Clinical Outcome of Endodontic Microsurgery in Through-and-Through Lesion
: A Retrospective Case-Control Study

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ABSTRACT

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Through-and-through lesions, which means the loss of both lingual/palatal and buccal cortical bone plates could be hard to be properly managed in endodontic microsurgery field. Despite some recent studies reporting success rates of 45–100% for through-and-through lesions, limitations in sample size, follow-up duration, and direct comparisons with non through-and-through lesions highlight the need for more comprehensive analysis. This study aims to evaluate the clinical outcomes of endodontic microsurgery in through-and-through lesions, compare them with non through-and-through lesions, and identify factors influencing these outcomes.

This retrospective case-control study reviewed 115 cases of endodontic microsurgery with through-and-through lesions(T-T group) and 294 with intact palatal or lingual cortical bone(non T-T group). Propensity score matching (1:2) was applied to reduce bias. Clinical outcomes were evaluated at 1 year and 3 years intervals, as well as cumulatively using Kaplan-Meier survival analysis. Logistic regression and Cox proportional hazard regression analyses were used to identify prognostic factors affecting short- and long-term outcomes, with statistical significance set at $p < 0.05$.

In Part I, 1-year success rates were 88.0% for the non T-T group and 77.3% for the T-T group ($P < 0.05$). For the 3-year outcome, success rates were 97.1% (non T-T) and 88.2% (T-T). Tooth position and lesion type were significant predictors of the 1 year outcome, with mandibular anterior teeth and T-T group associated with higher failure rates. No statistically significant factors were identified for the 3 years outcome. Cumulative survival analysis showed no significant difference between groups (P = 0.103).

In Part II, Logistic regression revealed that sex was a statistically significant factor for 3-year success, with males showing higher success rates (Odds ratio = 19.466). There was no statistically significant factor for 1 year and cumulative outcome.

Within the limitation of the present study, while short-term outcomes of endodontic microsurgery significantly differ between through-and-through lesions and non through-and-through lesions, these differences gradually diminish over longer follow-up periods. The cumulative success rates suggest that endodontic microsurgery is a reliable treatment option for through-and-through lesions, achieving comparable long-term outcomes to non through-and-through lesions. This suggests that a sufficient follow-up period longer than 1 year may be necessary for accurately interpret the outcomes of through-and-through lesions, considering the dynamics of healing in through-and-through lesions.

Key words : Endodontic microsurgery; Through-and-through lesion; Treatment outcome; Prognostic factor; Radiographic healing

1. Introduction

The introduction of contemporary surgical methods, including high-power magnification, ultrasonic preparation tools, and biocompatible filling materials, has contributed to the reported high success rate of endodontic microsurgery, ranging from 89% to 94%. (Setzer et al., 2012; Setzer et al., 2010; Tsesis et al., 2013). As a result, endodontic microsurgery is considered as a reliable treatment option to manage persistent apical periodontitis which is difficult to be treated with non-surgical retreatment(Kang et al., 2015).

However still success rates in larger periapical lesions with loss of buccal and lingual cortical plates have been reported to be lower. (Kim et al., 2016; Kim et al., 2008; Song, Kim, Shin, et al., 2013). Larger apical lesion may connect to the periodontal space, which is called as 'endo-perio lesion' or lead to full dehiscence of the buccal bone plate. Sometimes bony repair in such lesions can be prolonged and may involve fibrous tissue healing.

Through-and-through lesions indicate the loss of lingual/palatal and buccal cortical bone plates due to progression of pathology or access window creation during surgical treatment. (Thomas von Arx, 2001). In the field of endodontic microsurgery, older literature has reported very low success rates of 25%, with findings suggesting that connective tissue may grow into the bone defect during healing process, which interrupts normal bony healing(Hirsch, 1979).

The number of studies evaluating the success rates of endodontic microsurgery in through-and-through lesions is limited. The recent success rates of endodontic microsurgery in through-and-through lesions are reported to be higher than before, ranging from 45% to 100% although surgical techniques or evaluation periods vary significantly between studies(Arpitha, 2023; Dhamija et al., 2024; Dhamija et al., 2020; Parmar et al., 2019; Taschieri et al., 2007).

However, none of the studies have compared the clinical outcomes of endodontic microsurgery between through-and-through lesions and other normal lesions with intact palatal/lingual cortical bone, which can be called as non through-and-through lesions. To determine whether the loss of palatal or lingual cortical bone in through-and-through lesions affects clinical outcome of endodontic microsurgery, a comparison with a control group is necessary.

Propensity score matching is a statistical method used in observational studies, which can help to reduce bias from confounding variables when comparing outcomes between two groups(Rosenbaum & Rubin, 1984). There have been a few studies using propensity score matching in the field of endodontic microsurgery. Song et. al. compared the success rates between endo-perio lesions and isolated endodontic lesions using this method(Song et al., 2018). Similarly, Kim et. al. used propensity score matching to compare the success rates of micro-resurgery and primary endodontic microsurgery(Kim et al., 2018). This study also used propensity score matching to compare the clinical outcomes of microsurgery between through-and-through lesions and non through-and-through lesions.

Previous studies have primarily focused on reporting the success rates and differences in healing when various graft materials (e.g., Platelet-rich fibrin + type I collagen mixture, Platelet-rich plasma, resorbable collagen membrane, xenogenic bone grafting) were used in through-and-through lesions(Dhamija et al., 2024; Dhamija et al., 2020; Parmar et al., 2019; Taschieri et al., 2011). To understand the inherent characteristics of through-and-through lesions and the differences in their associated healing processes, it may be helpful to exclude the influence of graft materials during analysis. This is particularly important for bone grafts, as the presence of radiopaque graft material within the lesion on post-operative radiographs can make it challenging to accurately assess bony healing and determine the success of the procedure.

Additionally, mentioned studies included only 30 to 40 teeth each (Arpitha, 2023; Dhamija et al., 2024; Dhamija et al., 2020; Parmar et al., 2019; Taschieri et al., 2011). Also there are few studies that have evaluated long-term success rates beyond the 1-year. Only one retrospective study reported 4-year outcome as 88%(Taschieri et al., 2011) and one randomized controlled study reported 5-year success rate as 95.8%(Dhamija et al., 2024). These findings highlight the need for studies that not only focus on the intrinsic characteristics of through-and-through lesions but also conduct comprehensive analyses based on larger datasets over longer periods.

Therefore, the primary goal of this study is to evaluate the clinical outcomes of endodontic microsurgery in through-and-through lesions and compare these outcomes with those of non through-and-through lesions. Furthermore, both cross-sectional analysis and survival analysis were performed to compare outcomes, allowing for a multifaceted evaluation of the results. The secondary goal is to identify predisposing or intraoperative factors that may influence clinical outcomes of endodontic microsurgery in through-and-through lesion.

2. Material and Methods

2.1. Study design for 2 parts

As described in the introduction part, since this study has two main objectives—(1) to compare the clinical outcomes of microsurgery between through-and-through lesions and non through-and-through lesions, and (2) to identify clinical factors influencing the outcomes in through-and-through lesions—the study design is divided into two parts, each corresponding with these objectives. The design and following descriptions are visually represented in a Figure 1.

Study design

Part I : Clinical Outcome Comparison Between T-T Group and Non-T-T Group

- Survival analysis : Cumulative outcome
- Cross-sectional analysis : 1 year, 3 years outcome

Part II : Prognostic Factors of Clinical Outcomes of Endodontic Microsurgery in Through-and-through Lesion

- Survival analysis : Cumulative outcome
- Cross-sectional analysis : 1 year, 3 years outcome

Figure 1 Study design and for each part

Part I, titled *"Clinical Outcome Comparison Between T-T Group and non T-T Group,"* focused on comparing clinical outcome between T-T group (Endodontic microsurgery in through-and-through lesion) and non T-T group (Endodontic microsurgery in non through-and-through lesion) (Figure 2). Both 1) survival analysis of cumulative outcome based on the last follow-up as well as 2) cross-sectional analysis at 1 year and 3 years, were performed.

Part II, titled *"Prognostic Factors of Clinical Outcomes of Endodontic Microsurgery in*

Through-and-Through Lesion" analyzes factors influencing success rates only within T-T group, without comparisons to the non T-T group (Figure 2).

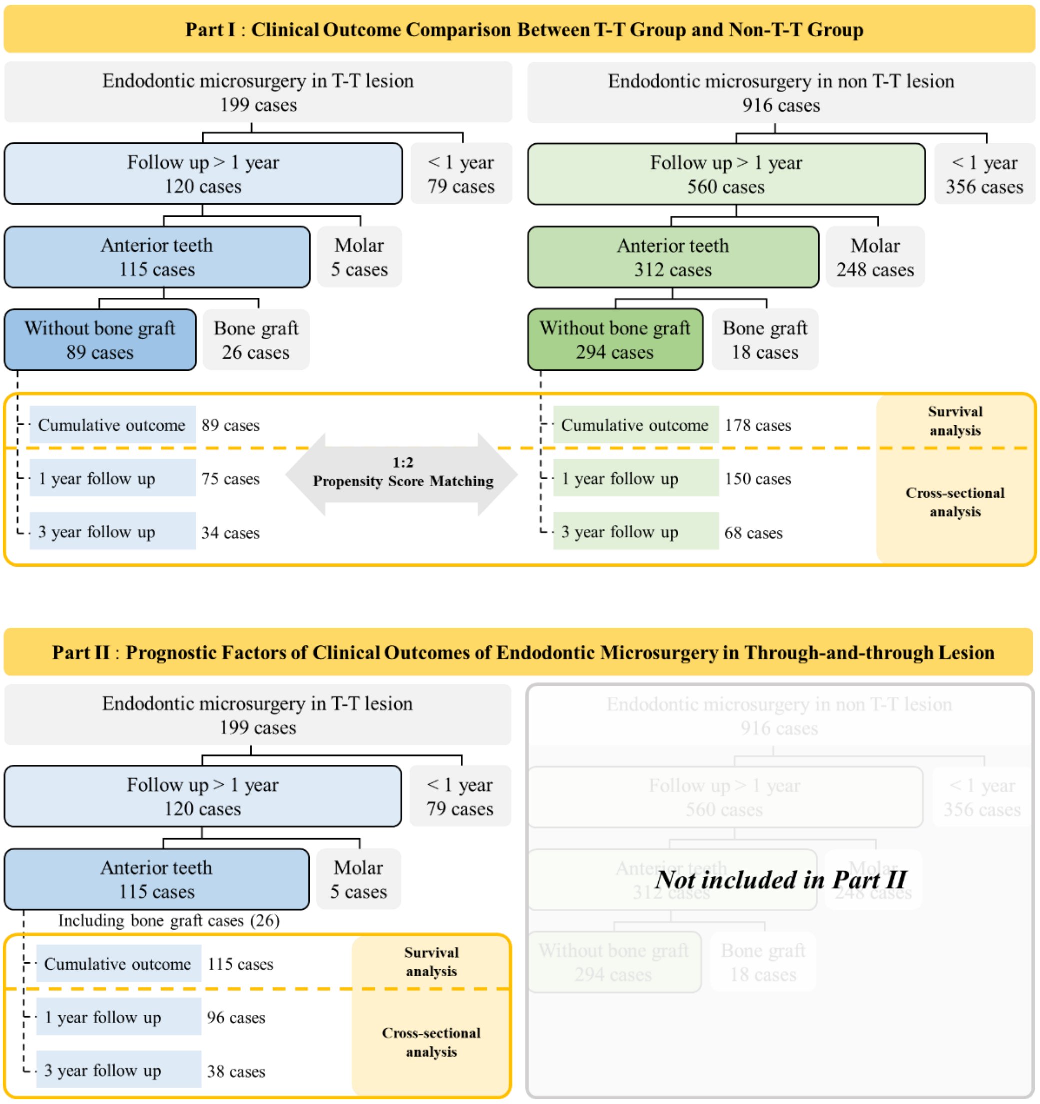

Figure 2 Study design and case selection for each part :
The cases included in the analysis are grouped within the yellow box, while survival analysis and cross-sectional analysis are separated by a yellow dash line.
In Part I, cases for T-T group are on left column, colored with blue box. Cases for non T-T group are on right column with green box. In Part II, analysis was performed only for through-and-through lesion, including bone graft cases.

Also there are slight differences in case selection criteria for each part, which will be described in the following case selection part.

2.2. Case selection

This study was conducted with approval from the Yonsei University Institutional Review Board for Human Research (2-2024-0078) and took place at the Microscope Center within the Department of Conservative Dentistry at Yonsei University College of Dentistry and Dental Hospital, located in Seoul, South Korea. Patient records were reviewed to identify individuals who underwent endodontic microsurgery between January 2013 and December 2023, with all surgical procedures performed by endodontic faculty members.

The Inclusion and exclusion criteria were shown on Table 1, each for Part I and II. Cases involving bone grafting during surgery were excluded from Part I, because the criteria for bone graft application were unclear among various surgeons, and there were differences in indications between the T-T and non T-T groups. These cases, therefore, were excluded for Part I, which focused on inter-group analysis while included in Part II.

2.3. Surgical procedures

Local anesthesia was done using 2% lidocaine with 1:80,000 or 100,000 epinephrine. Full-thickness mucoperiosteal flap was elevated with a Molten 2-4 curette (G Hartzell and Son Inc, Concord, Ca).

Table 1 Inclusion and exclusion criteria for Part I and Part II

Part I	**Part II**
Inclusion criteria	Inclusion criteria
1) **Through-and-through group (T-T group) :** Discontinuity of the palatal or lingual bone is identified on preoperative CBCT images. **Non through-and-through group (non T-T group)** : Endodontic microsurgery cases in which intact palatal or lingual bone is identified on preoperative CBCT images.	1) Endodontic microsurgery cases in which discontinuity of the palatal or lingual bone is identified on preoperative CBCT images.
2) Cases with at least 1 year follow up.	2) Cases with at least 1 year follow up.
3) Endodontic microsurgery performed on anterior teeth.	3) Endodontic microsurgery performed on anterior teeth.
Exclusion criteria	Exclusion criteria
1) Follow-up period of less than 1 year.	1) Follow-up period of less than 1 year.
2) Patients with severe systemic diseases, including having taken bisphosphonates for more than 4 years.	2) Patients with severe systemic diseases, including having taken bisphosphonates for more than 4 years.
3) Tooth with extensive resorptive lesion or crack.	3) Tooth with extensive resorptive lesion or crack.
4) Tooth with a deep post which disturbs achieving 3mm depth for retropreparation.	4) Tooth with a deep post which disturbs achieving 3mm depth for retropreparation and retrofilling.
5) Tooth with marginal bone completely lost, called as "endo-perio lesion.“.	5) Tooth with marginal bone completely lost, called as "endo-perio lesion“.
6) Cases involving bone grafting during surgery.	

From the osteotomy onward, all surgical procedures were carried out under an operating microscope (OPMI PICO; Carl Zeiss, Göttingen, Germany). The osteotomy was performed in an Impact Air 45 handpiece (Palisades Dental, Englewood, NJ). After curettage of granulation tissue, root tip was resected at 3 mm point from apex, with a 170-tapered fissure bur or high-speed diamond bur under copious water-irrigation. Retropreparation was performed with KIS ultrasonic tips (ObturaSpartan, Fenton, MO) and ultrasonic unit (Spartan MTS; ObturaSpartan), extending at least 3 mm depth into the canal space.

The resected root surfaces were stained with methylene blue and inspected with micromirrors (ObturaSpartan) to ensure proper retropreparation and also to identify other anatomic details, for example, crack line or lateral canals, or isthmus. Stropko irrigator/drier (Obtura/Spartan) was used to dry cavity.

The root-end cavity was filled with one of following materials, which was selected by operators : Intermediate Restorative Material (Caulk Dentsply, Milford, DE), Super EBA (Harry J. Bosworth, Skokie, IL), ProRoot MTA (Dentsply, Tulsa, OK), Retro MTA(Bio MTA, Seoul, Korea) and Endocem (Maruchi, Wonju, Korea). The adaptation of the filling material to the canal apical walls was confirmed with the aid of an operating microscope at high magnification.

In some cases, additional graft materials including collagen sponges, bone graft materials and collagen membrane were applicated. These are name of materials that are used during surgery : Ateloplug (Bioland, Seoul, Korea), Inducera (Oscotec, Seongnam, Korea), Osteon (Dentium, Suwon, Korea), Bio-oss (Geistlich Pharma AG, Wolhusen, Switzerland), The Graft (Purgo Biologics, Seongnam, Korea) EZ Cure (DIO, Busan, South Korea), CollaTape (Integra NeuroSciences, Plainsboro, NJ).

The surgery site was sutured and stitches were removed after 7 days. Further periodic check-up was followed.

2.4. Prognostic factors

Several preoperative and intraoperative factors were evaluated for each endodontic microsurgery cases. Age, sex, and tooth position were included for preoperative factors. Intraoperative factors included graft materials. Table 1 presents the prognostic factors and their subcategories for Part I and Part II of the study.

Table 2 Prognostic factors for Part I, Part II

Part I		Part II	
Preoperative		Preoperative	
Age	≤45 >45	Age	≤45 >45
Sex	Male Female	Sex	Male Female
Tooth position	Mx. anterior tooth Mn. Anterior tooth	Tooth position	Mx. anterior tooth Mn. Anterior tooth
		Intraoperative	
		Graft materials	None Collagen sponge Bone graft

2.5. Outcome assessment

To assess the cumulative outcome over a long-term period by survival analysis, the treatment outcome for each case was evaluated by considering clinical records and periapical radiographs obtained at last follow-up visit. Additionally, to assess short-term clinical outcome at 1 year (12 – 18 months) and 3 years (30 – 42 months) after surgery respectively, the treatment outcome was also evaluated for cases which have a 1 year and 3 years follow-up.

Clinical evaluation included the presence of signs and/or symptoms, tenderness on percussion or palpation and sinus tract formation. Two independent examiners(H. P., E. K.) evaluated radiographic healing pattern according to the criteria proposed by Rud et al and Molven et al. : complete, incomplete, uncertain, and unsatisfactory healing. The two examiners standardized the evaluation criteria prior to the assessment. Any disagreements were resolved through discussion to reach a consensus. Following criteria is used for outcome assessment :

1. Success : Complete or incomplete healing on radiographic evaluation AND absence of clinical

abnormalities

2. Failure : Uncertain or unsatisfactory healing on radiographic evaluation OR presence of clinical abnormalities

Cases requiring intervention (e.g. extraction, re-surgery) before the 1-year were classified as failures.

2.6. Statistical Analysis

All statistical analyses were performed by using SPSS software (version 27.0.0, IBM Corp, Somers, NY), R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). The level of significance was set at .05

Inter-examiner agreement for radiographic evaluations was measured using the Cohen's Kappa statistic. The agreement was judged according to the method of Landis and Koch(Landis & GG., 1977).

For Part I (Clinical Outcome Comparison Between T-T Group and Non T-T Group), 1:2 Propensity score matching was performed for T-T group and non T-T group. 3 variables were included in propensity score matching : age, sex, tooth position. For long-term cumulative analysis, cumulative success probability was calculated by using the Kaplan-Meier survival curve and Log-rank test. Multivariate logistic regression model followed by stepwise regression with the backward elimination method was used to evaluate whether prognostic factors, including the presence of through-and-through lesions, were associated with the success rate of endodontic microsurgery.

Bivariate analysis ($\chi 2$ or Fisher exact tests) was performed to compare radiographic healing patterns at 1 year and 3 years.

For Part II (Prognostic Factors of Clinical Outcomes of Endodontic Microsurgery in Through-and-Through Lesions), both multivariate Cox proportional hazard regression analysis and multivariate logistic regression model followed by stepwise regression with the backward elimination method were used.

3. Results

The kappa value representing the inter-examiner agreement (H, P., E. K.) for radiographic evaluation was 0.78, which indicated substantial agreement.

3.1 Part I : Clinical Outcome Comparison Between T-T Group and Non T-T Group

Based on the inclusion and exclusion criteria, a total of 89 cases in the T-T group and 294 cases in the non T-T group were included in the Part I analysis. As described in the Materials and Methods section, cases with bone grafts were excluded from both groups (Figure 2).

3.1.1 Survival analysis : Cumulative outcome

A total of 89 cases (T-T group) and 294 cases (non T-T group) were included in the cumulative evaluation analysis. After 1:2 propensity score matching, 89 cases from the T-T group were matched with 178 cases from the non T-T group. The baseline characteristics before and after matching are presented in Table 3. The difference in the sex variable between the two groups before matching was improved after matching ($p<0.001$ before matching, $p=0.483$ after matching). The histogram and distribution of propensity scores are shown in Figures 3 and 4.

Table 3 Baseline Characteristics and Distribution before and after 1:2 Propensity Score Matching: Cumulative outcome

Variable	Total population			Propensity score-matched pairs (1:2)		
	Non T-T (n=294)	T-T (n=89)	P value	Non T-T (n=178)	T-T (n=89)	P value
Age	37.39±13.23	37.30±12.98	0.954	37.89±12.60	37.30±12.98	0.724
Sex			**<0.001***			0.483
Male	77 (24.5%)	40 (44.9%)		72 (40.4%)	40 (44.9%)	
Female	222 (75.5%)	49 (55.1%)		106 (59.6%)	49 (55.1%)	
Tooth position			0.807			0.770
Mx. Anterior tooth	265 (90.1%)	81 (91.0%)		160 (89.9%)	81 (91.0%)	
Mn. Anterior tooth	29 (9.9%)	8 (9.0%)		18 (10.1%)	8 (9.0%)	

*p < .05 according to t tests, $\chi 2$ tests, or Fisher exact tests

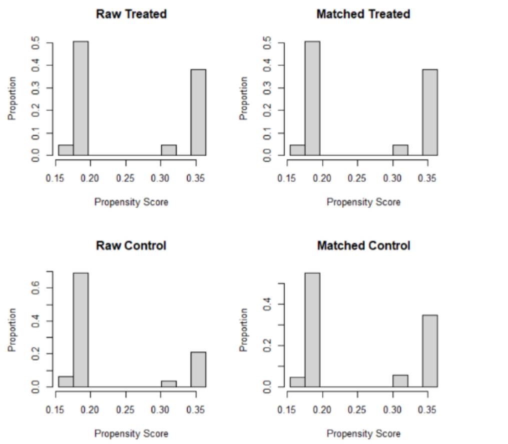

Figure 3 Histogram of Propensity Score Matching for cases of T-T and non T-T group : Cumulative outcome

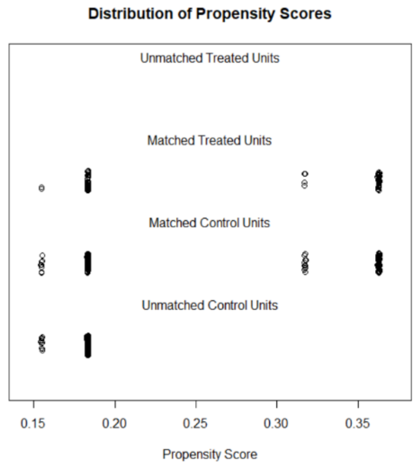

Figure 4 Distributions of propensity scores for matched and unmatched cases : Cumulative outcome

Figure 5 compares the cumulative success rates between the T-T group and the non T-T group using Kaplan-Meier survival curves based on the matched cases. The mean survival periods were 8.50 years (95% confidence interval [CI], 7.60–9.39 years) for the non T-T group and 8.16 years (95% CI, 6.80–9.52 years) for the T-T group. The Log Rank test showed no statistical difference in cumulative success probability between the two groups (P = 0.103).

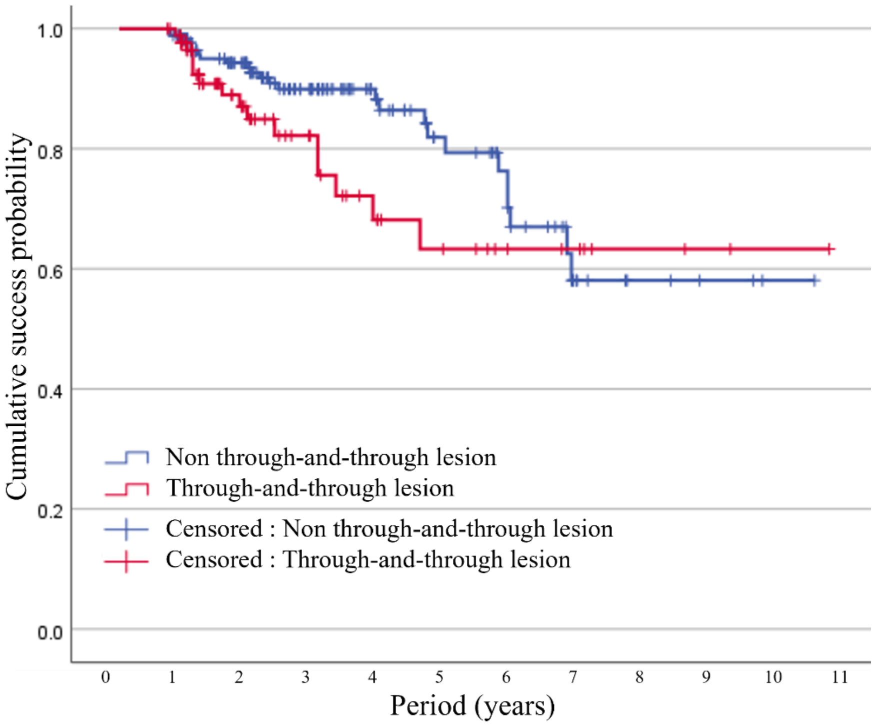

Figure 5 Kaplan-Meier survival curve presenting cumulative success probabilities for endodontic microsurgery in T-T group vs non T-T group.

3.1.2 Cross-sectional analysis : 1 year, 3 years outcome

For 1 year outcome, 75 cases (T-T group) and 238 cases (non T-T group) were eligible for analysis. After 1:2 propensity score matching, 75 cases (T-T group) were matched with 150 cases (non T-T group). For 3 years outcome, 34 cases (T-T group) and 147 cases (non T-T group) were included. After 1:2 propensity score matching, 75 cases (T-T group) were matched with 150 cases (non T-T group). The baseline characteristics before and after matching for both 1 year, 3 years are presented in Table 4 and 5. As same as cumulative analysis, The difference in the sex variable was improved after matching. The histogram and distribution of propensity scores are shown in Figure 6, 7, 8 and 9.

Table 4 Baseline Characteristics and Distribution before and after 1:2 Propensity Score Matching: 1 year outcome

Variable	Total population			Propensity score-matched pairs (1:2)		
	Non T-T (n=238)	T-T (n=75)	P value	Non T-T (n=150)	T-T (n=75)	P value
Age	37.58±13.192	38.79±13.238	0.491	38.83±14.662	38.79±13.238	0.984
Sex			**0.001***			0.391
Male	61 (25.6%)	35 (46.7%)		61 (40.7%)	35 (46.7%)	
Female	177 (74.4%)	40 (53.3%)		89 (59.3%)	40 (53.3%)	
Tooth position			0.885			0.881
Mx. Anterior tooth	214 (89.9%)	67 (89.3%)		133 (88.7%)	67 (89.3%)	
Mn. Anterior tooth	24 (10.1%)	8 (10.7%)		17 (11.3%)	8 (10.7%)	

*p < .05 according to t tests, χ2 tests, or Fisher exact tests

Table 5 Baseline Characteristics and Distribution before and after 1:2 Propensity Score Matching: 3 years outcome

Variable	Total population			Propensity score-matched pairs (1:2)		
	Non T-T (n=147)	T-T (n=34)	P value	Non T-T (n=68)	T-T (n=34)	P value
Age	36.11±11.094	37.76±12.449	0.445	33.51±10.050	37.76±12.449	0.066
Sex			**0.022***			0.674
Male	36 (24.5%)	15 (44.1%)		33 (48.5%)	15 (44.1%)	
Female	111 (75.5%)	19 (55.9%)		35 (51.5%)	19 (55.9%)	
Tooth position			0.729			0.330
Mx. Anterior tooth	136 (92.5%)	31 (91.2%)		66 (97.1%)	31 (91.2%)	
Mn. Anterior tooth	11 (7.5%)	3 (8.8%)		2 (2.9%)	3 (8.8%)	

*p < .05 according to t tests, χ2 tests, or Fisher exact tests

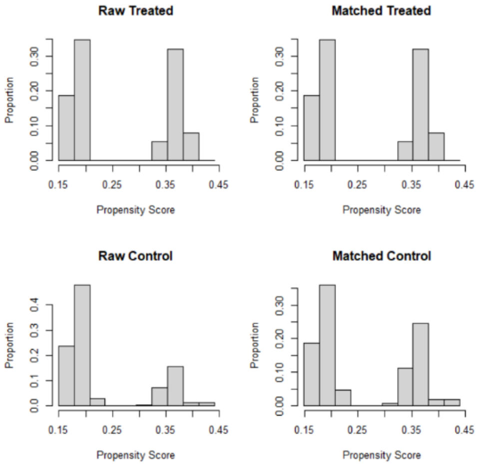

Figure 6 Histogram of Propensity Score Matching : 1 year outcome

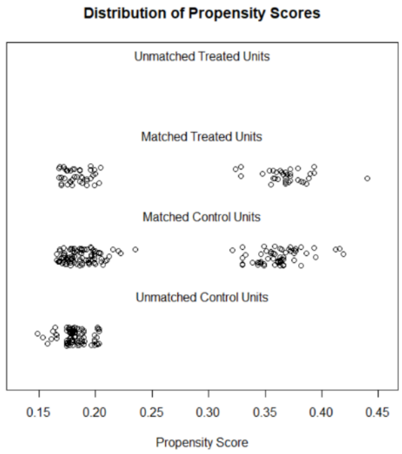

Figure 7 Distributions of propensity scores for matched and unmatched cases : 1 year outcome

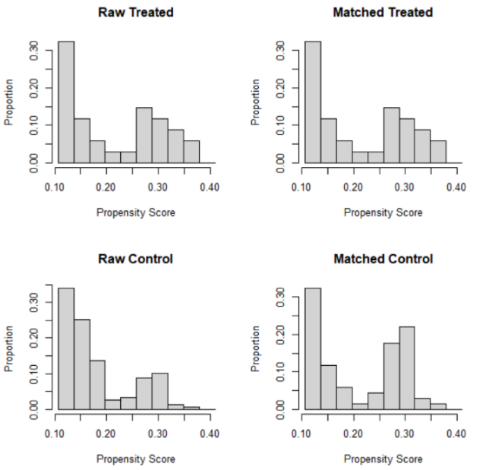

Figure 8 Histogram of Propensity Score Matching : 3 years outcome

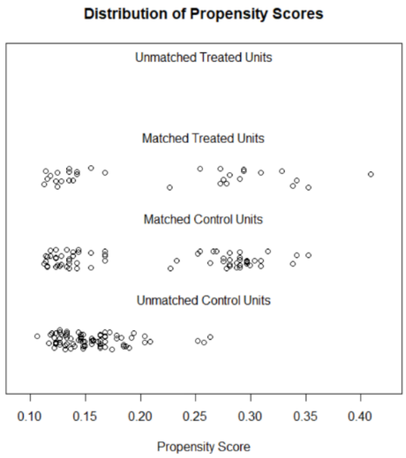

Figure 9 Distributions of propensity scores for matched and unmatched cases : 3 years outcome

Success rates for 1 year were 88.0% (non T-T, 132/150) vs 77.3% (T-T, 58/75). For 3 years, success rates were 97.1% (non T-T, 66/68) vs 88.2% (T-T, 30/34). Table 5 lists the distribution of cases according to success and failure, and bivariate analysis ($\chi 2$ tests, or Fisher exact tests). Bivariate analysis showed that 1 year after endodontic microsurgery, the success rate in the non T-T group was higher than that in the T-T group (P < 0.05).

Table 6 1 year, 3 years success rates of non T-T group and T-T group

		Non T-T	T-T	P value
1 year outcome	Success	132 (88.0%)	58 (77.3%)	**0.037***
	Fail	18 (12.0%)	17 (22.7%)	
	Total N	150	75	
3 years outcome	Success	66 (97.1%)	30 (88.2%)	0.094
	Fail	2 (2.9%)	4 (11.5%)	
	Total N	68	34	

*p < .05 according to t tests, χ2 tests, or Fisher exact tests

Logistic regression model was designed to determine prognostic factors influencing the 1 year and 3 years success rates. Variables included age, sex, tooth position, and lesion type (Table 7).

Table 7 Findings of Logistic regression model identifying predictors for 1 year and 3 years clinical outcome, final model after backward elimination

	Variable	Odds ratio	95% Confidence interval		P value
			Lower	Upper	
1 year outcome	Tooth position				
	Mx anterior† vs Mn. Anterior tooth	3.145	1.217	8.132	**0.018***
	Lesion type				
	Non T-T† vs T-T	2.220	1.055	4.672	**0.036***
3 years outcome	Sex				
	Male† versus Female	7.230	0.742	70.478	0.089
	Age				
	≤45† vs >45	5.284	0.896	31.153	0.066

Variable † : reference category
*p < .05 after logistic regression analysis

For the 1 year outcome, tooth position and lesion type were statistically significant factors affecting success rates. Endodontic microsurgeries on mandibular anterior teeth had a 3.145 times higher likelihood of failure compared to maxillary anterior teeth (P < .05), and the T-T group had a 2.22 times higher failure rate at 1 year compared to the non T-T group (P < .05).

In contrast, for the 3 years outcome, no statistically significant factors were identified. While females had a 7.23 times higher likelihood of failure compared to males, and patients over 45 years old had a 5.284 times higher likelihood of failure compared to those 45 years or younger, these differences were not statistically significant (P > .05).

In summary, tooth position and the presence of through-and-through lesions influenced success rates at the 1-year postoperative outcome, but they did not have an impact on the 3-year outcome.

3.1.3 Cross-sectional analysis: Radiographic evaluation

The distribution of 1 year and 3 years radiographic healing patterns is presented in Table 8 and Figures 10. When comparing the 1-year and 3-year results, the proportion of complete healing increased at the 3-year outcome in both the T-T and non T-T groups. Comparing the T-T and non T-T group, the proportion of incomplete healing was higher in the T-T group at both the 1-year and 3-year outcomes. [1 year: 17.3% (non T-T) vs. 50.7% (T-T) / 3 years: 10.3% (non T-T) vs. 44.1% (T-T)].

Table 8 Radiographic healing pattern distribution between 1 year and 3 years.

Radiographic Healing pattern	1 year evaluation		3 years evaluation	
	Non T-T	T-T	Non T-T	T-T
Complete	106 (70.7%)	22 (29.3%)	59 (86.8%)	15 (44.1%)
Incomplete	26 (17.3%)	38 (50.7%)	7 (10.3%)	15 (44.1%)
Uncertain	13 (8.7%)	13 (17.3%)	0 (0.0%)	1 (2.9%)
Unsatisfactory	5 (3.3%)	2 (2.7%)	2 (2.9%)	3 (8.8%)
Total N	150	75	68	34

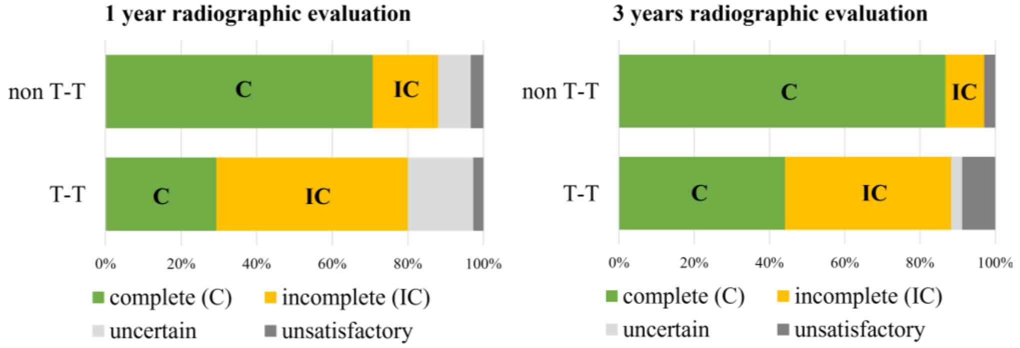

Figure 10 Radiographic healing pattern of T-T and non T-T group : 1 year and 3 years outcome

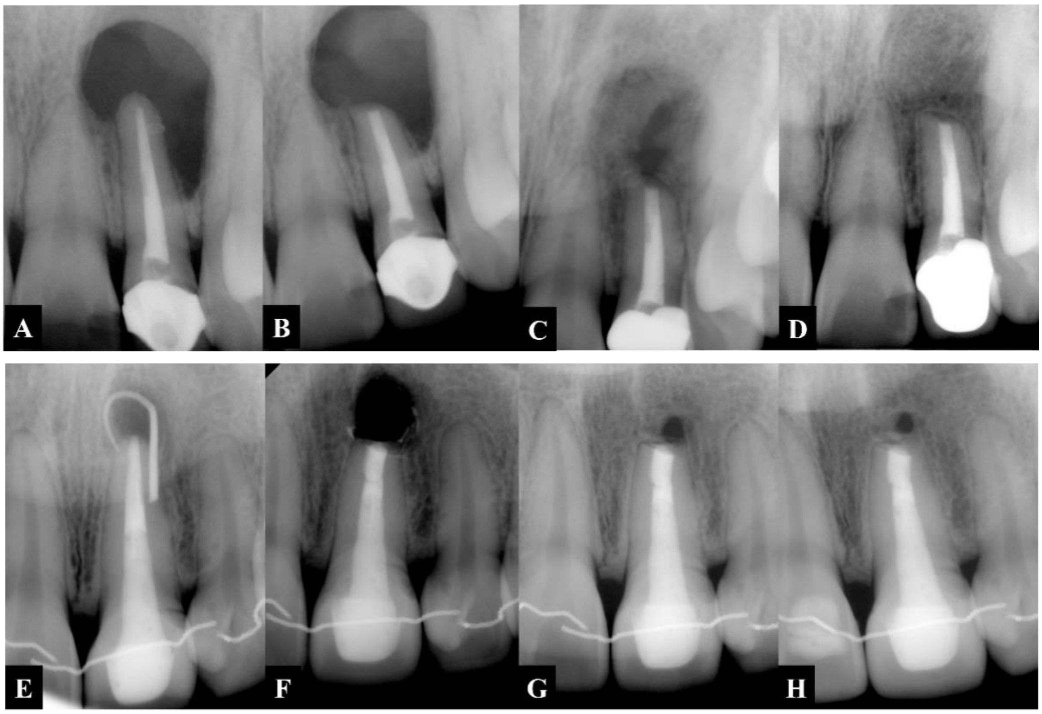

Figure 11 Representative radiographs of surgery outcome in through-and-through lesion. (A) Pre-operative radiograph of maxillary lateral incisor (B) post-operative radiograph after endodontic microsurgery (C) 1 year after surgery, showing incomplete healing with scar tissue (D) 3 year after surgery, showing complete healing without scar tissue (E) Another case, pre-operative radiograph of maxillary central incisor (F) post-operative radiograph after endodontic microsurgery (G) 1 year after surgery, showing incomplete healing with scar tissue (H) 3 year after surgery, still showing incomplete healing with scar tissue

3.2 Part II : Prognostic Factors of Clinical Outcomes of Endodontic Microsurgery in Through-and-Through Lesion

Based on the inclusion and exclusion criteria, a total of 115 cases with through-and-through lesion, including 26 cases with bone graft were included in the Part II analysis (Figure 2).

3.2.1 Survival analysis : Cumulative outcome

Multivariate Cox proportional hazard regression in this study revealed that pre-operative and intra-operative prognostic factors (age, sex, tooth position, graft material) did not have a significant effect on cumulative success rate (Table 9).

Table 9 Cox proportional Hazard model identifying predictors for cumulative clinical outcome, initial model for stepwise regression

Variable	Hazard ratio	Standard error	CI	P value
Age				
≤45 vs >45†	1.018	0.021	0.977-1.061	0.400
Sex				
Male vs Female†	1.197	0.499	0.450-3.184	0.719
Tooth position				
Mx. Anterior tooth vs Mn. Anterior tooth†	0.405	0.808	0.083-1.974	0.263
Graft material				
None vs bone graft†	1.470	1.144	0.156-13.831	0.736
Collagen sponge vs bone graft†	2.861	1.122	0.317-25.809	0.349

Variable † : reference category

3.2.2 Short term analysis : 1 year, 3 years outcome

A total of 96 cases were included in 1 year analysis and success rate was 81.3% (78/96). For 3 years, a total of 38 cases were included and success rate was 86.8% (33/38). Table 10, 11 lists the distribution of cases according to the variables/category and bivariate analysis for 1 year and 3 years each.

Logistic regression analysis revealed that none of the variables(age, sex, tooth position, or graft material) had a statistically significant impact on the 1 year outcome ($P > .05$) (Table 12). However, for the 3 years outcome, sex was identified as a statistically significant factor ($P < .05$), with males showing a higher success rate compared to females (Odds ratio = 19.466) (Table 13).

Table 10 Distribution of Cases per Variables/Category and Bivariate Analysis for 1 year

Variable	Total n	Success n (%)	Failure n (%)	P value
Total	96	78 (81.3%)	18 (18.8%)	
Age				0.749
≤45	67	55 (82.1)	12 (17.9)	
>45	29	23 (79.3)	6 (20.7)	
Sex				0.716
Male	41	34 (82.9)	7 (17.9%)	
Female	55	44 (80.0)	11 (20.0%)	
Tooth position				1.000
Mx. Anterior tooth	86	70 (81.4)	16 (18.6)	
Mn. Anterior tooth	10	8 (80.0)	2 (20.0)	
Graft Material				0.132
None	41	33 (80.5)	8 (19.5)	
Collagen sponge	34	25 (73.5)	9 (26.5)	
Bone graft	21	20 (95.2)	1 (4.8)	

p value according to $\chi 2$ tests, or Fisher exact tests

Table 11 Distribution of Cases per Variables/Category and Bivariate Analysis for 3 years

Variable	Total n	Success n (%)	Failure n (%)	P value
Total	38	33 (86.8%)	5 (13.2%)	
Age				**0.019***
≤45	27	26 (96.3)	1 (3.7)	
>45	11	7 (63.6)	4 (36.4)	
Sex				0.35
Male	17	16 (94.1)	1 (5.3)	
Female	21	17 (81.0)	4 (19.0)	
Tooth position				0.353
Mx. Anterior tooth	35	31 (88.6)	4 (11.4)	
Mn. Anterior tooth	3	2 (66.7)	1 (33.3)	
Graft Material				0.370
None	21	19 (90.5)	2 (9.5)	
Collagen sponge	13	10 (76.9)	3 (23.1)	
Bone graft	4	4 (100.0)	0 (0.0)	

p value according to $\chi 2$ tests, or Fisher exact tests

Table 12 Findings of Logistic regression model for prognostic factors of 1 year outcome, final model after backward elimination

Variable	Odds ratio	95% Confidence Interval		P value
		Lower	Upper	
Graft material				
None versus Bone graft†	0.206	0.024	1.774	0.150
Collagen sponge versus Bone graft†	0.139	0.016	1.190	0.072

Variable † : reference category

Table 13 Findings of Logistic regression model for prognostic factors of 3 years outcome, final model after backward elimination

Variable	Odds ratio	95% Confidence Interval		P value
		Lower	Upper	
Age				
≤45 vs >45 †	51.743	2.667	1003.786	0.054
Sex				
Male vs Female †	19.466	0.948	399.832	**0.009***

Variable † : reference category
***p** < .05 after logistic regression analysis

4. Discussion

Through-and-through lesions exhibit delayed healing compared to non through-and-through lesions due to anatomical complexities such as cortical bone involvement on both buccal and lingual sides, which hinder vascular supply and bone regeneration. Also because of its large bone defect and loss of palatal or lingual cortical bone, optimal intraoperative management could be challenging.

However, due to the limited number of cases, studies that directly report the surgical success rates for through-and-through lesions are rare. Some recent studies about clinical outcomes of endodontic microsurgery in through-and-through lesions have reported success rates ranging from 45% to 100% with minimum 30 to maximum 59 teeth per study (Arpitha, 2023; Dhamija et al., 2024; Dhamija et al., 2020; Parmar et al., 2019; Taschieri et al., 2011, Taschieri et al., 2007). However, as mentioned in the introduction part, these studies differ from the present study in following key aspects: (1) There is a lack of direct comparison with non-through-and-through lesions and (2) Their primary goal is not to explore the inherent characteristics of through-and-through lesions; instead, they focus on demonstrating differences in success rates based on various graft materials or evaluation methods (e.g., 2D assessment vs. 3D assessment).

Therefore, this retrospective case-control study aimed to conduct a comprehensive analysis of endodontic microsurgery in through-and-through lesions, structured into two main parts. **Part I** focused on comparing the clinical outcomes of endodontic microsurgery between through-and-through lesions and non through-and-through lesions using propensity score matching. **Part II** aimed to identify predisposing or intraoperative factors within the through-and-through lesions that may influence clinical outcomes.

Also the present study employed both cross-sectional analysis and survival analysis for comprehensive evaluation. While cross-sectional analysis provided a point-in-time assessment of treatment success, survival analysis provided valuable insights into the time-dependent dynamics of treatment success, recurrence, and long-term prognosis. By employing both two statistical approaches, this study aimed not only to observe through-and-through lesions' unique characteristics such as initial healing patterns but also to offer valuable insights into the long-term prognosis of endodontic microsurgery in through-and-through lesions.

Another statistical feature of this study is the use of propensity score matching, which was utilized to compare the T-T and non T-T groups in Part I. Propensity score matching is a statistical technique used in observational studies to minimize bias by accounting for confounding variables when comparing two groups (Rosenbaum & Rubin, 1984). By estimating the likelihood of a subject being assigned to a particular group based on observed covariates, propensity score matching creates matched pairs or groups with similar baseline characteristics, allowing for more accurate comparisons. In the field of endodontic microsurgery, propensity score matching has been applied in several studies. For instance, Song et al. used propensity score matching to compare the success rates between endo-perio lesions and isolated endodontic lesions(Song et al., 2018), while Kim et al. employed the method to analyze differences in success rates between micro-resurgery and primary microsurgery(Kim et al., 2018).

The present study included 3 matching covariates (age, sex, tooth position) for propensity score matching. These covariates were determined based on prior studies that evaluated the outcomes of endodontic microsurgery(Song et al., 2011; Song, Kim, Lee, et al., 2013). Among the covariates suggested in the referenced study, postoperative restoration was excluded because only anterior teeth cases were included, and cases involving abutments for long bridges were extremely rare. Before propensity score matching, there was a disparity in the sex distribution between the two groups (Table 2, 3, 4) which was improved through propensity score matching, enabling a more accurate comparison.

Reported success rate of endodontic microsurgery in through-and-through lesions are as follows, varying depending on the evaluation period (1 year or 4 - 5 years) or assessment methods (2D assessment with periapical radiographs or 3D assessment with cone-beam computed tomography; CBCT). For 1 year evaluation, the lowest success rate was reported in Taschieri's study as 78% (Taschieri et al., 2007), while Palmar reported 93-100% for 2D evaluation, 87% for 3D evaluation respectively (Parmar et al., 2019). Also Dhamija reported 91-93% (Dhamija et al., 2024; Dhamija et al., 2020) and even 100% success rate was reported by Arpitha in both 2D and 3D evaluations (Arpitha, 2023).

In Part I of the present study, the 1-year success rate for T-T group was 77.3% and 88.0% for non T-T group respectively. This result shows a similar level to the success rate reported by Taschieri, which is 78% (Taschieri et al., 2007) but relatively lower than the 4 randomized controlled studies reported since 2019 (Arpitha, 2023; Dhamija et al., 2024; Dhamija et al., 2020; Parmar et al., 2019). There are several possible reasons for this relatively lower success rate. Since this is a retrospective study involving cases performed over a 10-year period from 2013 to 2023, the operator and root-end filling materials were not standardized. Besides calcium silicate-based material, root-end filling materials such as super ethoxybenzoic acid (super-EBA) and intermediate restorative material (IRM), were also used among 20 cases. Additionally, in the Part I analysis, cases involving bone grafts were excluded from both the non T-T and T-T lesion groups. This decision was made because the criteria for performing bone grafts varied among the operators included in this study, which is unclear and potentially influence the outcomes. In short-term radiographic evaluations, such as at 1 year, cases with bone grafts often appears radiographically filled with graft material and tend to be classified as complete healing. Excluding these bone graft cases from the success rate evaluation may have contributed to the slightly lower success rates observed in this study compared to other studies.

In this study, a multifaceted approach was taken by performing both cross-sectional analysis (at 1 year and 3 years) and cumulative survival analysis, revealing differences in outcomes between the T-T group and the non-T-T group depending on the type of analysis. T-T group showed 1 year success rate of 77.3% (58/75), which was significantly lower than the 88.0% (132/150) observed in the non T-T group ($P < 0.05$). However, in the 3-year analysis, the success rates did not show statistically significant difference, 88.2% (30/34) for the T-T group and 97.1% (66/68) for the non T-T group ($P > 0.05$). Similarly, also in cumulative survival analysis, the mean survival periods were 8.16 years for the T-T group and 8.50 years for the non T-T group, with no significant difference in cumulative success probability between the two groups ($P = 0.103$). This indicates that while there was a significant difference in short-term outcomes such as 1 year, the difference diminished over longer follow-up periods.

This finding deviates to some extent from the prevailing notion in endodontic microsurgery that 1-year short-term outcomes are highly predictive of long-term outcomes. Several researchers have suggested that a 1-year follow-up period is sufficient to reliably predict long-term outcomes in conventional endodontic microsurgery, though variations exist depending on lesion size, technique, and materials used (Ng & Gulabivala, 2023; Song et al., 2012; von Arx et al., 2019; Yoo et al., 2024). When longer follow-up periods are involved, the long-term success rate may decrease due to post-surgery relapse in previously healed teeth (Pallares-Serrano et al., 2022; Tsesis et al., 2013; von Arx et al., 2012).

However, underlying pathologic natures of through-and-through lesions are as follows : (1) the destruction of both buccal and palatal cortical bone and (2) an inherently larger lesion volume. These features suggest that additional factors must be considered when interpreting the clinical outcomes of surgery in these lesions. Studies indicate that lesions with cortical bone destruction, particularly those classified as through-and-through, may exhibit slower healing rates (Bieszczad et al., 2023). Also, several previous studies have reported that larger lesions take longer to heal (Çalışkan et al., 2016; Kim et al., 2016). Çalışkan et al. noted that the average healing time increases as the lesion size increases. It is likely due to compromised alveolar bone support, which can hinder effective healing and prolong recovery times(Çalışkan et al., 2016).

Therefore, as initial poorer 1-year outcomes of through-and-through lesions were observed in the present study, these lesions may require a longer monitoring period to accurately assess the final surgical outcomes. Long-term follow-up is essential to capture eventual healing, as studies have shown that long-term success rates can align with those of non through-and-through lesions. The use of advanced imaging techniques, such as cone-beam computed tomography (CBCT), can enhance monitoring accuracy and provide insights into healing progress over time.

At the end of Part I (result 3.1.3), this study presents the distribution of radiographic healing patterns in the T-T group and non-T-T group according to Molven and Rud' classification (Molven et al., 1987; Rud et al., 1972). Incomplete healing is the characteristic healing pattern associated with through-and-through lesions, which can be also called as ‘scar tissue’. It often appears as a periapical radiolucency or rarefaction, typically lacks a surrounding radiopaque lamina, which can be a distinguishing factor (Caliskan et al., 2016; Saraf et al., 2014). Representative postoperative periapical radiographs with and without scar tissue formation are presented in Figure 12. In the upper row case(A-D), scar tissue observed immediately after surgery and at the 1 year follow-up had completely healed by the 3 years follow-up. In contrast, the lower row case(E-H) demonstrates scar tissue persisting even at the 3 years follow-up.

Scar tissue observed after endodontic microsurgery predominantly consists of dense fibrous collagenous tissue with minimal to no inflammatory cell infiltration, and absence of bacterial infection, indicating a stable, non-pathogenic reparative process. Histologically, it is characterized by spindle-shaped fibroblasts scattered among the collagen fibers, occasional hyalinization (Caliskan et al., 2016; Lee et al., 2021). Histologic studies conducted on animals have shown that in through-and-through lesions, connective tissue ingrowth into the osseous defect occurs (Baek & Kim, 2001; Christer Dahlin, 1988; Dahlin et al., 1990). This process interrupts normal healing process with bone regeneration which usually leads to complete healing. Instead, fibrous tissue formation leads to periapical scarring that sometimes observed on post-operative periapical radiographs.

In the present study, the comparison of radiographic healing patterns between the T-T group and the non T-T group showed similar results to those reported in previous studies. As presented in Table 7 and Figure 9, 10, the proportion of incomplete healing was higher in the T-T group at both the 1 year and 3 years outcomes. Although the small number of cases included in the analysis requires cautious interpretation, the percentage difference tended to be more pronounced at the 1 year. As discussed earlier, this may be attributed to the longer time required for sufficient healing in through-and-through lesions, suggesting that scar tissue can potentially progress to complete healing over time.

In Part II, the only statistically significant factor was sex in 3 years outcome of cross-sectional analysis. Male showed a higher success rate compared to female. In the female group, all four failed cases involved patients aged over 50 years, suggesting that decreased estrogen levels after menopause may have contributed to reduced bone regeneration capacity. However, given the limited sample size of 38 cases included in the 3-year analysis, caution is required when interpreting these findings. Previous studies in the field of endodontic microsurgery have generally reported no significant differences in outcomes based on sex (Azim et al., 2021; Song et al., 2011; Song, Kim, Lee, et al., 2013; Yoo et al., 2024). Similarly, in the present study, sex had no statistically significant impact on 1 year outcome or cumulative success rates, but it emerged as a significant factor exclusively in the 3 years outcome. Therefore, considering these factors collectively, cautious interpretation is necessary and further studies with larger sample sizes should be needed.

5. Conclusion

While short-term outcomes of endodontic microsurgery significantly differ between through-and-through lesions and non through-and-through lesions, these differences gradually diminish over longer follow-up periods. The cumulative success rates suggest that endodontic microsurgery is a reliable treatment option for through-and-through lesions, achieving comparable long-term outcomes to non through-and-through lesions. This suggests that a sufficient follow-up period longer than 1 year may be necessary for accurately interpret the outcomes of through-and-through lesions, considering the dynamics of healing in through-and-through lesions.

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Abstract in Korean

협-설측 관통 병변에서의 치근단 미세수술의 임상적 결과 : 후향적 사례 대조 연구

협-설측 관통 병소는 설측/구개 및 협측 피질골판이 모두 결손된 상태를 의미하며, 치근단 미세수술 분야에서 수술적 처치에 있어 주의를 기울여야 하는 분야 중 하나이다. 최근 일부 연구에서 협-설측 관통 병소의 수술 성공률이 45~100%로 보고되었으나, 표본 크기, 추적 관찰 기간의 제한, 그리고 비관통 병소와의 직접적인 비교 부족은 보다 포괄적인 분석의 필요성을 상기시킨다. 본 연구는 협-설측 관통 병소에서의 치근단 미세수술의 임상적 결과를 평가하고, 이를 일반적인 비관통 병소와 비교하며, 성공률에 영향을 미치는 요인을 규명하는 것을 목표로 한다.

본 후향적 사례 대조 연구는 협-설측 관통 병소를 가진 치근단 미세수술 증례 115 건과 비관통 병소 증례 294 건을 검토하였다. 편향을 줄이기 위해 1:2 비율의 성향 점수 매칭을 적용하였으며, 임상 결과는 단기인 1 년 및 3 년 시점에서 평가하였으며, 장기 분석을 위해 카플란-마이어 생존 분석을 이용하여 누적 결과를 평가하였다. 단기 및 장기 결과에 영향을 미치는 예후 인자를 확인하기 위해 로지스틱 회귀분석 및 콕스 비례 위험 회귀분석을 수행하였으며, 통계적 유의수준은 $p < 0.05$ 로 설정하였다.

본 연구의 1 부에서는 1 년 성공률이 비관통 병소군에서 88.0%, 협-설측 관통 병소군에서 77.3%로 나타났으며, 3 년 성공률은 각각 비관통 병소군 97.1%와 협설측 관통 병소군 88.2%로 나타났다. 1 년 결과에서는 치아의 위치 (하악 전치부)와 협-설측 관통 병소가 더 높은 실패율과 연관된 유의미한 요인으로 나타났으며, 3 년 결과에서는 통계적으로 유의한 요인이 확인되지 않았다. 누적 생존 분석에서는 두 그룹 간 유의한 차이가 나타나지 않았다(P = 0.103).

2 부에서는 로지스틱 회귀분석 결과, 3 년 성공률에서 성별이 유의미한 요인으로 나타났으며, 남성이 여성보다 더 높은 성공률을 보였다. 1 년 및 누적 결과에서는 유의미한 요인이 발견되지 않았다.

본 연구의 한계 내에서, 협-설측 관통병소와 비관통 병소 간의 치근단 미세수술의 단기 결과에는 유의미한 차이가 있었으나, 이러한 차이는 장기 추적 관찰 기간 동안 점차 감소하였다. 누적 성공률은 협-설측 관통 병소에서도 비관통 병소와 유사한 장기 결과를 보였으며 이는 협-설측 관통 병소의 치료 있어 치근단 미세수술이 신뢰할 수 있는 수술적 치료방법임을 시사한다. 협-설측 관통 병소의 수술 결과를 정확히 해석하기 위해서는 1 년 이상의 충분한 추적 관찰 기간이 필요할 수 있음을 시사하며, 협-설측 관통 병소 수술 증례의 치유 역학을 고려할 때 이러한 평가가 중요함을 보여준다.

핵심 되는 말 : 치근단 미세수술, 협-설측 관통병소, 수술 결과, 성공 요인, 방사선학적 치유