CLINICAL RESEARCH

Healing of 295 Endodontic Microsurgery Cases After Long-Term (5-9 Years) Versus Middle-Term (1-4 Years) Follow-up

Antonio Pallarés-Serrano, DDS,[*] Pablo Glera-Suarez, DDS,[*] Beatriz Tarazona-Alvarez, DDS, PhD,[†] David Peñarrocha-Oltra, DDS, PhD,[‡] Miguel Peñarrocha-Diago, MD, PhD,[§] and María Peñarrocha-Diago, MD, DDS, PhD[‡]

SIGNIFICANCE

This study provides information on the success of periapical surgery over time (1–4 years vs 5–9 years), analyzing the influence of variables that could influence the success of long-term treatment.

ABSTRACT

Introduction: Some evidence suggests that teeth treated with endodontic surgery and considered to have healed over the short term are seen to relapse when evaluated again after 3 or more years. However, long-term evidence is limited. This study compares healing after endodontic microsurgery over long-term (5–9 years) vs middle-term (1–4 years) follow-up and assesses the influence of different healing predictors over time. **Methods:** A retrospective study was made, comparing the endodontic microsurgery healing rates after 1–4 vs 5–9 years of follow-up. Healing was assessed based on clinical and radiographic parameters. Simple binary logistic regression models were used to analyze the influence of patient age and gender, the type of tooth, previous radiographic lesion size, apical extent of previous root canal filling, the presence of a post, type of restoration, and interproximal bone level upon the endodontic microsurgery healing rate. A sensitivity analysis was used excluding cases of vertical root fracture. Two calibrated observers independently evaluated the periapical radiographs. **Results:** A total of 332 patients (60% women and 40% men) were included in the study. Of the 332 analyzed teeth, 198 were subjected to middle-term follow-up (1–4 years), with a healing rate of 86.9%, while 134 were subjected to long-term follow-up (5–9 years), with a healing rate of 67.2%. There were no statistically significant differences in terms of gender, age, type of tooth, size of the lesion, apical extent of previous root canal filling, presence of a post, or type of restoration. The regression models identified 2 statistically significant associations: cohort and interproximal bone level ($P < .05$). **Conclusions:** A success rate of 86.9% was recorded after 1-4 years of follow-up, vs 67.2% after 5–9 years. Excluding cases of vertical root fractures, in the shortest follow-up cohort (1–4 years), the healing rate was 92.5%, vs 82.6% in the cohort with longer follow-up (5–9 years). The prognosis was influenced by the crestal bone level in relation to the cementoenamel junction of the tooth, being significantly poorer when probing depth was >3 mm mesial or distal to the treated tooth. *(J Endod 2022;48:714–721.)*

KEY WORDS

Apicoectomy; endodontic microsurgery; follow-up

From the *Resident of the Master in Oral Surgery and Implant Dentistry, [†]Full Professor, Orthodontic Unit, Department of Stomatology, Faculty of Medicine and Dentistry, University of Valencia; and [‡]Full Professor, Oral Surgery Unit, [§]Chairman, Oral Surgery Unit, Department of Stomatology, Faculty of Medicine and Dentistry, University of Valencia, Researcher of the IDIBELL, Barcelona, Spain

Address requests for reprints to Dr David Peñarrocha-Oltra, Clínica Odontológica, Unidad de Cirugía Bucal, Gascó Oliag 1, 46021 Valencia, Spain.
E-mail address: david.penarrocha@uv.es
0099-2399

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Healing in endodontic microsurgery is the subject of debate among the experts. On the one hand, the preliminary outcome over short periods of time has been suggested to be predictive of the outcome over longer periods of follow-up[1,2], while on the other hand, postsurgery relapse has been reported to occur in healing or already healed teeth when longer periods of follow-up are involved[3,4].

Endodontic microsurgery is characterized by success rates of 90%–94% after approximately 1–2 years of follow-up[4–7]. In this respect, short-term monitoring may overestimate the prognosis, since it has been reported that 5%–25% of the teeth considered to have healed over the short term are seen to relapse when evaluated again after 3 or more years[3,8–11]. While the long-term evidence is limited, the healing rate may decrease to 78%–81.5% after 5–10 years of follow-up[10,12–14]. Such clinical evidence may help to identify predictive factors with an impact upon the prognosis.

The prognosis in endodontic microsurgery can be influenced by a number of variables (demographic parameters, type and location of the tooth, or the type of coronal restorations involved)[11]. Such factors must be taken into account when analyzing treatment success.

The present study was carried out to compare the healing of teeth subjected to endodontic microsurgery over long-term (5–9 years) vs middle-term (1–4 years) follow-up and assess the influence of different healing predictors over time. The null hypothesis that the long-term group has a lower healing rate than the healing rate at 1–4 years of follow-up was adopted.

MATERIAL AND METHODS

Study Design

A retrospective study was made of a series of patients subjected to endodontic microsurgery between January 2016 and December 2019 in the Oral Surgery Unit (University of Valencia, Valencia, Spain). Data were collected with the sample of the years 2011–2015, published in a previous study[14].

The study was carried out following the recommendations of the Declaration of Helsinki (2013). All patients signed the corresponding informed consent, and the study protocol was approved by the Ethics Committee of the University of Valencia (Ref. UV-SOLTIT-1238454). The study was conducted in accordance with the STROBE[15] statement.

Sample Selection

The following inclusion criteria were applied: patients subjected to endodontic microsurgery with ultrasonic tips, magnification systems (microscope and/or endoscope), and the use of MTA® (ProRoot; Dentsply Tulsa Dental, Tulsa, OK, USA) as retrograde filling material; and patients subjected to follow-up during 1–9 years after the procedure. The following exclusion criteria were applied: patients failing to report to the control visits.

Treatment Procedures and Follow-up

Two experienced surgeons (MPD and DPD) performed all the operations, using a Moeller® Dental 300 surgical microscope (Möller-Wedel International, Bedel, Germany) and an endoscope (Karl Storz®, Tuttlingen, Germany) for magnification and illumination purposes.

Following the methodology of von Arx et al.,[3] the interproximal bone level was recorded probing the tooth targeted for treatment, measuring the distance from the crestal bone to the cementoenamel junction (or the limit of the prosthetic restoration), both mesial and distal to the tooth.

A marginal or paramarginal incision was made, a full thickness flap was raised, and osteotomy was performed with a handpiece (W&H®, Bürmoos, Austria) under irrigation with sterile saline solution. Hemostasis was performed with Expasyl® (Pierre Rolland, Merignac, France) or sterile polytetrafluoroethylene strips[16].

The apical portion of the tooth was resected 3 mm as perpendicular as possible to the long axis of the tooth, and methylene blue staining was used when root fractures were suspected. The retrograde cavity was prepared to a depth of 3 mm using ultrasonic tips (Piezomed®, W&H, Bürmoos, Austria), followed by retrograde filling with MTA®. Pressure-free flap suturing was carried out using 6/0 suture material (Polinyl®, Sweden & Martina, Carrare, Italy).

The patients returned for a control visit one month after endodontic microsurgery to assess healing and again after 6 months and subsequently on an annual basis to evaluate the presence of signs and symptoms. Intraoral periapical radiographs were obtained with a Rinn XCP Ring® positioner (Dentsply, Constanz, Germany). In the case of multiple-root teeth with superpositioning of the roots, periapical radiographs were obtained with distal angulation in the case of upper molars and mesial angulation in the case of lower molars.

Those patients who could not be contacted or who rejected the control visits were regarded as lost cases. Following the methodology of von Arx et al.,[13] in patients with multiple teeth subjected to endodontic microsurgery, only one tooth was randomly selected for the statistical analysis. Randomization was generated at the website http://www.randomization.com.

Data Collection

The patients were subjected to clinical evaluation, observing the presence of symptoms (pain, sensitivity in response to percussion, and/or palpation) and signs (fistulas, swelling). Radiographs were interpreted independently by 2 examiners (APS and PGS) and by the treatment provider, who were all previously calibrated for use of the healing classification described by Rud et al.[17] and Molven et al.[18]

The following variables were recorded from the case history and the periapical radiographs and were entered in a database (Numbers, Apple, Cupertino, CA, USA): gender; age at the time of endodontic microsurgery ($<$45 years vs $\geq$45 years); type of tooth (anterior, premolars or molars; maxillary or mandibular); previous radiographic lesion size ($\geq$5 mm vs $<$5 mm); apical extent of previous root canal filling ($\geq$2 mm vs $<$2 mm); presence of a post; type of restoration (reconstruction vs crown); interproximal bone level (normal probing depth $\leq$3 mm mesial and distal vs bone loss $>$3 mm mesial or distal); and healing.

Radiographic healing around the treated teeth was classified into 4 groups according to the criteria of Rud and Molven: complete healing, incomplete healing, uncertain healing, or unsatisfactory healing[17,18]. The teeth were considered to be "healed" when presenting complete or incomplete healing without clinical signs or symptoms and were considered to be "not healed" when presenting uncertain or unsatisfactory healing, or with clinical signs or symptoms[13,14,19]. In multiple-root teeth subjected to endodontic microsurgery, the root with the poorest healing score was used to classify radiographic healing. Cases diagnosed as vertical root fracture were classified as failure. The periapical radiographs were evaluated by 2 calibrated observers in independent databases (Figs. 1–3).

Statistical Analysis

Simple binary logistic regression models were used, with the probability of success as the dependent variable, obtaining unadjusted odds ratios (ORs) and assessing the degree of association between variables. The impact or degree of association between the different factors and healing was evaluated based on the OR and 95% confidence interval (95% CI). A second simple binary logistic regression model was performed excluding vertical root fracture cases. All the cases were re-evaluated for healing by a second operator according to the criteria of Rud and Molven. Interexaminer reproducibility was assessed based on Cohen's kappa index (k).

The SPSS, version 21, statistical package for Macintosh (SPSS, Chicago, IL, USA) was used throughout.

RESULTS

A total of 244 patients were subjected to endodontic microsurgery between 2016 and 2019. We excluded 46 patients due to follow-up problems (30 patients could no longer be contacted, 10 patients were too old or too ill to attend, and 6 patients died).

The final sample thus consisted of 198 patients subjected to endodontic microsurgery. Women predominated (n = 119; 60%) over men (n = 79; 40%).

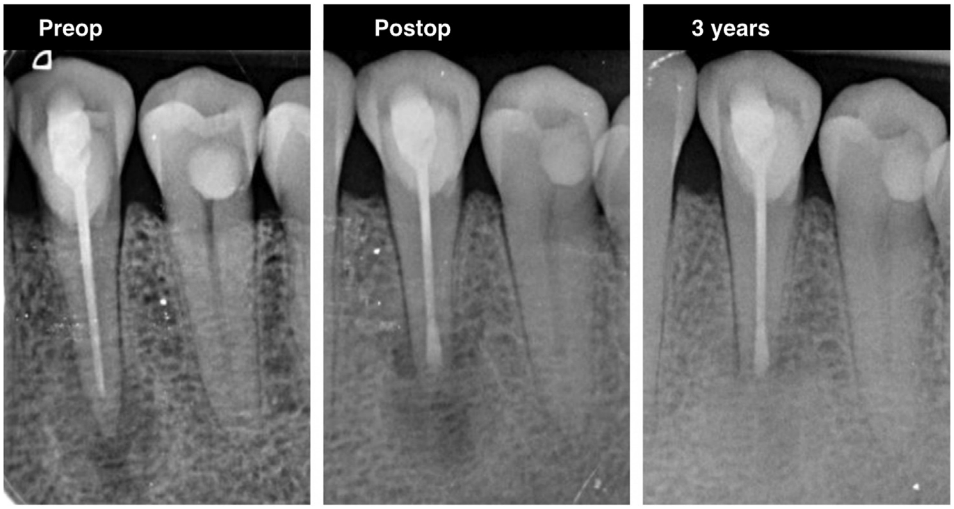

FIGURE 1 – Endodontic microsurgery of a lower left first premolar. Periapical radiographic view before and after surgery and at 3 years of follow-up, showing complete healing.

Table 1 shows the distribution of the study sample according to age and gender. Combining data of the cohort of 1 to 4 years of follow-up, with the cases published in the previous study (5–9 years of follow-up)[14], the study series comprised a total of 332 teeth subjected to endodontic microsurgery; of these, 198 teeth underwent middle-term follow-up (1–4 years), while 134 teeth underwent long-term follow-up (5–9 years). The percentage agreement between examiners was 91.4%. The linear weighted kappa index was 0.861 (95% CI: 0.79–0.93), showing reproducibility to be quite high.

Over the middle term, 86.9% of the teeth were classified as healed, while over the long term, 67.2% of the teeth were classified as healed. Table 2 shows the association between the healing score and the different prognostic factors. The regression models identified 5 statistically significant associations: cohort, gender, type of tooth, post, and interproximal bone level. A patient from the most recent cohort shows a higher probability of healing (OR = 2.85; P = .001). Males showed a lower probability of healing (OR = 0.38; P = .003). A worse prognosis was shown in lower molars (OR = 0.39; P = .031) and upper premolars (OR = 0.36; P = .012). Post placement reduced success rate (OR = 0.50; P = 0.35). When the interproximal bone level was greater than 3 mm, the probability of healing was significantly reduced (OR = 0.14; $P < 0.01$).

A sensitivity analysis excluding vertical root fractures (12 in the middle-term cohort and 25 in the long-term cohort) was performed. The middle-term cohort (1-4 years) included 186 patients (63.05%), and the long-term cohort (5–9 years) included 109 (36.95%). Over the middle term, 92.5% of the teeth were classified as healed and 7.5% as not healed, while over the long term, 81.8% of the teeth were classified as healed and 18.9% as not healed. Table 3 shows the association between the healing score and the different prognostic factors. There were no statistically significant differences in relation to gender, age, type of tooth, size of the lesion, apical extent of previous root canal filling, the presence of a post, or type of restoration. The regression models identified 2 statistically significant associations: cohort and interproximal bone level.

Belonging to the more recent cohort increased the odds of healing more than 2.5-fold with respect to belonging to the older cohort (OR = 2.59; P = .011). With regard to interproximal bone level, the odds of healing decreased significantly on exceeding the

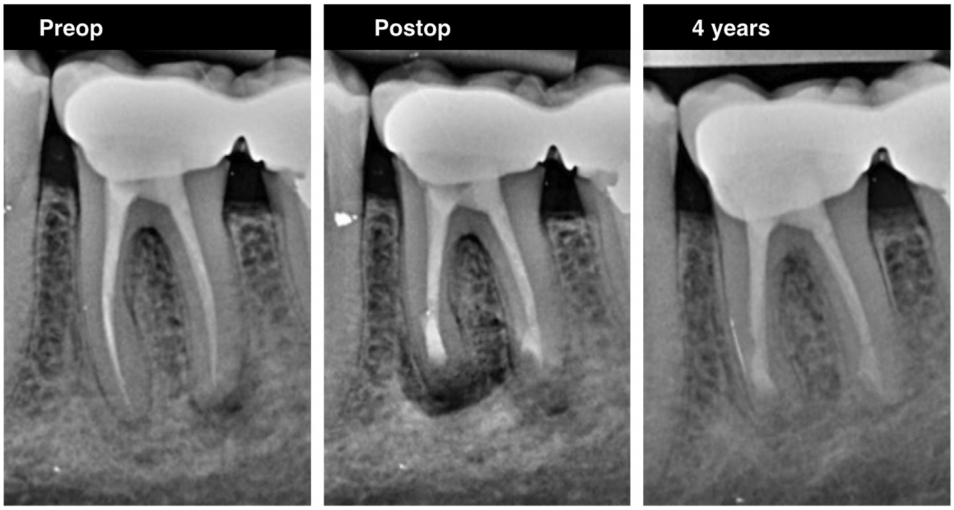

FIGURE 2 – Endodontic microsurgery of a lower left first molar. Periapical radiographic views over time, showing complete healing at 4 years of follow-up.

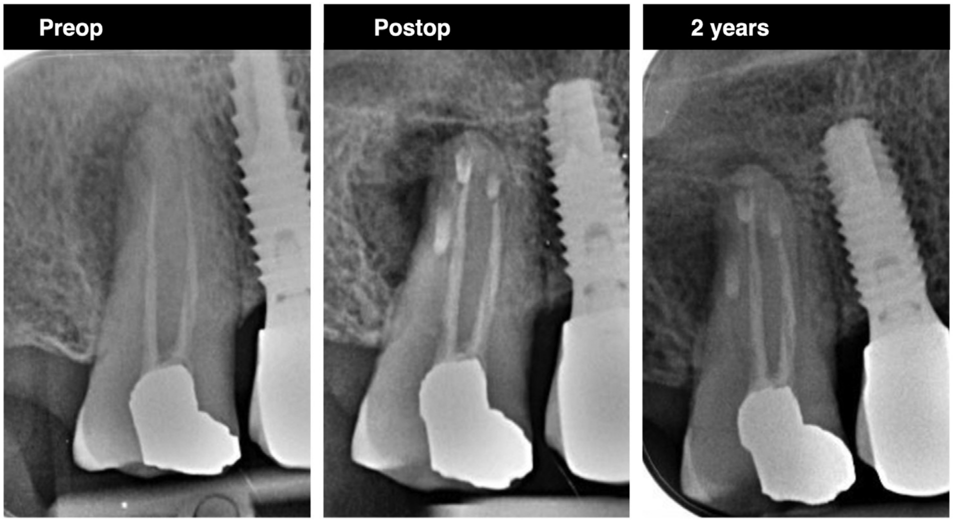

FIGURE 3 – Endodontic microsurgery of an upper right second molar. Periapical healing was considered to be unsatisfactory after 2 years of follow-up.

threshold of 3 mm. Figure 4 shows the healing rate according to cohort and interproximal bone level, as these were the 2 most relevant factors of the study.

DISCUSSION

The present study was carried out to compare the healing rates of teeth subjected to endodontic microsurgery over short- (1–4 years) and long-term follow-up (5–9 years) and to analyze the influence of different prognostic factors. Healing was classified in concordance with the practice in a number of other studies[12–14,19–21]. The classification of radiographic outcomes defined by Rud et al.[17] and Molven et al.[18] is widely accepted due to its strong concordance between observers after isolated examinations[11,22]. The null hypothesis that the long-term group has a lower healing rate than the healing rate at 1–4 years of follow-up was accepted.

One of the limitations of the present study is the fact that follow-up was based on the use of 2-dimensional periapical radiographs. In this regard, cone-beam computed tomography may soon prove to be an excellent alternative for assessing healing in endodontic microsurgery in 3 dimensions[11,13] since it has been shown to be more sensitive and specific than periapical radiographs in evaluating radiolucent periapical zones[23].

Song et al. found the healing rate of 115 cases one and 4 years after endodontic microsurgery to be 87.8% and 91.3%, respectively, though the difference was not statistically significant[21]. In turn, von Arx et al. found the healing rate of 170 teeth one and 5 years after surgery to be 83.8% and 75.9%, respectively. These authors suggested that the outcome 5 years after endodontic microsurgery may be 8% poorer than that one year after surgery[3]. Over the long term, treatment success rates of 78%–81.5% have been reported after 5–10 years of follow-up[10,12–14]. In our study, significant differences were recorded, with a success rate of 92.5% as determined 1-4 years after endodontic microsurgery, vs 81.8% after 5–9 years of follow-up.

With regard to the influence of the patient demographic characteristics upon endodontic microsurgery, the data found in the literature are inconsistent[14]. In the study published by Liao et al., women showed significantly higher healing rates after microsurgery than men[19]. In our study, however, neither patient age nor gender was seen to influence the outcome of endodontic microsurgery.

In relation to the type of tooth, von Arx et al. recorded higher healing rates for upper molars (95.2%) vs premolars (67.7%)[13]. In our study, the healing rate was 85% for upper molars and 82.8% for premolars—though the type of tooth did not have a significant influence upon healing rate.

In different studies, teeth with radiographic lesions measuring under 5 mm in size were found to have significantly higher healing rates than teeth with lesions over 5 mm in size[24–26]. In contrast, in our series, and in concordance with the observations of other authors involving longer follow-up periods[12,14,27], no significant differences were observed in relation to lesion size. This could be explained by the fact that the healing of larger lesions takes longer, and large lesions moreover may present scarring, which can complicate the assessment of radiological healing[28].

With regard to the extent of previous root canal filling, other studies have reported better outcomes in teeth presenting excessively short root canal filling (>2 mm)[19,28]. No statistically significant differences were recorded in our study, however.

Truschnegg et al. found that endodontic microsurgery in teeth with core and post restorations using intermediate restorative material (Dentsply Caulk, Milford, DE, USA) as filling material achieves excellent outcomes after 1.5–5 years of follow-up (97.6%), with good results even after 10–13 years of follow-up (75.8%)[27]. In our study, we compared teeth restored with composite resins vs reconstructions with crowns; the success rates were 86.7% and 90.1%, respectively, though the difference failed to reach statistical significance. According to the literature[14,19,28], the presence or absence of posts has no significant prognostic influence if we exclude

TABLE 1 - Distribution of the Study Sample According to Age and Gender

Gender	Patients, *n* (%)
Males	79 (39.9)
Females	119 (60.1)
	Age (y)*
Mean	50.6 ± 17
Median	52.5
Minimum	17
Maximum	85

*Age at the time of periapical surgery

TABLE 2 - Association Between Healing (Yes/No) and Independent Variables, *n* (%). Results of the Simple Binary Logistic Regression Models: Unadjusted Odds Ratio (OR) and 95% Confidence Interval

	Healing				
Independent variables	**No**	**Yes**	**OR**	**95% CI**	***P*-value**
n (teeth)	70 (21.1)	262 (78.9)			
Cohort					
2011–15	44 (32.8)	90 (67.2)	1		
2016–19	26 (13.1)	172 (86.9)	3.23	1.87–5.59	**<.001***
Year of treatment					**.002***
2011	10 (43.5)	13 (56.5)	1		
2012	9 (30.0)	21 (70.0)	1.80	0.58–5.59	.313
2013	6 (35.3)	11 (64.7)	1.41	0.39–5.13	.602
2014	9 (47.4)	10 (52.6)	0.86	0.25–2.90	.801
2015	10 (22.2)	35 (77.8)	2.69	0.91–7.95	.073
2016	12 (23.1)	40 (76.9)	2.56	0.90–7.30	.078
2017	6 (12.2)	43 (87.8)	5.51	1.68–18.1	**.005***
2018	1 (2.1)	46 (97.9)	35.4	4.14–302.5	**.001***
2019	7 (14.0)	43 (86.0)	4.73	1.50–14.9	**.008***
Gender					
Females	32 (16.1)	167 (83.9)	1		
Males	38 (28.6)	95 (71.4)	0.48	0.28–0.82	**.007***
Age					
<45 years	23 (19.7)	94 (80.3)	1		
≥45 years	47 (21.9)	168 (78.1)	0.88	0.50–1.53	.639
Type of tooth					.093
Upper anterior	12 (13.0)	80 (87.0)	1		
Upper premolar	20 (29.4)	48 (70.6)	0.36	0.16–0.80	**.012***
Upper molar	16 (23.9)	51 (76.1)	0.48	0.21–1.09	.080
Lower anterior	3 (11.5)	23 (88.5)	1.15	0.30–4.43	.839
Lower premolar	5 (17.2)	24 (82.8)	0.72	0.23–2.25	.572
Lower molar	14 (28.0)	36 (72.0)	0.39	0.16–0.92	**.031***
Arch					
Maxilla	48 (21.1)	179 (78.9)	1		
Mandible	22 (21.0)	83 (79.0)	1.01	0.57–1.79	.968
Lesion size					
≤5 mm	43 (19.4)	179 (80.6)	1		
>5 mm	27 (24.5)	83 (75.5)	0.74	0.43–1.28	.277
Extent of previous filling					
≤2 mm	55 (22.7)	187 (77.3)	1		
>2 mm	15 (16.7)	75 (83.3)	1.47	0.78–2.76	.231
Post					
No	53 (19.0)	226 (81.0)	1		
Yes	17 (32.1)	36 (67.9)	0.50	0.26–0.95	**.035***
Restoration					
Reconstruction	30 (23.4)	98 (76.6)	1		
Crown	40 (19.6)	164 (80.4)	1.26	0.74–2.14	.406
Crestal bone level					
≤3 mm mesial and distal	20 (9.5)	190 (90.5)	1		
>3 mm mesial or distal	50 (41.0)	72 (59.0)	0.15	0.08–0.27	**<.001***

Bold indicates independent variables.
*$P < .05$.

cases of vertical root fracture. The placement of posts could be related to vertical root fractures.

Von Arx et al. recorded poorer healing when the mesial or distal interproximal bone level exceeded 3 mm from the cementoenamel junction than when exceeding ≤3 mm (52.9% vs 78.2%, respectively), suggesting that the prognosis is influenced by the mesiodistal bone level of the treated tooth[3]. In concordance with the observations of von Arx et al., we recorded significant differences in relation to the mesiodistal bone level (80% vs 92.7%).

In the present study, the roots of 12 teeth experienced fracture after 1–4 years of follow-up, vs 23 teeth after 5–9 years. A considerably greater number of fractures were thus observed over the long term. However, it is currently unknown if and how apical surgery may contribute to the development of vertical root fractures[13]. The literature on this subject does not address the relationship between endodontic microsurgery and root fractures. Several authors have excluded cases of vertical root fractures[3,13,19,29,30]. In this study, a sensitivity analysis was performed, excluding fractures for statistical analysis. The way in which vertical root fractures influence the prognosis

TABLE 3 - Association Between Healing (Yes/No) and Independent Variables, *n* (%). Results of the Second Simple Binary Logistic Regression Models, Excluding Vertical Root Fractures: Unadjusted Odds Ratio (OR) and 95% Confidence Interval

	Healing				
Independent variables	**No**	**Yes**	**OR**	**95%CI**	***P*-value**
n (teeth)	33 (11.2)	262 (88.8)			
Cohort					
2011–15	19 (17.4)	90 (82.6)	1		
2016–19	14 (7.5)	172 (92.5)	2.59	1.24–5.41	**.011***
Gender					
Females	19 (10.2)	167 (89.8)	1		
Males	14 (12.8)	95 (87.2)	0.77	0.37–1.61	490
Age					
<45 y	13 (12.1)	94 (87.9)	1		
≥45 y	20 (10.6)	168 (89.4)	1.16	0.55–2.44	692
Type of tooth					467
Upper anterior	7 (8.0)	80 (92.0)	1		
Upper premolar	10 (17.2)	48 (82.8)	0.42	0.15–1.18	420
Upper molar	9 (15.0)	51 (85.0)	0.50	0.17–1.42	496
Lower anterior	0 (0.0)	23 (100)	—	—	—
Lower premolar	1 (4.0)	24 (96.0)	2.10	0.25–17.9	498
Lower molar	6 (14.3)	36 (85.7)	0.53	0.17–1.67	525
Arch					
Maxilla	26 (12.7)	179 (87.3)	1		
Mandible	7 (7.8)	83 (92.2)	1.72	0.72–4.13	223
Lesion size					
≤5 mm	20 (10.1)	179 (89.9)	1		
>5 mm	13 (13.5)	83 (86.5)	0.71	0.34–1.50	374
Extent of previous filling					
≤2 mm	28 (13.0)	187 (87.0)	1		
>2 mm	3 (7.7)	36 (92.3)	2.25	0.84–6.04	109
Post					
No	30 (11.7)	226 (88.3)	1		
Yes	3 (7.7)	36 (92.3)	1.59	0.46–5.49	461
Restoration					
Reconstruction	15 (13.3)	98 (86.7)	1		
Crown	18 (9.9)	164 (90.1)	1.40	0.67–2.89	372
Crestal bone level					
≤3 mm mesial and distal	15 (7.3)	190 (92.7)	1		
>3 mm mesial or distal	18 (20.0)	72 (80.0)	0.32	0.15–0.66	**.002***

Bold indicates independent variables.
*$P < .05$.

of periapical surgery has not been investigated[13]. Ultrasonic retrograde preparation may be associated with a greater risk of root microfractures in already weakened teeth such as those subjected to endodontic treatment and apicoectomy, and a prolonged monitoring period could cause such microfractures to become complete fractures[19].

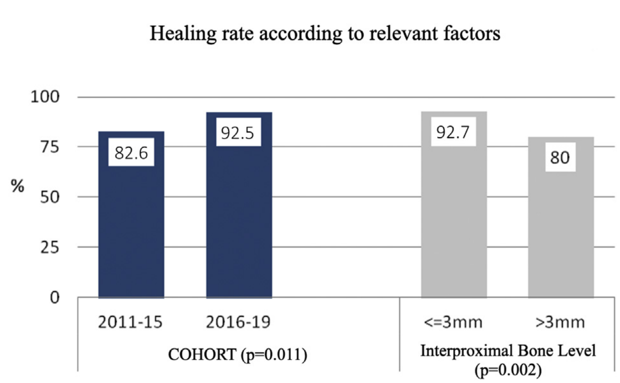

FIGURE 4 – Healing rates according to relevant factors (cohort and interproximal bone level).

Independently of all other factors, the results obtained suggest that the duration of follow-up is a key parameter for the final evaluation. Regarding the success rate of endodontic microsurgery, we recorded no statistically significant differences in relation to patient age or gender, previous radiographic lesion size, the type of tooth, the presence of a post, the type of restoration, or the apical extent of previous root canal filling. Interproximal bone level is considered a variable of clinical importance, which could have a guide value when making a decision whether or not to carry out conservative surgical treatment.

CONCLUSIONS

In the cohort with 1–4 years of follow-up, the healing rate was 67.2% vs 86.9% in the cohort with 5–9 years of follow-up. Excluding fractures, in the patients with the shortest follow-up (1–4 years), the healing rate was 92.5%, vs 82.6% in those with longer follow-up (5–9 years) (OR = 2.6; $P = .014$). The prognosis was influenced by the crestal bone level in relation to the cementoenamel junction of the tooth, being significantly poorer when probing depth was $>$3 mm mesial or distal to the treated tooth.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Antonio Pallarés-Serrano: Conceptualization, Methodology, Software. **Pablo Glera-Suarez:** Methodology, Software, Visualization. **Beatriz Tarazona-Alvarez:** Investigation, Writing – review & editing, Visualization. **David Peñarrocha-Oltra:** Resources, Writing – review & editing, Supervision. **Miguel Peñarrocha-Diago:** Writing – review & editing, Supervision.

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The authors declare that they have no conflicts of interest in relation to this study.

SUPPLEMENTARY DATA

Supplementary material associated with this article can be found in the online version at www.jendodon.com (https://doi.org/10.1016/j.joen.2022.03.001).

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