Received: 21 January 2019 | Revised: 6 May 2019 | Accepted: 13 May 2019

DOI: 10.1002/JPER.19-0033

JOURNAL OF Periodontology

CASE SERIES

Outcomes of root resection therapy up to 16.8 years: A retrospective study in an academic setting

Madi Alassadi | **Musa Qazi** | **Andrea Ravidà** | **Rafael Siqueira** | **Carlos Garaicoa-Pazmiño** | **Hom-Lay Wang**

Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, MI

Correspondence
Hom-Lay Wang, DDS, MS, PhD, Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry, 1011 North University Avenue, Ann Arbor, MI 48109-1078.
Email: homlay@umich.edu

Abstract

Background: Root resection has been considered a viable treatment option for molars with furcation defects. However, need of a multidisciplinary approach could potentially deem this procedure less successful. The aim of the present article was to determine survival rates of root resection procedure and reasons for failure in an academic setting.

Methods: Patient-related demographic data, medical history information, and relevant data pertaining to the root-resected teeth performed from January 1990 to September 2017 were reviewed through electronic and paper chart. Survival rates were analyzed using Kaplan-Meier estimate. Association between the reasons for failure and independent variables was established by a Pearson Chi-squared and Kruskal-Wallis test.

Results: A total of 85 patients with an average follow-up of 5 ± 4.3 years (range: 1 to 16.8 years) were included in the present article. A total of 47 molar teeth treated with root resection remained as part of the dentition (55.3%) and 38 (44.7%) failed. The mean survival time with the Kaplan-Mayer analysis was 109.9 months (9.1 years). Fracture (39.5%), caries (26.3%), and periodontal disease (23.7%) were the most common causes for failure. Interestingly, the majority of failures occurred in the first 4 years after therapy (n = 31; 81.5% of all failures).

Conclusions: Root resection therapy remains a treatment solution for molars with furcation defects. In an academic setting, >50% of teeth remained functional after 9 years of root resection therapy.

KEYWORDS

furcation lesions and treatment, periapical diseases, periodontal surgery, periodontitis, prognosis, tooth loss, tooth root

1 | INTRODUCTION

Molars with intra-radicular horizontal and vertical bone destruction tend to respond less favorably to routine periodontal treatment than single-rooted teeth.[1–4] In fact, narrow furcation anatomy, due to convergent roots and the presence of concavities, often limits the efficacy of periodontal therapy.[5] Soon after periodontal treatment, maxillary molars have demonstrated less probing depth (PD) reduction as well as greater relapse on PD than non-molar teeth.[6] Previous investigations report that the presence of Class II and III furcation involvement have an increased risk for tooth loss

in molars with or without supportive periodontal maintenance therapy (SPMT).[7,8] Therefore, to ensure long-term stability of a furcation-involved molar, recreating furcal topography that enables ideal plaque control becomes necessary.

Root resection has been considered a viable treatment for multi-rooted teeth with furcation defects before considering tooth extraction and subsequently, the need to prosthetically replace the missing teeth.[9–11] Through this procedure, Class III furcation involvements of multi-rooted teeth are converted into two- or single-rooted units to create an environment that facilitates adequate oral hygiene. Nonetheless, the introduction of periodontal regeneration and implant therapy has led to a significant shift in the decision-making process for more cost-effective approaches, shorter treatment duration and more predictable outcomes.[12,13] Nowadays, root resection remains a viable procedure when a compromised tooth is of strategic importance or when a nearby anatomic structure (e.g., inferior alveolar canal, maxillary sinus) precludes other more invasive surgical approaches.[14] Additionally, a more specific indication for root resection also exists; that being the presence of marginal bone loss caused by periodontal disease or fracture affecting a single root.

Classic literature has reported predictable long-term outcomes for teeth undergoing root resection when performed by clinicians with expertise in clinical endodontics, prosthodontics, and periodontics.[11,15] However, the need of a multidisciplinary approach and expert surgeons could potentially deem this procedure less predictable for less experienced clinicians. Hence, the aim of this article was to determine survival rates of root resection therapy and reasons for failure in an academic setting with less experienced providers.

2 | MATERIALS AND METHODS

The study protocol was approved by the Institutional Review Board at the University of Michigan (HUM00114382) and conducted in accordance with the Helsinki Declaration of 1975 as revised in 2013. The study population includes patients who had undergone root resection therapy at the University of Michigan, School of Dentistry, Graduate Periodontics Clinic, between January 1990 and September 2017. To be eligible for this study, patients met the following criteria: 1) underwent a root resection procedure and maintained a follow-up of at least 12 months, 2) SPMT within the same school setting, and 3) have an opposing tooth or implant in function. Each patient contributed with only one root resected tooth. According to the treatment protocol established in our Graduate Periodontics clinic, all patients are required to receive non-surgical periodontal treatment before surgical (e.g., root resection) therapy. Patients with short-term follow up (<12 months), unclear/incomplete clinical records, or unavailable pre- and post-operative radiographs were excluded. Retrospective data were gathered from patient records by two calibrated examiners (MA and MQ). Given the retrospective nature of the study and the use of anonymized patient data, requirement for informed consent was waived.

2.1 | Data collection

Patient-related demographic data (e.g., age, sex) and medical history information (e.g., smoking, diabetes) were recorded throughout the entire follow-up period. Additionally, dental history and site-specific factors including history of periodontal disease, presence of bleeding on probing (BOP), presence of exudate, radiographic bone loss (BL), PD, and parafunctional habits (e.g., bruxism) were registered. Furthermore, relevant data pertaining to the root-resected tooth such as location in the oral cavity, specific resected root, purpose of the surgical procedure, reasons for tooth extraction (divided into four possible categories of failure: caries/restorative, fracture, endodontic, periodontal), history of endodontic treatment (≥6 months prior, < 6 months before/in concomitance with, or after the root resection procedure), type of final restoration (e.g., composite, porcelain-fused metal crown, tooth-supported fixed partial prosthesis), presence/absence of post in non-resected roots, presence/absence of adjacent teeth and type of opposing dentition (e.g., natural intact tooth, tooth-supported single crown, implant-retained restoration) were obtained.

Tooth survival was defined as any tooth that had undergone root resection, remained in functional loading, and confirmed by clinical or radiographic evidence (periapical x-ray, periodontal chart, and provider notes) upon dental records. Conversely, failure status was given to any tooth extracted after a root sectioning procedure due to any reasons throughout the observational period.

2.2 | Statistical analyses

Descriptive and inferential statistics were obtained from collected data including mean, median, standard deviation, absolute frequency, and odds ratio values. The Kaplan-Meier estimate was used to analyze the survival rates of root-resected teeth. A mean survival rate, standard error, and a 95% confidence interval were provided. Additionally, the log-rank test was used in case independent factors generated different survival curves.

Subsequently, all statistically significant variables or close to P values of <0.2 were considered of interest for a Cox regression model. This method explains the individual importance of each factor associated with the failure rate by a fully adjusted hazard ratio and a forward Euler method. Ultimately, the association between the reason for extraction and independent variables was established by Pearson Chi-squared and Kruskal-Wallis tests. The level of significance used in the analysis was 5% ($\alpha = 0.05$).

TABLE 1 Overall demographic data and recorded variables

Variable		Total, n (%)	Survival, n (%)	Failure, n (%)	*P* value
Number of patients		85 (100%)	47 (55.3%)	38 (44.7%)	
Male		49 (57.6%)	29 (61.7%)	20 (52.6%)	0.167
Female		36 (42.4%)	18 (38.3%)	18 (47.4%)	
Smokers		33 (38.8%)	16 (34.0%)	17 (44.7%)	0.852
Diabetes		8 (9.4%)	4 (8.5%)	4 (10.5%)	0.414
Bruxism		21 (25.0%)	9 (19.1%)	12 (32.4)	0.097
Hx of periodontitis		29 (34.1%)	15 (31.9)	14 (36.8%)	0.987
Age (mean)		62.5 ± 10.8	61.6 ± 12.6	63.7 ± 7.9	0.148
Tooth type	Max first molar	54 (63.5%)	33 (70.2%)	21 (55.3%)	0.184
	Max second molar	15 (17.6%)	7 (14.9%)	8 (21.1%)	
	Mand first molar	14 (16.5%)	5 (10.6%)	9 (23.7%)	
	Mand second molar	2 (2.4%)	2 (4.3%)	0 (0%)	
Arch	Maxillary	69 (81.2%)	40 (85.1%)	29 (76.3%)	0.511
	Mandibular	16 (18.8%)	7 (14.9%)	9 (23.7%)	
Resected root	Palatal	5 (5.9%)	2 (4.3%)	3 (7.9%)	0.414
	Mesio-buccal	35 (41.2%)	18 (38.3%)	17 (44.7%)	
	Disto-buccal	29 (34.1%)	20 (42.6%)	9 (23.7%)	
	Mesial	10 (11.8%)	4 (8.5%)	6 (15.8%)	
	Distal	6 (7.1%)	3 (6.4%)	3 (7.9%)	
Reasons for root resection	Periodontal	40 (47.1%)	29 (61.7%)	11 (28.9%)	<0.001[a]
	Endodontic	23 (27.1%)	11 (23.4%)	12 (31.6%)	
	Fracture	22 (25.9%)	7 (14.9%)	15 (39.5%)	
Opposing dentition	Natural tooth	38 (44.7%)	22 (46.8%)	16 (42.1%)	0.493
	Crown	40 (47.1%)	22 (46.8%)	18 (47.4%)	
	Implant	7 (8.2%)	3 (6.4%)	4 (10.5%)	
Adjacent tooth	Mesial	61 (71.8%)	33 (70.2%)	28 (73.7%)	0.342
	Distal	58 (68.2%)	33 (70.2%)	25 (68.8%)	0.264
RCT	Prior resection	63 (74.1%)	35 (74.5%)	28 (73.7%)	0.682
	During resection	17 (20)	10 (21.3%)	7 (18.4%)	
	After resection	3 (3.5%)	2 (4.3%)	1 (2.6%)	
Type of restoration	Crown	64 (75.3%)	36 (76.6%)	28 (73.7%)	0.484
	Filling	9 (10.6%)	4 (8.5%)	5 (13.2%)	
	FPD	12 (14.1%)	7 (14.9%)	5 (13.2%)	
New restoration after root resection		9	4 (8.5%)	5 (13.2%)	0.602
Splinting		12 (14.1%)	7 (14.9%)	5 (13.2%)	0.247
Presence of Post/Core		25 (29.4%)	13 (27.7%)	12 (31.6%)	0.792

FPD, Fixed partial denture; Hx, history; RCT, root canal therapy.
[a]*P* value <0.001.

3 | RESULTS

3.1 | Clinical characteristics and demographic profiles

One hundred and thirty-six clinical records with root resection procedures were identified during initial screening. Fifty-one cases were excluded for any of the following reasons: 1) 38 cases with <12 months of follow-up, 2) eight unclear/incomplete clinical records, and 3) five cases with incomplete root resection procedures (e.g., apicoectomy). A total of 85 patients, composed of 49 males (57.6%) and 36 females (42.4%) with an overall mean age of 62.5 ± 10.8 years and a mean follow-up of 5 ± 4.3 years (range: 1 to 16.8 years), were included. The sample demographic data, such as reasons for root resection and recorded variables were summarized in Table 1. The distribution of all resected roots is shown in supplementary Figure 1 in online *Journal of*

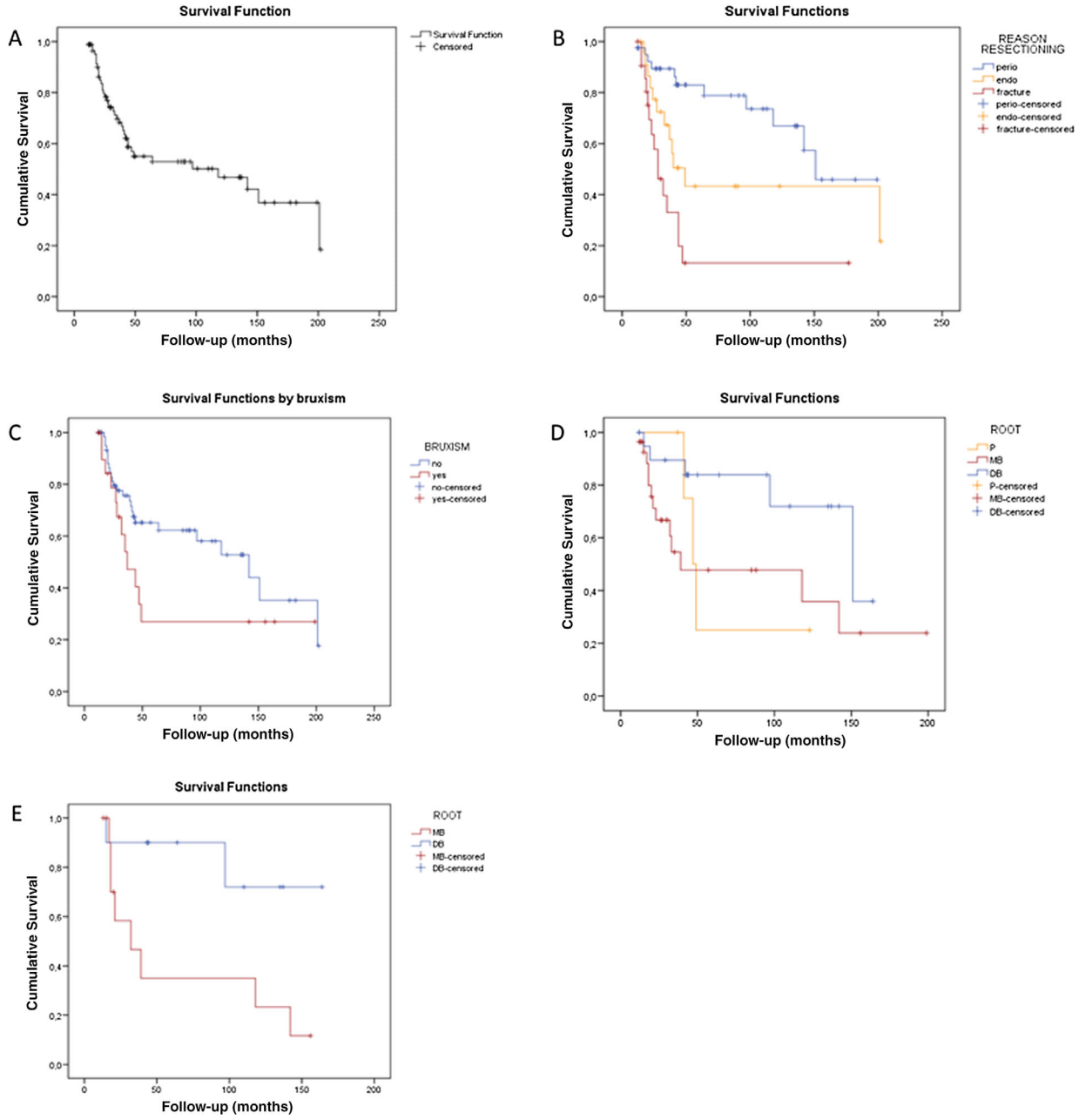

FIGURE 1 Cumulative survival rates for molars with resected roots. (**A**) Overall cumulative survival rates of root resected teeth. (**B**) Cumulative survival rates based on reason for root resection. (**C**) Cumulative survival rates based on patients with or without bruxism. (**D**) Cumulative survival rates based on mesio-buccal versus disto-buccal versus palatal resected roots among maxillary first molars. (**E**) Cumulative survival rate based on mesio-buccal versus disto-buccal resected roots among maxillary right first molars

Periodontology. Limited information was obtained regarding BOP, PD, and radiographic BL, hence being unsuitable for statistical analysis.

3.2 | Cumulative survival rates of root resected teeth

Based on the Kaplan-Meier method, the mean survival time of root-resected teeth was 109.9 months (9.1 years). Only a total of 47 teeth remained as part of the dentition (55.3%), while 38 failed due to the above-mentioned reasons (44.7%). Figure 1A depicts the cumulative survival rate with a maximum follow-up of 202 months (16.8 years). A significant decrease in the survival rates is shown during the first 4 years after root-resection therapy (n = 31; 81.5% of all failures), being stable after this period. Table 2 includes the cumulative survival rate of root-resected teeth at different intervals, revealing an 18.4% survival rate after >144 months of treatment.

TABLE 2 Cumulative survival rate of root resection therapy at different intervals

Follow-up	Sample size	Failures	Percentage of failure per interval	Cumulative survival rate
<12 months	85	1	1.2%	98%
12 to 24 months	81[a]	15	18.5%	79.6%
>24 to 36 months	61	7	11.5%	69.7%
>36 to 48 months	46	8	16.7%	56.8%
>48 to 96 months	31	2	6.5%	52.9%
>96 to 144 months	19	3	15.8%	42.1%
>144 months	8	2	25%	18.4%

[a]Values adjusted per observation period.

TABLE 3 Proportional hazard model

Variable		Hazard Ratio	Confidence interval 95%	*P* value
Sex	Male	1		0.883
	Female	1.05	0.53 to 2.08	
Age		1.03	0.99 to 1.06	0.201
Bruxism	Without	1		0.609
	With	1.23	0.56 to 2.71	
Type of tooth	Max first	1		0.932
	Max second	0.98	0.40 to 2.47	0.319
	Mand first	0.73	0.28 to 1.88	0.511
Reason for root resection	Periodontal	1		<0.001[b]
	Endodontic	3.1	1.26 to 7.64	0.014[a]
	Fracture	9.44	3.26 to 27.3	<0.001[b]

[a]*P* value <0.05.
[b]*P* value <0.001.

Figure 1B denotes the differences in survival rates of teeth treated with root resection according to the reason of treatment. Overall, high failure rate was observed for root-resected teeth due to endodontic reasons or vertical fracture with a three-fold (210%) and nine-fold (840%) increased risk of failure than those resected due to a periodontal etiology ($P < 0.01$) (Table 3).

Furthermore, the presence of parafunctional habits decreased the teeth survival rate ($P = 0.097$) yet failed to achieve statistical significance (Fig. 1C).

Table 4 reports the possibility of survival rate being affected by the resection of one specific root using a log rank test. The results identified that the survival rate of the 54 maxillary first molars was lower when the mesio-buccal root was extracted ($P = 0.081$) (Fig. 1D), reaching significance when only maxillary first right molars were analyzed ($P = 0.029$) (Fig. 1E).

TABLE 4 Comparison between tooth type and resected roots

Variable	Resected root	*P* value
Tooth #3	MB versus DB	0.029[a]
Tooth #14	MB versus DB	0.595
Max first molars	P versus MB versus DB	0.081
Max second molars	MB versus DB	0.693
Mand first molars	M versus D	0.581
Maxillary molars	P versus MB versus DB	0.230
Mandibular molars	M versus D	0.898
First molars	P versus MB versus DB versus M versus D	0.052
Second molars	MB versus DB	0.693

MB, mesio-buccal; DB, disto-buccal; P, palatal; M, mesial; D, distal.
[a]*P* value < 0.05.

3.3 | Causes for extraction of root resected teeth

Among the 38 that failed, root-resected teeth, fracture (39.5%), caries (26.3%) and periodontal disease (23.7%) were the most common causes for failure. Two cases (2.4%) were attributed to endodontic failure and the remaining two cases cause of extraction could not be determined (2.4%) (Fig. 2).

Furthermore, 45.5% of the teeth that underwent root resection for a periodontal condition failed due to periodontal reasons. Conversely, this association was not reported when fracture and endodontic failure were the cause of extraction. Maxillary first molars exhibited greater failure rates then the

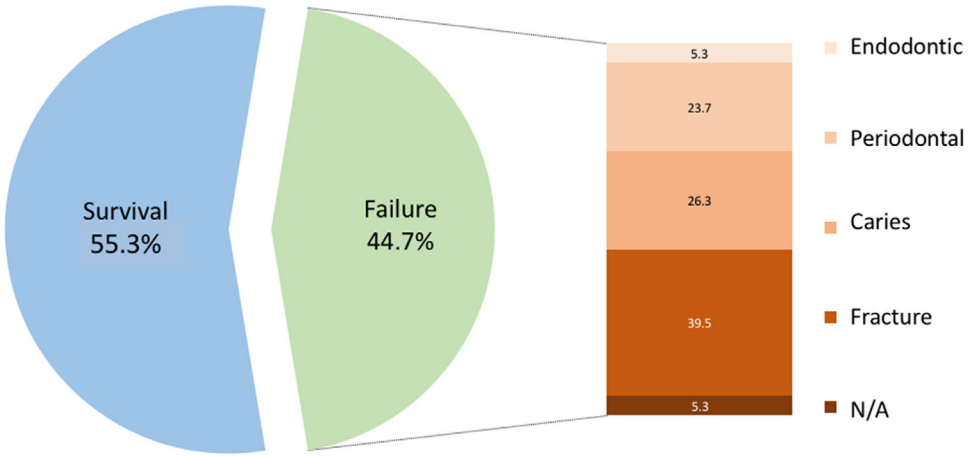

FIGURE 2 Frequency distribution of survival rate of root resection therapy and causes for extraction

rest of the dentition ($P = 0.007$). More than 80% of the failures were caused by fractures (47.6%) and recurrent periodontal disease (38.1%).

Ultimately, a higher tendency of failure was observed when the antagonist was a dental implant; four out of seven teeth failed ($P = 0.062$). The reason for failure was due to a fracture (100%). No other correlation with the type of failure was found with the remaining variables.

4 | DISCUSSION

The present article retrospectively assesses specific parameters potentially associated with the survival of molars undergoing root resection therapy in an academic setting. This investigational setting enables the ability to explore the predictability of this procedure, whilst simultaneously ensuring external validity, in the hands of relative novice-level experience (e.g., periodontal graduate students).

Contrary to the failure rate observed in our study (44.7%), previous studies have reported lower 10-year failure rates ranging between 3% and 38%.[11,15–18] The differences noted between these studies and the current study can be associated with the eligibility criteria, patient compliance, and a need for multidisciplinary approach with experienced clinicians.[11,16,17,19,20] An evident example of this is in the article of Fugazzotto et al. (2001), where the root resection therapy had only been performed in good plaque control patients (plaque score ≤10%), implying a study sample of high compliance.[16] Similarly, other studies included a sequence of treatment (endodontic therapy, root resection, and prosthetic reconstruction) performed by experienced individuals.[15,21] This poses the question of how much the level of prior experience pertaining to the root resection and secondary restorative work may influence the treatment outcome.

It is important to note our treatment failure mostly occurred in the first 4 years after therapy. This observation may partially explain the discrepancy compared with the study by Megarbane et al. (2018), which excludes early failures (50.5%), being patients who failed to complete the 5-year follow-up, led to a high survival rate of 94.8%.[22] Additionally, the high failure rate we report here is higher than Buhler et al. (1988) and Langer et al. (1981) that reported 10-year failure rates of 32.1% and 38%, respectively.[11,18]

Periodontitis was one of the most frequent causes of failure, with 23% of the teeth having been extracted due to this reason. This rate is comparable with that of Langer et al.,[11] where 26.3% of the teeth were lost to periodontitis, and lower than those reported by Buhler et al.,[18] Svardstrom et al.,[23] Park et al.,[17] and Lee et al.[24] (44%, 80%, 50%, and 74.2% respectively). The relatively low failure rate due to periodontitis reported in the present paper could be associated with the treatment and patient maintenance related to being performed in a periodontal department. However, interestingly, almost half (45.5%) of the teeth that received a root resection for a periodontal reason failed due to periodontitis. Hence, this highlights the importance of creating a cleansable environment for periodontal maintenance, providing constant oral hygiene instruction, and encouraging patient compliance when performing root resection.

In the present study, the most frequent cause of failure as root resection was root fracture (39.5%). This result was slightly lower when compared with that of Langer et al. (47.4%)[11] but higher than the majority of the relevant literatures.[15–18,22,24] The considerably high failure rate caused by fracture could be explained by the fact that nearly the entire sample comprised non-splinted teeth. Unfortunately, we were unable to statistically support this statement with a direct comparison between the splinted and non-splinted teeth due to the vast majority (85.9%) having received either a single crown or a simple restoration, reducing the statistical power

significantly. However, it has been previously highlighted that splinting a resected tooth to neighboring teeth confers a protective effect toward its survival.[17,24] Moreover, the lack of splinted teeth may further explain the increased failure in the presence of parafunctional habit. In fact, the prevalence of bruxism among patients who presented with failure due to fracture was 32.4%. A comparable observation was only noted in the article of Fugazzotto et al., where 34.4% of the failures were attributed to detectable parafunctional habits.[16] Another factor that could lead to root fracture of the remaining roots is the post-space preparation of the intraradicular canal and post selection.[25] However, the results of the present study failed to identify any correlation between failure and the presence of prosthetic posts.

Additionally, the location of the resected root in the oral cavity played a key role in the survival rate. In terms of root location per arch, as was the case with other investigations in the present literature,[11,17] failure rate was higher in mandibular (nine out of 16 roots, 56.25%) than maxillary molars (29 out of 69 roots, 42%). This is morphologically explained by the presence of two roots after resection in maxillary teeth, as opposed to just one; and usually including a large palatal root. Furthermore, the residual tooth structure in a maxillary molar possesses a surface area large enough to provide adequate retention for an overlying casting. In terms of root location within a given tooth, we have found a certain tendency of poorer prognosis for teeth with a resected mesio-buccal root. This result is in contrast with Park and coworkers (2009),[17] where teeth that underwent disto-buccal or palatal root resection exhibited more failures than their mesio-buccal counterparts in the maxilla. Moreover, the articles of both Lee[24] and Fugazzotto[16] do not report a significant correlation between the location of the remaining roots and the tooth survival at recall.

Ultimately, root resection should be considered a valid option before implant therapy, especially in patients with identifiable risk factors (e.g., heavy smokers) associated with peri-implant diseases. Root resection in a maxillary molar functioning as an abutment tooth for a fixed partial denture (FPD) could extend the life span of the FPD and selectively remove the endodontically failing root. It is of paramount importance to note that the prevalence of peri-implant diseases have been exhibiting an exponential increase in the last few decades[26] and thus, case selection and multiple treatment options before extraction are key components in the prevention of these conditions.

The present article is not exempt from limitations such as the retrospective nature of the study that increases the risk of bias. Moreover, the limited sample size, low prevalence of splinted restorations, slight external validity (data from only less experienced surgeons), and the presence of various operators should be taken into consideration when interpreting the data from the present article.

5 | CONCLUSIONS

Within the imitations of this study, root resection therapy remains a treatment solution for molars with furcation defects. In an academic setting with less experienced clinicians, >50% of teeth remained functional after 9 years of root resection therapy. The majority of failures occurred in the first 4 years after therapy. Tooth fracture, caries, periodontal and endodontic failures remain as common reasons for failure. Finally, parafunctional habits have a significant impact upon the long-term survival of root-resected teeth.

ACKNOWLEDGMENT

This manuscript was partially supported by the University of Michigan Periodontal Graduate Student Research Fund. The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the paper.

ORCID

Carlos Garaicoa-Pazmiño https://orcid.org/0000-0001-8486-6810
Hom-Lay Wang https://orcid.org/0000-0003-4238-1799

REFERENCES

1. Wang HL, Burgett FG, Shyr Y, Ramfjord S. The influence of molar furcation involvement and mobility on future clinical periodontal attachment loss. *J Periodontol*. 1994;65:25-29.
2. Kaldahl WB, Kalkwarf KL, Patil KD, Molvar MP. Responses of four tooth and site groupings to periodontal therapy. *J Periodontol*. 1990;61:173-179.
3. Nordland P, Garrett S, Kiger R, Vanooteghem R, Hutchens LH, Egelberg J. The effect of plaque control and root debridement in molar teeth. *J Clin Periodontol*. 1987;14:231-236.
4. Kalkwarf KL, Kaldahl WB, Patil KD. Evaluation of furcation region response to periodontal therapy. *J Periodontol*. 1988;59:794-804.
5. Bower RC. Furcation morphology relative to periodontal treatment. Furcation entrance architecture. *J Periodontol*. 1979;50:23-27.
6. Ramfjord SP, Caffesse RG, Morrison EC, et al. 4 modalities of periodontal treatment compared over 5 years. *J Clin Periodontol*. 1987;14:445-452.
7. Nibali L, Zavattini A, Nagata K, et al. Tooth loss in molars with and without furcation involvement – a systematic review and meta-analysis. *J Clin Periodontol*. 2016;43:156-166.
8. Nibali L, Krajewski A, Donos N, et al. The effect of furcation involvement on tooth loss in a population without regular periodontal therapy. *J Clin Periodontol*. 2017;44:813-821.
9. Filipowicz F, Umstott P, England M. Vital root resection in maxillary molar teeth: a longitudinal study. *J Endod*. 1984;10:264-268.
10. Erpenstein H. A 3-year study of hemisectioned molars. *J Clin Periodontol*. 1983;10:1-10.
11. Langer B, Stein SD, Wagenberg B. An evaluation of root resections. A ten-year study. *J Periodontol*. 1981;52:719-722.

12. Murphy KG, Gunsolley JC. Guided tissue regeneration for the treatment of periodontal intrabony and furcation defects. A systematic review. *Ann Periodontol*. 2003;8:266-302.
13. Avila-Ortiz G, De Buitrago JG, Reddy MS. Periodontal regeneration – furcation defects: a systematic review from the AAP regeneration workshop. *J Periodontol*. 2015;86:S108-130.
14. Minsk L, Polson AM. The role of root resection in the age of dental implants. *Compend contin educ dent*. 2006;27:384-388.
15. Carnevale G, Pontoriero R, di Febo G. Long-term effects of root-resective therapy in furcation-involved molars. A 10-year longitudinal study. *J Clin Periodontol*. 1998;25:209-214.
16. Fugazzotto PA. A comparison of the success of root resected molars and molar position implants in function in a private practice: results of up to 15-plus years. *J Periodontol*. 2001;72:1113-1123.
17. Park SY, Shin SY, Yang SM, Kye SB. Factors influencing the outcome of root-resection therapy in molars: a 10-year retrospective study. *J Periodontol*. 2009;80:32-40.
18. Buhler H. Evaluation of root-resected teeth. Results after 10 years. *J Periodontol*. 1988;59:805-810.
19. Hamp SE, Nyman S, Lindhe J. Periodontal treatment of multirooted teeth. Results after 5 years. *J Clin Periodontol*. 1975;2:126-135.
20. Dannewitz B, Zeidler A, Husing J, et al. Loss of molars in periodontally treated patients: results 10 years and more after active periodontal therapy. *J Clin Periodontol*. 2016;43:53-62.
21. Derks H, Westheide D, Pfefferle T, Eickholz P, Dannewitz B. Retention of molars after root-resective therapy: a retrospective evaluation of up to 30 years. *Clin Oral Investig*. 2018;22:1327–1335.
22. Megarbane JM, Kassir AR, Mokbel N, Naaman N. Root resection and hemisection revisited. part ii: a retrospective analysis of 195 treated patients with up to 40 years of follow-up. *Int J Periodontics Restorative Dent*. 2018;38:783-789.
23. Svardstrom G, Wennstrom JL. Periodontal treatment decisions for molars: an analysis of influencing factors and long-term outcome. *J Periodontol*. 2000;71:579-585.
24. Lee KL, Corbet EF, Leung WK. Survival of molar teeth after resective periodontal therapy–a retrospective study. *J Clin Periodontol*. 2012;39:850-860.
25. Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. *J Endod*. 2010;36:609-617.
26. Derks J, Tomasi C. Peri-implant health and disease. A systematic review of current epidemiology. *J Clin Periodontol*. 2015;42:S158-S171.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Alassadi M, Qazi M, Ravidà A, Siqueira R, Garaicoa-Pazmiño C, Wang H-L. Outcomes of root resection therapy up to 16.8 years: A retrospective study in an academic setting. *J Periodontol*. 2020;91:493–500. https://doi.org/10.1002/JPER.19-0033