablation of dentin and enamel for fast and more precise dental cavity preparation. Mater Sci Eng C Mater Biol Appl 2018;90:433–438.
18. Chen H, Li H, Sun Y, Wang Y, Lü P. Femtosecond laser for cavity preparation in enamel and dentin: ablation efficiency related factors. Sci Rep 2016;6:20950.
19. Chen H, Liu J, Li H, et al. Femtosecond laser ablation of dentin and enamel: relationship between laser fluence and ablation efficiency. J Biomed Opt 2015;20:28004.
20. Bertrand Q-TLC, Vilar R. Structural modifications induced in dentin by femtosecond laser. J Biomed Opt 2016;21: 125007.
21. Daskalova A, Bashir S, Husinsky W. Morphology of ablation craters generated by ultra-short laser pulses in dentin surfaces: AFM and ESEM evaluation. Appl Surf Sci 2010;257:1119–1124.
22. Gordienko VM, Makarov IA, Khomenko AS, Timofeev MA, Tuchin VV. Microspectral analysis of dentine with femtosecond laser induced plasma. Laser Phys 2009;19:1288–1293.
23. Hamakawaa PST, Otsukia M, Tagamia J, et al. Morphological changes on enamel after irradiation with femtosecond pulsed laser. Int Congr Ser 2003;1248:121–125.
24. Loganathan S, Santhanakrishnan S, Bathe R, Arunachalam M. Prediction of femtosecond laser ablation profile on human teeth. Lasers Med Sci 2019;34:693–701.
25. Loganathan S, Santhanakrishnan S, Bathe R, Arunachalam M. Prediction of femtosecond laser ablation parameter on Human teeth using chemical compositional analysis. Procedia Manuf 2019;34:379–384.
26. Yuan F, Zheng J, Sun Y, Wang Y, Lyu P. Regulation and Measurement of the Heat Generated by Automatic Tooth Preparation in a Confined Space. Photomed Laser Surg 2017;35:332–337.
27. Le QT, Vilar R, Bertrand C. Influence of external cooling on the femtosecond laser ablation of dentin. Lasers Med Sci 2017;32:1943–1951.
28. de Menezes RF, Harvey CM, de Martínez Gerbi MEM, et al. Fs-laser ablation of teeth is temperature limited and provides information about the ablated components. J Biophotonics 2017;10:1292–1304.
29. Chang KP, Tsai TW, Huang KY, et al. Thermal response of a dental tissue induced by femtosecond laser pulses. Appl Opt 2013;52:6626–6635.
30. Cangueiro LT, Vilar R. Influence of the pulse frequency and water cooling on the femtosecond laser ablation of bovine cortical bone. Appl Surf Sci 2013;283:1012–1017.
31. Pike P, Parigger C, Splinter R, Lockhart P. Temperature distribution in dental tissue after interaction with femtosecond laser pulses. Appl Opt 2007;46:8374–8378.
32. Rode AV, Gamaly EG, Luther-Davies B, et al. Precision ablation of dental enamel using a subpicosecond pulsed laser. Aust Dent J 2003;48:233–239.
33. Krüger J, Kautek W, Newesely H. Femtosecond-pulse laser ablation of dental hydroxyapatite and single-crystalline fluoroapatite. Appl Phys A 1999;69:S403–S407.
34. Ji L, Li L, Devlin H, Liu Z, Jiao J, Whitehead D. Ti: sapphire femtosecond laser ablation of dental enamel, dentine, and cementum. Lasers Med Sci 2012;27:197–204.
35. Sallé B, Gobert O, Meynadier P, Perdrix M, Petite G, Semerok A. Femtosecond and picosecond laser microablation: ablation efficiency and laser microplasma expansion. Appl Phys A 1999;69:S381–S383.

Address correspondence to:
Hu Chen, DDS
Center of Digital Dentistry
Department of Prosthodontics
Peking University School
and Hospital of Stomatology
22 Zhongguancun South Avenue,
Haidian District
Beijing 100081
P.R. China

E-mail: ccen@bjmu.edu.cn

Yuchun Sun, DDS, PhD
Center of Digital Dentistry
Department of Prosthodontics
Peking University School
and Hospital of Stomatology
22 Zhongguancun South Avenue,
Haidian District
Beijing 100081
P.R. China

E-mail: kqsyc@bjmu.edu.cn

Received: September 8, 2021.
Accepted after revision: January 23, 2022.
Published online: May 19, 2022.