Journal of Dental Sciences 20 (2025) 2479–2482

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-jds.com

Short Communication

Carbon dioxide laser-assisted bone regenerative therapy without membrane use

Yoichi Taniguchi [a,b*], Akira Aoki [a], Koji Mizutani [c], Taichen Lin [a,d,e], Takanori Iwata [a]

[a] *Department of Periodontology, Graduate School of Medical and Dental Sciences, Institute of Science Tokyo (Science Tokyo), Tokyo, Japan*
[b] *Taniguchi Dental Clinic, Sapporo, Japan*
[c] *Department of General Dentistry, Graduate School of Medical and Dental Sciences, Institute of Science Tokyo (Science Tokyo), Tokyo, Japan*
[d] *School of Dentistry, Chung Shan Medical University, Taichung, Taiwan*
[e] *Department of Dentistry, Chung Shan Medical University Hospital, Taichung, Taiwan*

Received 17 June 2025; Final revision received 24 June 2025
Available online 15 July 2025

KEYWORDS
Blood clot formation;
Bone regeneration;
Carbon dioxide laser;
Laser-assisted bone regenerative therapy;
Periodontal regeneration

Abstract Favorable outcomes have been reported with periodontal regeneration therapies using dental lasers for blood clot formation. Herein, we presented the clinical and radiographic outcomes of carbon dioxide laser-assisted bone regenerative therapy (LBRT) in periodontology. A 60-year-old man presented with mobility in teeth 43 and 44. Accordingly, the extraction of tooth 44 and periodontal regeneration using carbon dioxide-LBRT around tooth 43 were planned. After thorough debridement, enamel matrix derivative and carbonated apatite (CA) were applied to the root surface and bone defects, respectively. Thereafter, the filled blood-mixed CA was irradiated using a carbon dioxide laser to accelerate blood clot formation for stabilizing the bone graft. At the 13-month follow-up, significant improvements in clinical parameters were observed, indicating substantial bone regeneration. In this patient, the excellent clinical and radiographic healing demonstrated the efficacy of carbon dioxide-LBRT for periodontal regeneration. Blood clot formation using a carbon dioxide laser may lead to favorable outcomes.

* Corresponding author. Department of Periodontology, Graduate School, Institute of Science Tokyo, 1-5-45, Yushima, Bunkyo-ku, Tokyo 113-8549, Japan.
E-mail address: taniguchi.peri@tmd.ac.jp (Y. Taniguchi).

https://doi.org/10.1016/j.jds.2025.06.018

Introduction

Enamel matrix derivative (EMD) has been widely applied for periodontal regenerative therapy. However, the indications for EMD alone are limited to three-wall intrabony defects, which impose several constraints.[1] For one- and two-wall defects, a combination of EMD, bone-graft materials, and guided tissue regeneration membranes is frequently recommended.[2] However, in cases involving the interdental regions of the molars or thin mucosal tissues, postoperative wound dehiscence and subsequent infection occur frequently, making these procedures technically challenging and not universally applicable.

To overcome the limitations of guided tissue regeneration using membranes, Taniguchi et al. applied an Er:YAG laser to autogenous bone mixed with blood placed in the bone defect to induce blood clot formation on the grafted bone surface after EMD was applied onto the root surface.[3] Er:YAG laser-assisted bone regenerative therapy (Er-LBRT) promoted significant periodontal tissue regeneration, even in teeth with one-wall defects, and reduced the risk of postoperative complications. Furthermore, in 2021, Taniguchi et al. successfully applied a similar technique using bovine bone mineral for alveolar ridge preservation and augmentation.[4]

However, Er:YAG laser energy is absorbed by the superficial layer of the material, and prolonged irradiation is required to form a blood clot with sufficient strength to maintain the shape of the bone graft.[5] Therefore, we considered the use of a carbon dioxide laser in the LBRT technique, which accelerates the formation of a robust blood clot. Herein, we present the clinical and radiographic characteristics before and after carbon dioxide-LBRT treatment to provide valuable insights into this novel approach.

Materials and methods

A 60-year-old man presented with mobility and swelling in tooth 44 as the chief complaint. Clinical and radiographic evaluation indicated that the prognosis of tooth 44 was hopeless owing to significant bone resorption. Furthermore, periapical radiographs revealed bone resorption around tooth 43, extending from the distal to the mesial aspect (Fig. 1A–C). The patient agreed to the extraction of tooth 44 but wanted to preserve tooth 43. Accordingly, the extraction of tooth 44 with simultaneous periodontal tissue regeneration therapy using LBRT in tooth 43 was planned. Owing to the large volume of bone graft required during

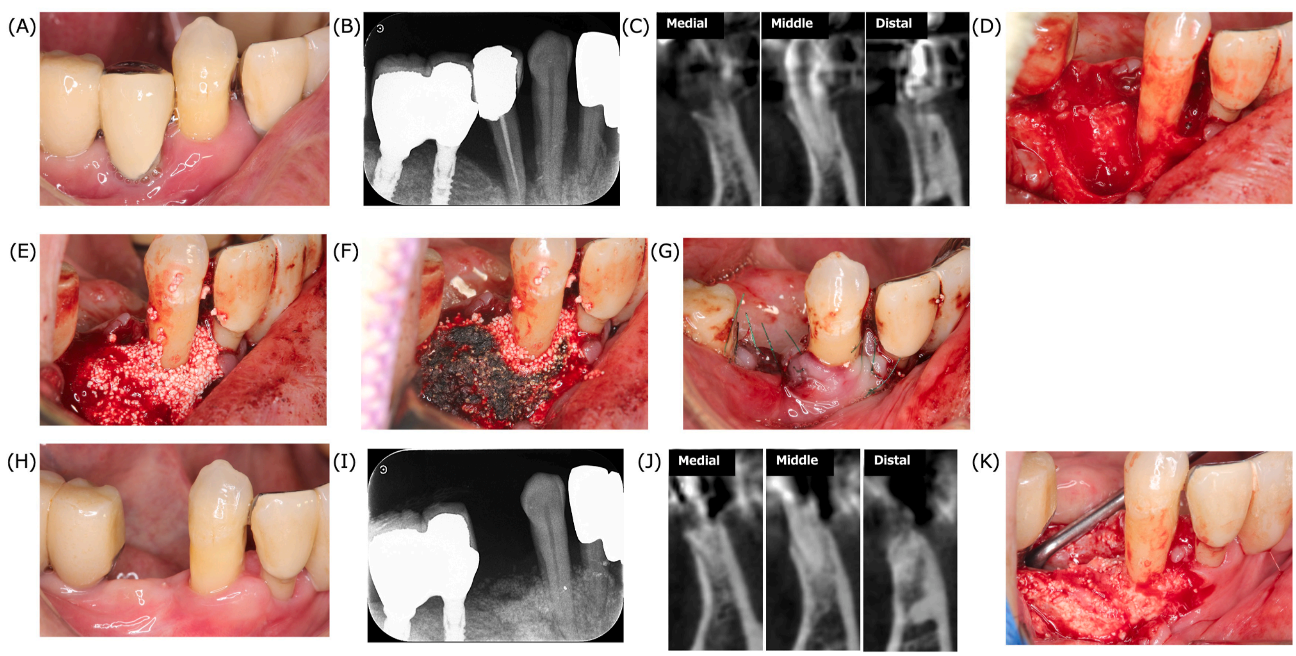

Figure 1 Carbon dioxide laser-assisted bone regenerative therapy (LBRT) case. (A) Intraoral photograph showing teeth 43 and 44 with severe periodontal destruction. (B) Periapical radiograph showing that the bone defect around tooth 44 is continuous with that on the distal aspect of tooth 43. (C) Coronal cone-beam computed tomography images of tooth 43 showing narrow and deep two-to three-wall bone defects on the mesial aspect and wide and deep one-to two-wall defects on the distal aspect. (D) The distal bone defect of tooth 43 was connected with the extraction socket of tooth 44. The mesial and distal bone defects were separated by the residual buccal bone. (E) Blood-mixed carbonated apatite (CA) has been filled in the bone defect. (F) Blood clot formed on the grafted CA after carbon dioxide laser irradiation. The formed blood clot effectively stabilized the bone graft material, similar to a collagen membrane. (G) The wound was closed with simple sutures using 5-0 nylon. (H) Pocket depth at all sites was $<$3 mm. No complications related to carbon dioxide laser-assisted bone regenerative therapy were observed. (I) Periapical radiograph showed that the bone defect had been filled with regenerated bone. (J) Coronal cone-beam computed tomography images showed bone fill in the area of the one-wall defect. (K) Intraoperative photograph during re-entry surgery showed dramatic bone regeneration without blackened fibrin clots.

bone regeneration in this case, a wide area of blood clot formation was necessary. Therefore, carbon dioxide laser was selected for this LBRT because carbon dioxide laser light reaches a slightly greater depth than Er:YAG laser light and has a longer thermal relaxation time and thus rapidly and strongly induces blood coagulation compared to Er:YAG laser.[6]

The risks and benefits of carbon dioxide-LBRT were explained verbally and in writing. After the patient was assured that personal data would not be released to ensure anonymity, informed consent was obtained. The probing depths (PDs) around tooth 43 at the mesial, midpoint, and distal aspects of the buccal and lingual surfaces were 8, 5, and 9 mm and 8, 3, and 11 mm, respectively (Table 1). The clinical attachment levels (CALs) at the mesial, midpoint, and distal aspects of the buccal and lingual surfaces were 10, 7, and 11 mm and 10, 5, and 13 mm, respectively. Bleeding on probing was observed at all sites, and suppuration was particularly evident on the distal aspect. Radiographic analysis using the method described by Taniguchi et al. revealed intrabony defect depths (IDDs) of 7.6 and 8.2 mm on the mesial and distal aspects, respectively.[3]

The surgical procedure was performed as follows. Under local anesthesia, a full-thickness flap was elevated, and tooth 44 was extracted. The granulation tissue and calculus were debrided using hand, ultrasonic, and rotary instruments (Fig. 1D). EMD (Emdogain, Straumann, Basel, Switzerland) was applied to the exposed root surface, and carbonated apatite (CA) (Cytrans Granules, GC Corporation, Tokyo, Japan) mixed with blood was grafted into the periodontal bone defect (Fig. 1E). To stabilize the grafted bone, its surface was irradiated using a carbon dioxide laser (Gas Laser Plus, GC Corporation, Tokyo, Japan) in continuous wave mode at 2.0 W to induce blood clot formation (Fig. 1F). After a minimal periosteum-releasing incision, primary closure was achieved with simple sutures using 5-0 nylon (Softretch 5-0, GC Corporation, Tokyo, Japan) (Fig. 1G).

Postoperatively, antibiotics were prescribed three times daily for 3 days. An analgesic was administered as needed. At the 13-month follow-up, the patient requested implant treatment for tooth 44, and reentry surgery at tooth 43 was performed simultaneously with implant placement. All clinical and radiographic parameters were measured pre- and postoperatively by the operating surgeon (Y.T.).

Results

The patient's postoperative course was uneventful, with no wound dehiscence or other complications. Sutures were removed 2 weeks postoperatively.

At the 13-month re-evaluation before the re-entry procedure (Fig. 1H—J), PDs on the mesial, midpoint, and distal aspects of the buccal and lingual surfaces of tooth #27 had decreased to 3, 2, and 3 mm and 3, 2, and 3 mm, respectively. Furthermore, CAL on the mesial, midpoint, and distal aspects of the buccal and lingual surfaces improved to 6, 4, and 6 mm and 6, 3, and 6 mm, respectively. Thus, the maximum PD reduction and CAL gain were 8 mm and 7 mm, respectively. No bleeding on probing was observed in the treated area. Radiographic analysis revealed complete bone regeneration up to the residual alveolar crest. IDD on the mesial and distal aspects reduced from the initial 7.6 mm and 8.2 mm—0.4 mm and 0.6 mm, respectively. Furthermore, the degree of mobility improved from Grade

Table 1 Clinical data of the patient.

Patient data						
Age (Y)	60					
Sex	Male					
Treatment site	Tooth 43 area					
Type of bone defect	2 + 1 wall					
Treatment site data	Buccal			Lingual		
	Medial	Middle	Distal	Medial	Middle	Distal
PD (baseline) (mm)	8	5	9	8	3	11
PD (12 months) (mm)	3	2	3	3	2	3
PD reduction (mm)	5	3	6	4	1	8
CAL (baseline) (mm)	10	7	11	10	5	13
CAL (12 months) (mm)	6	4	6	6	3	6
CAL gain (mm)	4	3	5	4	2	7
BoP (baseline)	+	+	+	+	+	+
BoP (12 months)	−	−	−	−	−	−
Mobility (baseline)	2					
Mobility (12 months)	0					
	Medial	Distal				
IDD (baseline) (mm)	7.6	8.2				
IDD (12 months) (mm)	0.4	0.6				
IDD reduction (mm)	7.2	7.6				

BoP, bleeding on probing; CAL, clinical attachment level; IDD, intrabony defect depth; PD, probing depth.

2 to Grade 0 (Table 1). Re-entry revealed dramatic bone regeneration around tooth #27 (Fig. 1K).

Discussion

Taniguchi et al.[3] introduced Er-LBRT and demonstrated its efficacy for stabilizing autogenous bone grafts through blood clot formation. However, a significant limitation of Er-LBRT is the repeated irradiation for extended durations required for clot formation because of the high absorption of Er:YAG laser energy at the tissue and material surfaces. In contrast, carbon dioxide-LBRT accelerated the formation of a stable blood clot, thereby reducing the surgical time. Similar to Er:YAG laser, carbon dioxide laser is characterized by surface absorption. However, the continuous wave irradiation and longer thermal relaxation time compared to that of the Er:YAG laser allowed the formation of a robust blood clot that effectively stabilized the bone graft.

Unlike previous studies,[3,4] which used autogenous bone and bovine bone minerals, we used a synthetic bone substitute (CA) with well-documented osteoconductive properties. Owing to its superior osteoconductive properties, CA has been used in periodontal and implant therapies.[7] Moreover, evidence suggests its eventual replacement by bone tissue after grafting.[8] The successful attainment of equivalent regenerative outcomes using a synthetic material underscores the wide range of potential applications of carbon dioxide-LBRT. Despite these advantages, careful handling of carbon dioxide lasers is essential to prevent thermal damage. Unlike Er:YAG lasers, carbon dioxide lasers cause carbonization of hard tissue,[9] necessitating a safety margin of approximately 2 mm from the root and bone surfaces. However, complications such as delayed healing due to laser-formed blood clots have not been reported.[3,4] In our patient, the initially blackened blood clots were fully resorbed within 13 months. Based on the current knowledge, we recommend using a superficially absorbed laser that does not cause thermal damage to the surrounding tissue while ensuring the formation of a stable blood clot that can substitute for a membrane.

Although Er-LBRT and carbon dioxide-LBRT achieve successful periodontal tissue regeneration, carbon dioxide-LBRT provides increased surgical efficiency. Laser-induced blood clot formation stabilizes the graft morphology, leading to favorable outcomes with Er-LBRT and carbon dioxide-LBRT techniques. Additionally, the effect of photobiomodulation is considered a contributing factor.[10] However, the optimal irradiation parameters for blood clot formation and tissue activation on the grafted bone surface remain unclear.

Forming a blood clot on the blood-mixed bone graft is a promising approach for achieving significant periodontal bone regeneration. Further studies with larger sample sizes and histological analyses are required to verify the effectiveness and safety of carbon dioxide-LBRT.

Declaration of competing interest

The authors have no conflicts of interest to declare.

References

1. Esposito M, Grusovin MG, Papanikolaou N, Coulthard P, Worthington HV. Enamel matrix derivative (Emdogain) for periodontal tissue regeneration in intrabony defects. A cochrane systematic review. *Eur J Oral Implant* 2009;2:247–66.
2. Cortellini P, Stalpers G, Mollo A, Tonetti MS. Periodontal regeneration versus extraction and prosthetic replacement of teeth severely compromised by attachment loss to the apex: 5-year results of an ongoing randomized clinical trial. *J Clin Periodontol* 2011;38:915–24.
3. Taniguchi Y, Aoki A, Sakai K, Mizutani K, Iwata T, Izumi Y. A novel surgical procedure for Er:YAG laser-assisted periodontal regenerative therapy: case series. *Int J Periodontics Restor Dent* 2016;36:507–15.
4. Taniguchi Y, Sawada K, Yamada A, et al. Er:YAG laser-assisted bone regenerative therapy for implant placement: a case series. *Int J Periodontics Restor Dent* 2021;41:e137–75.
5. Aoki A, Mizutani K, Schwarz F, et al. Periodontal and peri-implant wound healing following laser therapy. *Periodontol 2000* 2015;68:217–69.
6. Yu DS, Kim SN, Kye YC. Cutaneous resurfacing of the pitted acne scars with the Erbium:YAG laser in 100 patients. *Ann Dermatol* 2001;13:71–5.
7. Taniguchi Y, Koyanagi T, Takagi T, Kitanaka Y, Aoki A, Iwata T. Ridge preservation and augmentation using a carbonated apatite bone graft substitute: a case series. *Dent J* 2024;12:55.
8. Taniguchi Y, Koyanagi T, Kitanaka Y, Yamada A, Aoki A, Iwata T. Guided bone regeneration using carbonated apatite granules and L-lactic acid/ε-caprolactone membranes: a case series and histological evaluation. *Dent J* 2025;13:85.
9. Sasaki KM, Aoki A, Ichinose S, Yoshino T, Yamada S, Ishikawa I. Scanning electron microscopy and fourier transformed infrared spectroscopy analysis of bone removal using Er:YAG and CO_2 lasers. *J Periodontol* 2002;73:643–52.
10. Lin T, Taniguchi Y, Aoki A, Chen CC. Management of furcation-involved molar using Er:YAG laser-assisted bone regenerative therapy: a case report. *J Dent Sci* 2022;17:1836–8.