

Guided tissue regeneration for severe periodontal disease in dogs: A retrospective study

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Abstract: Clinical evidence on guided tissue regeneration (GTR) in dogs with advanced periodontal defects is limited. This retrospective study aimed to evaluate the clinical and radiographic outcomes and tooth survival after GTR in dogs with severe periodontal disease. The medical records of 67 dogs with 129 treated teeth/sites in total were reviewed. The regenerative treatment consisted of an enamel matrix derivative or bovine-derived xenograft in combination with a collagen membrane, which was selected based on the clinical characteristics of each case. Periodontal outcomes were assessed based on probing depth, clinical attachment level, radiographic bone defect size, and tooth survival at postoperative follow-up examinations. Significant postoperative improvements were observed in the clinical and radiographic parameters. The tooth survival rates at 3–5, 6–8, 10–13, and 18–24 months were 98.45%, 97.67%, 96.12%, and 93.02%, respectively. These findings suggest that GTR is a tooth-preserving treatment option for selected dogs with severe periodontal defects. However, the long-term outcomes should be interpreted cautiously because the follow-up was incomplete and variable, the number of cases decreased over time, and no control group was included.

Keywords: bone defect; clinical attachment level; dogs; guided tissue regeneration; periodontal disorder; probing depth

Periodontitis refers to inflammation of the supporting tissues of the teeth, including the gingiva, periodontal ligament, and alveolar bone, and

is characterised by tissue destruction and formation of periodontal pockets that result in increased probing depth (Lim et al. 2022). Management

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of dental disorders generally includes treatment of periodontitis, endodontic procedures, and guided tissue regeneration (GTR) (Bellows et al. 2019). Canine periodontal disease is highly prevalent, with an incidence of up to 85% for dogs aged 3 years (Lobprise and Dodd 2019) and is often difficult to stabilise even with specialised care (Gengler 2013). Progressive periodontitis can destroy the gingiva and alveolar bone and frequently results in tooth loss (McFadden and Marretta 2013; Wallis and Holcombe 2020). In dogs, GTR is recommended for managing moderate-to-severe periodontitis (Bellows et al. 2019). Furthermore, the alveolar bone volume may decrease by up to 63% at 6 months following tooth extraction (Sato et al. 2022), which is detrimental to canine oral health. In human dentistry, removable dentures and implant-supported fixed prostheses have emerged as reliable therapeutic options. However, implant placement may be restricted by inadequate bone height and/or width, inflammation, and peri-implant bone loss, often necessitating bone augmentation procedures (Bal et al. 2023). In veterinary dentistry, treatment decisions are often complex and may not always be fully appreciated by owners.

Dogs can survive after tooth loss or extraction, but these outcomes may have adverse consequences. Preserving teeth, particularly canine and carnassial teeth, benefits overall health because they are important for grasping, cutting, and chewing meat and other food materials (Lee et al. 2023). Periodontal degeneration is usually irreversible, and functional recovery through periodontal tissue reconstruction is considered a major goal of modern dentistry. Several interventions have been proposed to promote periodontal tissue regeneration, halt disease progression, or prevent further deterioration. These include laser therapy (Zuckerman et al. 2024), stem cell therapy (Crossman et al. 2018), biomaterial-based approaches (Sun et al. 2023), and guided tissue regeneration techniques (Esposito et al. 2005; Artzi et al. 2015).

GTR uses tissue barriers to selectively target specific cell populations, along with tissue morphogenic factors such as enamel matrix derivatives to stimulate tissue growth (Artzi et al. 2015). This technique reconstructs bone by applying barriers that prevent the ingrowth of undesirable soft tissue while promoting the migration of bone-forming cells into the defect site. In human dentistry, advanced periodontal procedures such as GTR are

preferred over tooth extraction whenever possible. However, clinical data on the efficacy, success, and complication rates of GTR for bone regeneration are extremely limited.

This study aimed to assess the clinical and radiographic outcomes of GTR for the treatment of partial periodontal defects. The follow-up lasted for 1–2 years, and this study specifically aimed to determine potential thresholds for bone gain and functional recovery.

MATERIAL AND METHODS

The Ethics Committee for the Care and Use of Animal Resources approved this retrospective study protocol (Approval No. RAMC 20-RS-11). All procedures performed in this study were conducted in accordance with approved guidelines and protocols. Permission for participation was obtained, and the director of the institution authorised the publication of the findings.

Animal selection, clinical history and diagnosis

This retrospective study included canine patients presented by their owners to the Department of Veterinary Dentistry at the Royal Animal Medical Centre, Jungnang-gu, Seoul, Republic of Korea between March 2020 and July 2023. We provided the owners with comprehensive information about the surgical procedure, and they provided written informed consent. We obtained a detailed clinical history for each patient. This included general health status from adoption to presentation; previous oral care practices such as tartar removal and tooth brushing; and any clinical signs of oral disease, including halitosis, pain, and/or unilateral bleeding. All patients underwent a comprehensive clinical examination and radiographic evaluation to confirm the diagnosis after reviewing their medical and dental histories (Figure 1).

Animal inclusion criteria and follow-up

After recovery from GTR reconstruction surgery and discharge from the hospital, owners were advised to return for follow-up examinations at 3, 6,

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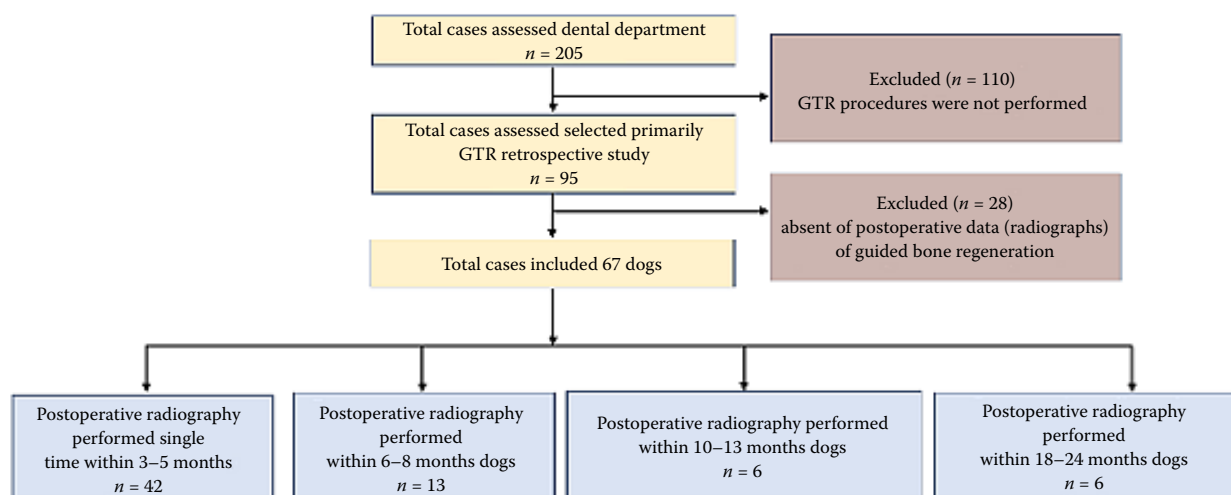


Figure 1. Flowchart of animal inclusion and exclusion criteria for a retrospective study on guided tissue regeneration (GTR) therapy

12, 18, and 24 months postoperatively. Each follow-up examination included assessments of periodontal probing depth (PD), clinical attachment level (CAL), and dental radiography to measure bone defect size (BDS).

However, owner compliance varied, and the follow-up intervals were not uniform. Based on the timing of the postoperative radiographic examinations, the animals were allocated to four follow-up groups: 3–5 months ($n = 42$), 6–8 months ($n = 13$), 10–13 months ($n = 6$), and 18–24 months ($n = 6$) (Figure 1, Table 1). Tooth survival was determined by direct clinical or radiographic examination performed by a veterinarian, or by telephone follow-up based on information provided by the owners when multiple postoperative re-examinations were not available.

Dogs were eligible for inclusion in this retrospective study if they had undergone GTR and had at least one postoperative follow-up assessment performed under anaesthesia within 3–12 months after the procedure. Additional telephone follow-up was available for up to 24 months. Cases were excluded if preoperative data or at least one postoperative follow-up dataset, including periodontal probing and dental radiographic findings, were unavailable or telephone follow-up for up to 24 months had not been obtained. Sixty-seven dogs fulfilled the inclusion criteria and were enrolled in the study.

Clinical data collected for each dog included breed, sex, age, body weight, treated tooth, exact location of the treated site on the tooth, type of bone graft material used, type of barrier membrane applied, and site of GTR.

Table 1. Guided tissue regeneration corrects bone defects and improves probing depth and clinical attachment loss in dogs

Groups	Time lines	Bone defect (mm)	Probing depth (mm)	CAL (mm)
3–5 months ($n = 42$)	preoperative	2.76 ± 0.14	4.56 ± 0.10	3.25 ± 0.11
	postoperative	$0.77 \pm 0.10^{***}$	$1.87 \pm 0.05^{***}$	$2.08 \pm 0.06^{***}$
6–8 months ($n = 13$)	preoperative	3.14 ± 0.21	4.72 ± 0.15	3.15 ± 0.20
	postoperative	$0.50 \pm 0.06^{***}$	$2.06 \pm 0.17^{***}$	$1.86 \pm 0.04^{***}$
10–13 months ($n = 6$)	preoperative	2.93 ± 0.16	4.60 ± 0.12	3.13 ± 0.13
	postoperative	$0.29 \pm 0.08^{***}$	$2.10 \pm 0.05^{***}$	$1.89 \pm 0.06^{***}$
18–24 months ($n = 6$)	preoperative	3.39 ± 0.33	4.29 ± 0.12	2.83 ± 0.20
	postoperative	$0.08 \pm 0.10^{***}$	$2.05 \pm 0.04^{***}$	$1.44 \pm 0.11^{***}$

Data are reported as means $\pm$ SEM; $^{***}P < 0.001$; Student's *t*-test or Mann-Whitney test versus preoperative value
CAL = clinical attachment loss; GTR = guided tissue regeneration

Surgical procedure

Following preoperative blood testing and thoracic radiography, the patients were anaesthetised and administered intravenous fluid therapy. Oral disinfection was subsequently performed, and standardised clinical photographs were obtained before and after scaling. Dental radiographs were acquired with the patient positioned in sternal or dorsal recumbency. A veterinarian recorded the number and location of abnormal teeth, severity and distribution of periodontal disease, presence of dental calculus, tooth wear (attrition), dental caries, and other oral abnormalities including oronasal fistulas, cutaneous fistulas, purulent discharge, and missing teeth.

Two experienced surgeons performed all surgical procedures to treat the identified periodontal lesions. Pre- and postoperative PD and CAL were recorded independently by Chul Park and Kwangil Han, and the mean values were used for the final analysis. In addition, the BDS was rechecked by all the authors. Before reconstructive surgery, all patients received prophylactic antibiotics and analgesics 2–3 h preoperatively, followed by long-term postoperative medication. Surgery was performed only after adequate general and local anaesthesia were confirmed.

Anaesthesia was induced with propofol (6–8 mg/kg i.v.) and maintained with sevoflurane (1–5%) (Kim et al. 2020). Positive pressure ventilation was provided throughout the procedure. Electrocardiography and end-tidal CO₂ were continuously monitored using an automated anaesthetic system (PAIEON; J & TEC, Goyang-si, Gyeonggi-do, Republic of Korea) (Jeong et al. 2019). During the first 24 h after surgery, injectable analgesics were administered every 4–6 h and antibiotics were administered every 8 hours. The postoperative oral medications included tramadol (2–4 mg/kg every 8–12 h), cephalexin (22 mg/kg every 12 h), and non-steroidal anti-inflammatory drugs prescribed by the attending veterinarian for 7–14 days (Seo et al. 2024; Han et al. 2025).

The surgical approach was determined by the location of the alveolar bone defect and the affected tooth. In general, the procedure consisted of gingival flap elevation, soft tissue removal from the defect site, root surface planing, and cortical perforation. Regenerative treatment included bovine-derived xenograft material (Bio-Oss[®]; Geistlich Pharma AG, Wolhusen, Switzerland) or enamel

matrix derivative (Emdogain[®]; Biora AB, Malmö, Sweden). This was applied in combination with a resorbable collagen membrane: Bio-Gide[®] (Geistlich) or an extracellular matrix-based membrane (Lyso-Gide; Oscotec Inc., Seongnam, Republic of Korea) or a collagen membrane NatraFuse[®] (VETEREGEN, Hanam-si, Republic of Korea).

The membrane was adapted to the defect and initially secured to the lingual or palatal side using osteosynthesis screws. The graft material was subsequently placed into the defect and the membrane was further stabilised on the buccal side using titanium pins. Care was taken to prevent contact between the membrane and adjacent teeth. When necessary, tenting screws were used in the two-stage technique to maintain sufficient space for regeneration. The flaps were then repositioned and closed using non-resorbable sutures. After placement between the bone and gingival tissue, the membrane maintains a protected space conducive to healing and regeneration. The membrane was gradually resorbed during healing, and the sutures were removed postoperatively according to the healing status of the surgical site.

Statistical analysis

Data were analysed using Prism v5.03 (GraphPad Software Inc., San Diego, CA, USA). Depending on the type of comparison and data distribution, statistical analysis was performed using one-way analysis of variance (ANOVA), followed by Bonferroni's post hoc test, Student's *t*-test, or the Mann-Whitney *U* test. The results are presented as the mean ± standard error of the mean (SEM) or as proportions. A value of *P* < 0.05 was considered statistically significant.

RESULTS

Study cohort

In total, 205 patient records were retrieved and screened. Of these, 138 cases were excluded for the following reasons: treatment of dental disorders using surgical or therapeutic procedures other than GTR (*n* = 110) and absence of postoperative radiographic follow-up data after guided bone regeneration (*n* = 28). GTR surgery was performed using

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Emdogain and a collagen membrane in 61 regions (47.29%, 61/129), Bio-Oss and a collagen membrane in 64 regions (49.61%, 64/129), and NatraFuse in 4 regions (3.10%, 4/129). Among the 129 treated regions, 65 (50.39%) had periodontal vertical bone defects, 53 (41.09%) had furcation bone defects, and 11 (8.53%) had interdental bone defects.

Sex and breeds

A total of 129 periodontal defects were treated in 67 dogs. Of these, 28 dogs (41.79%) were female (24 spayed and 4 intact). Thirty-nine (58.21%) were male (38 castrated and 1 intact). The dogs ranged in age from 2 to 18 years, with a mean of 8.51 ± 0.44 years.

The study sample included 19 breeds. The most common breeds were Poodle (16/67, 23.88%), Shih Tzu (10/67, 14.93%), mixed (5/67, 7.46%), Maltese (4/67, 5.97%), Golden Retriever (4/67, 5.97%), and Chihuahua (4/67, 5.97%). Other breeds included the Schnauzer (3/67, 4.48%), Pomeranian (3/67, 4.48%), Shiba Inu (3/67, 4.48%), Bichon Frise (3/67, 4.48%), Yorkshire Terrier (2/67, 2.99%), Welsh Corgi (2/67, 2.99%), and Cocker Spaniel (2/67, 2.99%). Each of the Border Collie, Maltipoo, Miniature Pinscher, Spitz, Pug, and Pungsan breeds was represented by one case.

Number and sites of GTR surgery

The number of teeth treated with GTR per dog ranged from 1 to 9, with a mean of 2.12 sites per dog. GTR was performed at a single site in 25 dogs

(37.31%) and at multiple sites in 42 dogs (62.69%). Among the dogs undergoing multisite treatment, the number of treated regions ranged from 2 to 9. Specifically, 29 of 42 dogs (69.05%) received treatment at 2 sites, 9 of 42 dogs (21.43%) at 3 sites, 3 of 42 dogs (7.14%) at 4 sites, and 1 of 42 dogs (2.38%) at 9 sites (Figure 2).

The fourth premolar (PM4; 49/129, 37.98%) was the most frequently treated tooth, followed by the canine (44/129), first molar (M1; 14/129, 10.85%), and first premolar (PM1; 3/129). In addition, 11 of the 129 procedures (8.53%) involved interdental GTR, including canine PM1 (8/129, 6.20%), PM4–M1 (2/129, 1.55%), and PM4–PM3 (1/129, 0.78%). The most common site of GTR surgery was the right PM4, with 24 cases in the maxilla and 4 in the mandible. On the left side, the corresponding values were 20 and 1, respectively. Overall, 86 of the 129 treated teeth (66.67%) were located in the maxilla, which was significantly higher than the number in the mandible (43/129, 33.33%) (Table 2).

Clinical consequences of GTR

In this study, treatment success was evaluated based on tooth survival and improvement in periodontal indices, including reductions in PD and BDS and an increase in CAL. At baseline, the bone defect size ranged from 1.10 to 5.75 mm, with a mean value of 2.76 ± 0.11 mm across the 129 treated sites. The PD ranged from 4.0 to 8.0 mm (mean 4.55 ± 0.06 mm), while the CAL ranged from 2.0 to 6.75 mm (mean 3.16 ± 0.08 mm).

At the 3-to-5-month follow-up, radiographic and clinical data were available for 93 sites from

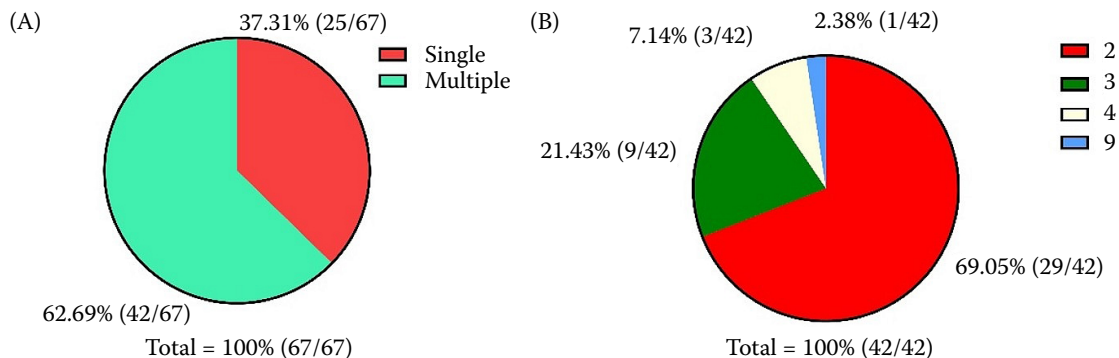


Figure 2. Prevalence and distribution of the number of regions treated with guided tissue regeneration surgery per case (A) Number of treated sites (single or multiple) per patient. (B) Number of treated sites per patient in dogs with multisite treatment (2, 3, 4, or 9 sites)

Table 2. Number and percentage of dental GTR procedures performed in dogs stratified by anatomical location

	Maxilla																					
	right										left											
	M2	M1	PM4	PM3	PM2	PM1	C	I3	I2	I1	I1	I2	I3	C	PM1	PM2	PM3	PM4	M1	M2		
Total	-	4	24	-	-	1	12	1	1	1	-	-	-	9	1	-	-	20	4	1		
Percentage	-	3.10	18.60	-	-	0.78	9.30	0.78	0.78	0.78	-	-	-	6.98	0.78	-	-	15.50	3.10	0.78		
GTR performed in intra-dental bone defect	-	-	1	-	-	2	-	-	-	-	-	-	-	2	-	-	-	2	-	-		
Percentage	-	-	0.78	-	-	1.55	-	-	-	-	-	-	-	1.55	-	-	-	1.55	-	-		
GTR performed in one site	47	-	-	-	-	-	-	-	-	-	-	-	-	-	39	-	-	-	-	-		
GTR performed in maxilla	86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	Mandible																					
	right										left											
	M3	M2	M1	PM4	PM3	PM2	PM1	C	I3	I2	I1	I1	I2	I3	C	PM1	PM2	PM3	PM4	M1	M2	M3
Total	-	1	3	4	-	-	-	11	1	1	1	-	-	-	12	1	-	-	1	3	-	-
Percentage	-	0.78	2.33	3.10	-	-	-	0.78	0.78	0.78	0.78	-	-	-	0.78	0.78	-	-	0.78	2.33	-	-
GTR performed in intra-dental bone defect	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	
Percentage	-	-	-	-	-	-	1.55	-	-	-	-	-	-	1.55	-	-	-	-	-	-	-	
GTR performed in one site	-	-	-	-	-	24	-	-	-	-	-	-	-	-	19	-	-	-	-	-	-	
GTR performed in mandible	-	-	-	-	-	-	-	-	-	-	-	43	-	-	-	-	-	-	-	-	-	
Total GTR performed	-	-	-	-	-	-	-	-	-	-	-	129	-	-	-	-	-	-	-	-	-	

(-) = no sites treated; C = canine; GTR = guided tissue regeneration; I = incisor; M = molar; PM = premolar

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42 cases. The mean bone defect size decreased significantly from 2.76 ± 0.14 to 0.77 ± 0.10 mm ($P < 0.001$). The mean PD was significantly reduced from 4.56 ± 0.08 mm to 1.87 ± 0.05 mm ($P < 0.001$), and the mean CAL decreased from 3.25 ± 0.11 mm to 2.08 ± 0.06 mm ($P < 0.001$) (Figures 3 and 4).

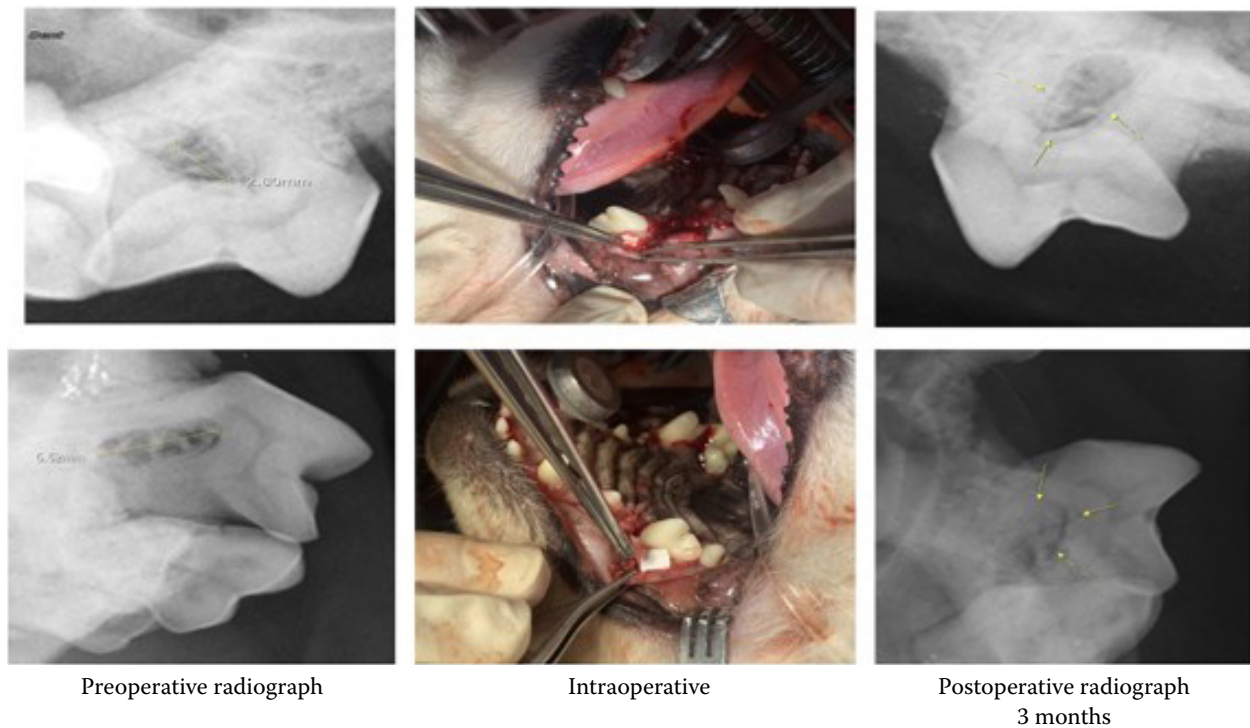


Figure 3. Representative images for the clinical diagnosis, surgical procedure, and radiographic postoperative follow-up for up to 3 months

Guided bone regeneration using Bio-Oss® and a collagen membrane was performed in an 8-year-old castrated male Pomeranian dog for furcation defects involving the right maxillary fourth premolar (PM4) and left mandibular fourth premolar (PM4). The osseous defects gradually resolved, and complete correction of the bone defects was observed by 3 months postoperatively. Clinical probing depth decreased from 6.6 to 1.4 mm and from 4.0 to 1.0 mm, while the clinical attachment level improved from 2.6 to 1.1 mm

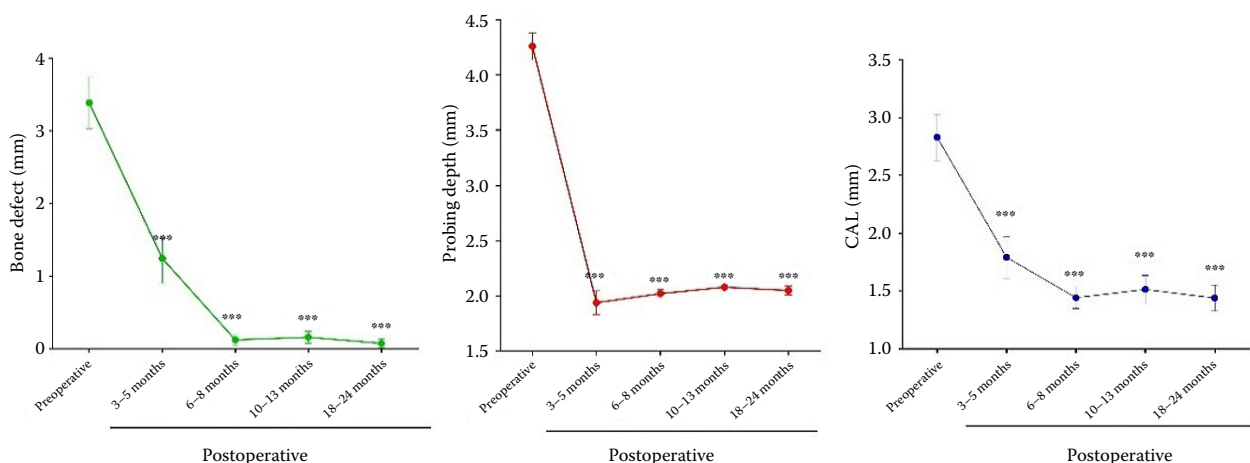


Figure 4. Follow-up results demonstrated gradual improvement in bone defects, probing depth, and clinical attachment loss over 18–24 months after the guided tissue regeneration procedure in dogs

Data are presented as mean $\pm$ SEM ($n = 9$ sites from 5 dogs); *** $P < 0.001$ compared with the preoperative value, as determined by Bonferroni post hoc testing following one-way ANOVA

At the 6–8-month follow-up, radiographic and clinical data were available for 15 sites in 13 patients. The mean bone defect size decreased significantly from 3.14 ± 0.21 mm to 0.50 ± 0.06 mm ($P < 0.001$). The mean PD was reduced from 4.72 ± 0.15 mm to 2.06 ± 0.17 mm ($P < 0.001$), and the mean CAL decreased from 3.15 ± 0.20 mm to 1.86 ± 0.04 mm ($P < 0.001$) (Figures 4 and 5).

At the 10-to-13-month follow-up, radiographic and clinical data were available for 7 sites from 6 cases. The mean bone defect size decreased significantly from 2.93 ± 0.16 to 0.29 ± 0.08 mm ($P < 0.001$). The mean PD was reduced from 4.60 ± 0.16 to 2.10 ± 0.04 mm ($P < 0.001$), and the mean CAL decreased from 3.13 ± 0.13 to 1.89 ± 0.06 mm ($P < 0.001$) (Figures 4 and 6).

At the final 18-to-24-month follow-up examination, radiographic and clinical data were available for 10 sites from 6 patients. The mean bone defect size decreased significantly from 3.39 ± 0.33 to 0.08 ± 0.05 mm ($P < 0.001$). The mean PD was also reduced from 4.29 ± 0.12 to 2.05 ± 0.04 mm ($P < 0.001$), and the mean CAL decreased from 2.83 ± 0.19 to 1.44 ± 0.11 mm ($P < 0.001$) (Figures 4 and 7).

The cumulative tooth survival rate decreased from 98.45% ($n = 127/129$) at 3–5 months to 93.02% ($n = 120/129$) at 18–24 months over the 24-month follow-up period, with intermediate survival rates of 97.67% ($n = 126/129$) at 6–8 months and 96.12% ($n = 124/129$) at 10–13 months.

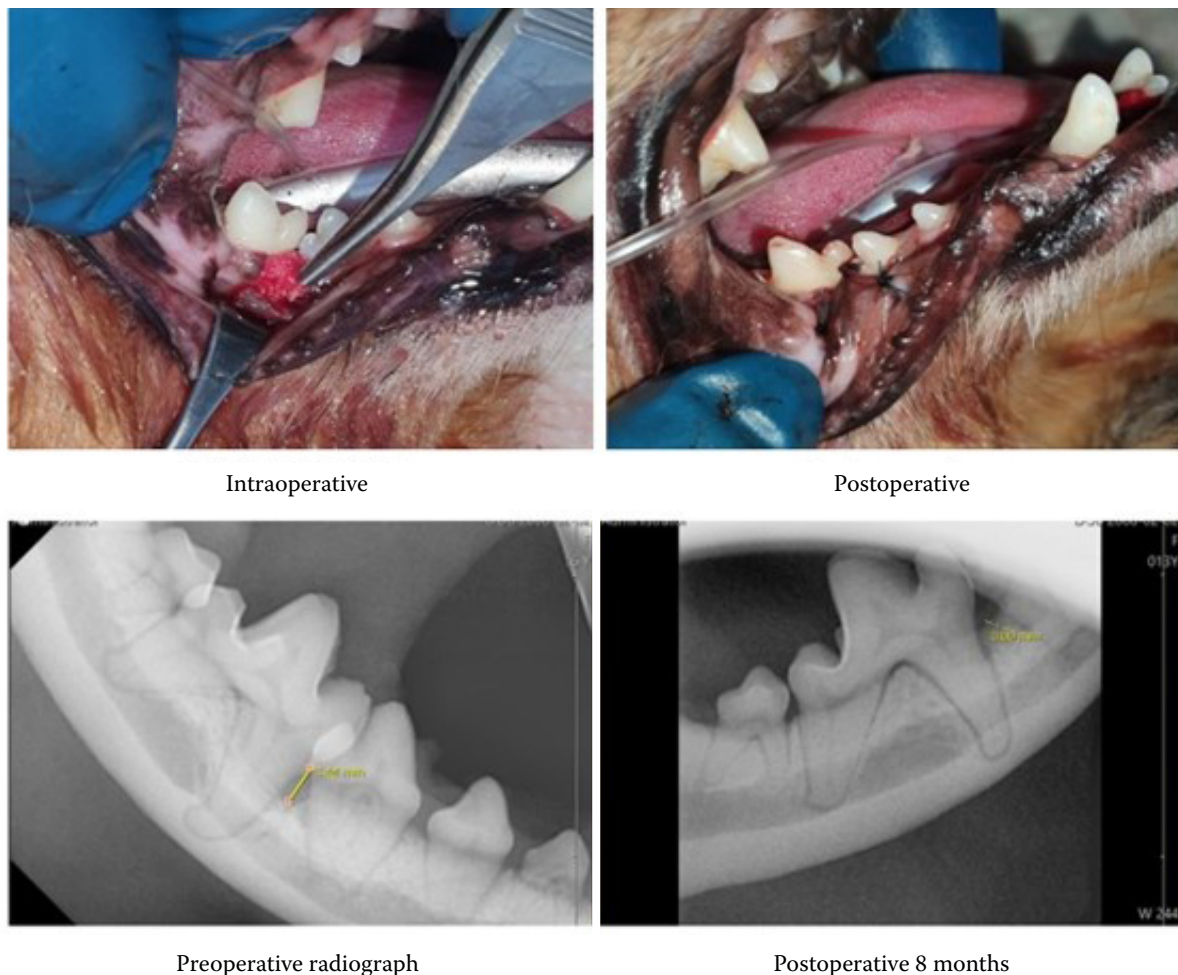


Figure 5. Representative images for the clinical diagnosis, surgical procedure, and long-term radiographic postoperative follow-up for up to 8 months

Guided bone regeneration using Bio-Oss® and a collagen membrane was performed to correct an intrabony defect involving the left mandibular canine and first premolar (PM1) in a 12-year-old spayed female Chihuahua dog. The bone defect gradually resolved, and complete correction was observed by 8 months postoperatively. Clinical probing depth decreased from 4.00 to 2.00 mm, while the clinical attachment level improved from 5.56 to 1.9 mm

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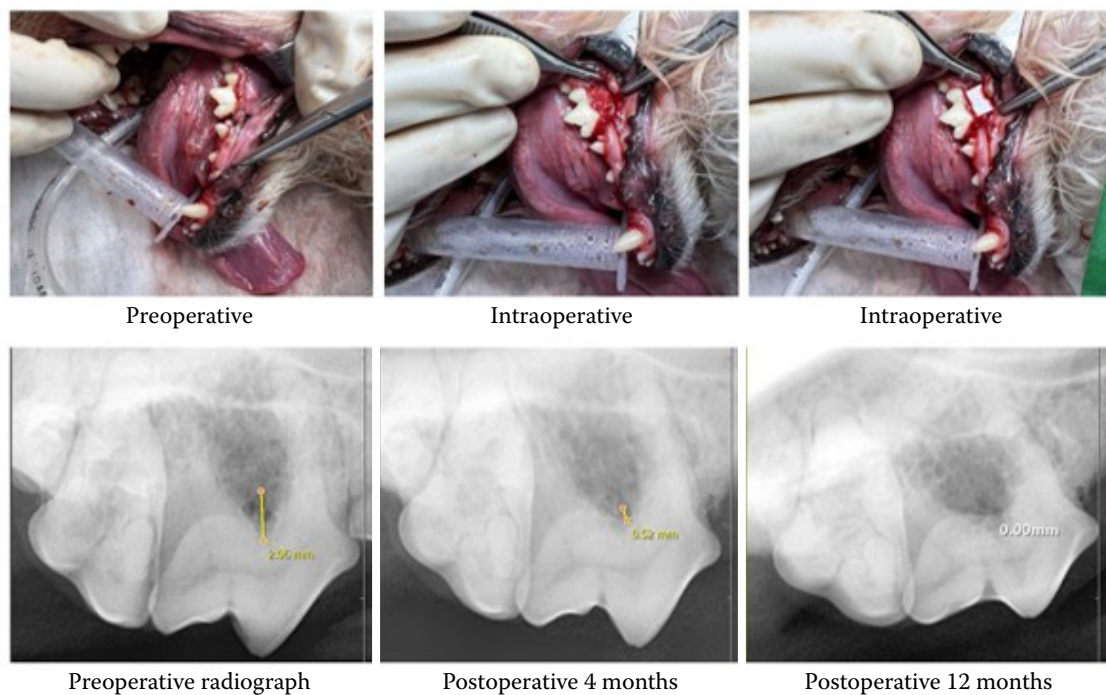


Figure 6. Representative images for clinical diagnosis, surgical procedure, and long-term radiographic postoperative follow-up up to 12 months

Guided bone regeneration using Bio-Oss® and a collagen membrane was performed to correct an intrabony defect involving the right maxillary fourth premolar (PM4) in a 10-year-old castrated male mixed-breed dog. The bone defect gradually resolved, and complete correction was observed by 12 months postoperatively. Clinical probing depth decreased from 4.00 to 1.00 mm, while the clinical attachment level improved from 4.2 mm to 2.2 mm

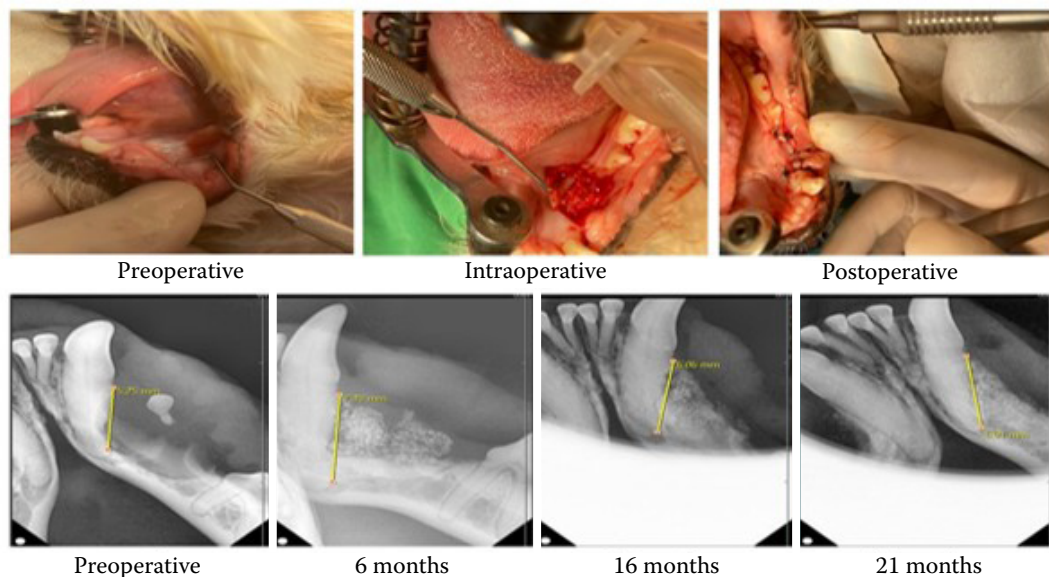


Figure 7. Representative images for clinical diagnosis, surgical procedure, and long-term radiographic postoperative follow-up

Guided bone regeneration using Bio-Oss® and a collagen membrane was performed in a 6-year-old spayed female Shih Tzu dog to treat an intrabony defect involving the left mandibular canine tooth. The bone defect gradually resolved, and complete correction of the defect was observed by 21 months postoperatively. Clinical probing depth decreased from 4.2 mm to 1.1 mm, while the clinical attachment level improved from 4.0 mm to 1.1 mm

DISCUSSION

Periodontitis is a chronic infectious disease of the gingiva that leads to the destruction of supporting structures of teeth and, ultimately, tooth loss. Surgical intervention may be required to halt disease progression and restore damaged tissues. Various surgical techniques, including guided tissue regeneration (GTR), bone grafting, and application of enamel matrix derivatives (EMDs), have been developed to regenerate periodontal tissues (Esposito et al. 2005). This retrospective study showed that GTR techniques using the natural bone substitute Geistlich Bio-Oss® or enamel matrix derivative Emdogain®, combined with an absorbable collagen membrane, effectively reduced bone defect size and probing depth while significantly improving CAL gain. The survival rates at 3–5, 6–8, 10–13, and 18–24 months were 98.45% (127/129), 97.67% (126/129), 96.12% (124/129), and 93.02% (120/129), respectively. Based on the clinical and radiographic findings and survival rate, GTR treatment for severe periodontal disease in dogs resulted in clinically successful outcomes. Consistent with our findings, previous experimental studies have shown that the application of Bio-Oss and absorbable collagen membranes effectively promotes bone regeneration, as evidenced by improvements in bone volume/total volume, trabecular number, trabecular separation, and trabecular thickness measured using three-dimensional reconstruction imaging and histomorphometric analysis (Alkan et al. 2013; Li et al. 2018). Histopathological studies have also demonstrated marked bone regeneration at EMD- or Bio-Oss Collagen-treated sites at 3 months after application (Alkan et al. 2013). In addition, the present study showed that our GTR procedures not only stimulated bone regeneration but also promoted periodontal ligament healing, as indicated by significant CAL gain. This was a retrospective clinical study involving client-owned dogs, and micro-CT and histopathological analyses could not be performed. Nevertheless, histological evaluation is necessary to confirm the true regenerative outcomes of GTR.

Guided bone regeneration (GBR) and GTR are dental surgical techniques that use barrier membranes placed between the gingival epithelium and alveolar bone or periodontal ligament tissues to facilitate the formation of new bone and periodontal tissues in areas with insufficient bone or tissue volume for optimal function, aesthetics,

or prosthetic restoration. In simple terms, GTR involves the regeneration of three of the four tissues of the diseased periodontium – the cementum, periodontal ligament, and alveolar bone, while the fourth tissue (gingival tissue) is excluded by means of a membrane barrier (Alqahtani et al. 2023). GBR is similar to GTR, but it generally refers to ridge augmentation or bone regenerative procedures, whereas GTR specifically focuses on regenerating hard tissues, including bone and cementum, and the soft tissues involved in periodontal attachment. This restores periodontal attachment (Miloró 2004). Thus, GTR aims to regenerate all three major periodontal components.

The use of barrier membranes for direct bone regeneration was first described in orthopaedic research in 1959 (Hurley et al. 1959). The fundamental theoretical concepts of guided tissue regeneration were later established by Melcher in 1976, who emphasised the importance of excluding undesirable cell types from healing sites to enable the formation of desired tissues (Melcher 1976). Following favourable clinical results in periodontal regeneration studies during the 1980s, research attention shifted toward the reconstruction of alveolar bone defects using guided bone regeneration. Guided tissue regeneration has attracted substantial attention in dentistry. Nyman first introduced the barrier membrane approach in 1982 (Nyman et al. 1982), and Gottlow later coined the term “guided tissue regeneration” in 1986 (Gottlow et al. 1986; Srivastava et al. 2015). GTR has been defined as a group of procedures aimed at regenerating lost periodontal structures through differential tissue responses. Barrier membranes are used to prevent the epithelium and gingival connective tissue from contacting the root surface based on the premise that such contact interferes with periodontal regeneration. Accordingly, the purpose of GTR membranes is to exclude the epithelial and gingival connective tissue, preserve the space between the defect and tooth, and stabilise blood clots. GBR is conceptually similar to GTR but primarily focuses on hard tissue regeneration in addition to the soft tissues of periodontal attachment. The principle of GBR was first examined by Dahlin et al. in 1988 using a rat model (Dahlin et al. 1988). Selective ingrowth of osteogenic cells into a bone defect can be enhanced if the adjacent soft tissue is excluded by a membrane, as later confirmed by Kostopoulos and Karring in 1994

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(Kostopoulos and Karring 1994). Non-resorbable membranes require a second surgical procedure for removal, and there has been an increasing interest in bioabsorbable membranes that provide equivalent or superior therapeutic outcomes. In addition, resorbable membranes reduce patient discomfort, lower treatment costs, and eliminate the risk of complications associated with secondary surgery (Bottino and Thomas 2015).

Emdogain is an EMD primarily used to enhance cementogenesis; however, it can also stimulate the expression of osteogenesis-related genes in mesenchymal cells and may serve as an osteopromotive agent in the treatment of destructive periodontal lesions (Lee et al. 2020). The adjunctive use of EMD is expected to exert synergistic and beneficial effects on periodontal tissue and bone healing. In the present study, we conducted a canine clinical trial and found that the application of Emdogain with a collagen membrane significantly reduced the bone defect size and PD. Consistent with these findings, previous controlled clinical trials in humans have shown that the adjunctive use of EMD improves early wound healing and promotes cementum-mediated new attachment and periodontal regeneration in both nonsurgical and surgical periodontal therapies (Wennstrom and Lindhe 2002; Tonetti et al. 2004).

Bio-Oss is a porous bone mineral derived from bovine bones. It is produced by deproteinising bovine bone, resulting in a structure similar to that of human cancellous bone. It is primarily used to correct bone defects but is also widely used in dentistry to promote periodontal bone growth and tissue regeneration (Alkan et al. 2013; Li et al. 2018). In the present canine clinical trial, we found that Bio-Oss in combination with a collagen membrane significantly reduced bone defect size and PD.

Among the dogs undergoing GTR for severe periodontal disease, bone defects, and marked PD in the present study, 58.21% (39/67) were male and 41.79% (28/67) were female. These findings are consistent with a previous report indicating that periodontal disease occurred in 52.7% of male dogs and 47.3% of female dogs (Wallis et al. 2021). Male dogs have greater aggressiveness and boldness than females (Scandurra et al. 2018), which may predispose them to dental injuries and periodontitis. Additionally, we found that 92.54% (62/67) of dogs that underwent GTR were neutered. Similarly, a previous survey reported that

70.8% of the dogs were neutered (Wallis et al. 2021). This observation is further supported by an earlier study (Marshall et al. 2014). The high proportion of neutered dogs in the present study may reflect the greater prevalence of neutering in Seoul, Korea, than in other countries (Jeong et al. 2019; Seo et al. 2020). Furthermore, neutering before the completion of skeletal growth and maturation may contribute to the development of bone and joint disorders (Oberbauer et al. 2019; Seo et al. 2020). Therefore, additional research is needed to evaluate the potential effects of neutering on the cementum, periodontal ligament, and alveolar bone, all of which may influence oral and dental health.

Among the 19 dog breeds included in this study, the most frequently represented were Poodle (23.88%), Shih Tzu (14.93%), mixed breed (7.46%), Maltese (5.97%), Golden Retriever (5.97%), Chihuahua (5.97%), Schnauzer (4.48%), Pomeranian (4.48%), Shiba Inu (4.48%), and Bichon (4.48%). These findings agree with those of a previous study showing that toy poodles have significantly thinner gingiva and alveolar bone than other small- and medium-sized breeds (Wallis and Holcombe 2020). Reduced gingival thickness is also associated with a high incidence of periodontal diseases (Harvey 2005). The differences among these studies may be attributed to geographic or regional variations. A previous study reported that periodontal disease was most prevalent in Yorkshire Terriers (25.2%), followed by Cocker Spaniels (12.8%) and Jack Russell Terriers (9.5%) (O'Neill et al. 2014). However, most dogs in Korea are small breeds (Jeong et al. 2019; Seo et al. 2020). Genetic differences and breed-specific oral morphologies have been proposed as risk factors for periodontal diseases (Wallis and Holcombe 2020). Small dogs tend to have relatively larger teeth than larger breeds and are more susceptible to malocclusion and dental diseases (Wallis and Holcombe 2020; Wallis et al. 2021).

To the best of our knowledge, this is the first report to describe site-specific GTR in dogs. Among all teeth treated with GTR, PM4 accounted for 49/129 (37.98%), followed by canine teeth for 44/129 (34.11%), M1 for 14/129 (10.85%), and PM1 for 3/129 (2.33%). The difficulty associated with these teeth may arise from the challenge of adequately removing plaque using routine brushing techniques. Previous studies have reported a higher prevalence of periodontal disease in the premolars and molars, particularly PM4 and PM1

(Kortegaard et al. 2008; Wallis and Holcombe 2020). Some investigators have suggested that premolars have the highest prevalence of periodontal lesions (Hoffmann and Gaengler 1996; Wallis et al. 2019), whereas others have proposed that incisors are particularly vulnerable to dental pathologies (Marshall et al. 2014; Wallis et al. 2018). In the present study, GTR was performed significantly more frequently in the maxilla (66.67%, 86/129) than in the mandible (33.33%, 43/129), although there was no significant difference in the number of teeth extracted from the maxilla and mandible. Consistent with this finding, several studies have reported a higher prevalence of periodontal disease involving maxillary than involving mandibular teeth (Kortegaard et al. 2008; Wallis et al. 2019; Wallis and Holcombe 2020).

Selection bias cannot be excluded because this retrospective study included only patients who returned for scheduled re-evaluation. Dogs assessed during the long-term follow-up by telephone and without clinical or radiographic re-examination may have had different outcomes; therefore, the reported success rates may have overestimated the true long-term effectiveness of GTR despite owner-confirmed telephone follow-up. Postoperative treatment included analgesics and antibiotics at the clinician's discretion, and owners were advised to return for re-evaluation at 3, 6, 12, 18, and 24 months. However, detailed information on owner compliance with home-based oral hygiene, plaque control, and minor postoperative complications was not consistently available in the medical records. Systemic health status, age-related changes, and other patient-related factors that may influence periodontal healing and regenerative outcomes were also not controlled. These limitations may have contributed to the variability in the treatment response and should be considered when interpreting the present findings. Likewise, the rationale for selecting one biomaterial over another could not be fully determined from the medical records. These factors may have influenced the outcome variability and should be addressed in future investigations. This study also highlighted the practical challenges inherent to retrospective veterinary dental research.

Within the limitations of this retrospective case series, GTR may represent a promising tooth-preserving treatment option for selected dogs with severe periodontal defects. Treatment was

associated with favourable clinical and radiographic outcomes and high tooth survival at post-operative follow-up examinations. However, the absence of a control group, incomplete and variable long-term follow-up, limited number of cases at later evaluation points, and lack of histological confirmation limit the strength of this inference. Further prospective, controlled studies are warranted to confirm the long-term efficacy, stability, and clinical predictability of GTR in dogs. Premolars, canines, and molars were the most commonly treated teeth, and multiple teeth and sites were frequently involved. These findings may assist clinicians with case selection and treatment planning.

Conflict of interest

The authors declare no conflict of interest.

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