Results of root canal treatment in dogs: 127 cases (1995–2000)

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Objective—To evaluate results of root canal treatment in dogs.

Design—Retrospective study.

Sample Population—127 tooth roots in 64 dogs.

Procedure—Radiographs obtained before surgery, immediately after surgery, and during follow-up examinations after surgery were evaluated by 2 individuals. Treatment was considered successful if the periodontal ligament space was normal and possible preoperative root resorption, if present, had ceased. Treatment was considered to show no evidence of failure if possible preoperative root resorption had ceased but a preexisting periapical lesion had remained the same or only decreased in size and not complete resolved. Treatment was considered to have failed if a periapical lesion or root resorption developed subsequent to endodontic treatment, if a preexisting periapical lesion had increased in size, or if possible preoperative root resorption appeared to continue after endodontic treatment.

Results—Follow-up time ranged from 1 to 60 months (mean, 13 months). Treatment was classified as successful for 87 (69%) roots, as showing no evidence of failure for 33 (26%) roots, and as having failed for 7 (6%) roots. The success rate was lower for canine teeth than for maxillary fourth premolar teeth. Roots with a preexisting periapical lucency or preexisting root resorption had lower success rates. The use of intracanal medication and the method and quality of obturation were not associated with outcome.

Conclusions and Clinical Relevance—Results suggest that root canal treatment offers a viable option for salvage of periodontally sound but endodontically diseased teeth in dogs. (*J Am Vet Med Assoc* 2002;220:775–780)

Endodontic treatment allows retention of periodontally sound teeth with pulp pathoses.[1] Periapical destruction is the result of an inflammatory reaction initiated by bacteria, their products, and the host's response to them. This destruction is radiographically visible as a periapical radiolucency.[1-4] Root canal treatment consists of cleaning and shaping the pulp cavity, obturating it with an inert material, and sealing the apex and access and exposure sites.[1,5,6]

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Although root canal treatment in dogs has been described, to our knowledge, there are no published studies of the success rate of root canal treatment in dogs. In humans, reported success rates range from 70 to 95%.[7-32] Differences in reported success rates are partially attributable to differences in how a successful outcome is defined and partially attributable to differences in a variety of preoperative, intraoperative, and postoperative factors. In some studies,[9,10,18,20,22,23,29,32] treatment is considered successful as soon as any possible periapical lucency has diminished. In other studies,[7,11,13-17,21,25,26] however, treatment is considered successful only if the periodontal ligament space around the root is normal. In people, the prognosis following root canal treatment is better for teeth without any preexisting periapical lucency[11,14,16,31,32] and with good obturation[13,15,31,32] and restoration.[33] The prognosis is also better if bacteria cannot be cultured from the pulp at the time of obturation than if bacteria are detected in the pulp cavity prior to obturation. Therefore, it has been suggested that root canal treatment should be staged, with final obturation after a period with intracanal medication, in teeth with initially infected pulp.[24,34,35]

The outcome of root canal treatment can only be determined radiographically. A decrease in the size of a preexisting periapical lucency is suggestive of healing, but treatment cannot be considered a success until the lucency has completely disappeared, which may take years.[36] The purpose of the study reported here was to evaluate results of root canal treatment in dogs.

Criteria for Selection of Cases

Medical records of dogs that underwent root canal treatment at either of 2 university-based veterinary teaching hospitals (University of California, Davis, and University of Helsinki, Finland) between 1995 and 2000 were reviewed. Dogs were included in the study only if they had returned to the hospital for at least 1 follow-up visit that involved dental radiography.

Procedures

Root canal treatment—Root canal treatments were performed according to principles accepted in human dentistry,[5,6,34,37] which were modified to accommodate the unique anatomy of canine teeth.[1,38] Treatments at the University of California were performed or supervised by a board-certified veterinary dentist; treatments at the University of Helsinki were performed by a human dentist or by a veterinarian who was supervised by a human dentist. Briefly, the pulp cavity was cleaned and shaped with endodontic files and flushing with 2.5% sodium hypochlorite; EDTA gel was used as a chelator and file lubricant as needed. If treatment was performed in 2 stages, calcium hydroxide was placed in the canal between stages. Final obturation was achieved with heated or cold gutta-percha and endodontic sealers. A variety of obturation methods were used, including lateral compaction, use of single-cone thermoplastic gutta-percha,[a] and vertical compaction with thermoplastic gutta-percha.[b,c] Access openings were closed with a glass-ionomer intermediate layer and an amalgam or composite restoration.

Follow-up evaluations—Radiographs were obtained before surgery, immediately after surgery, and during follow-up examinations after surgery. The bisecting angle technique was used,[2] and radiographs were obtained with a dental radiography unit and size-2 and -4 dental radiographic film.[d] At the University of California, the standard protocol was to request follow-up examinations 3 and 12 months after root canal treatment and annually thereafter. At the University of Helsinki, the standard protocol was to request annual follow-up examinations. However, few clients kept to these schedules. Thus, for purposes of evaluation, follow-up time was grouped as ≤ 3 months, 4 to 11 months, 12 to 23 months, and ≥ 24 months.

Evaluation of outcome—Radiographs were evaluated by 2 observers with a dental x-ray film viewer and calibrated magnification loupe.[e] The quality of obturation was assessed by dividing the root canal into 3 portions: coronal, middle, and apical third. Voids in each third were evaluated as small if they were narrower than half the width of the pulp cavity and shorter than the width of the pulp cavity. All other voids were considered large. Overfill was recorded if there was radiopaque material in the periapical area. The largest diameter of periapical lesions was measured, and comparable views obtained at each follow-up visit were examined. Widening of the periapical **periodontal ligament (PDL)** space was recorded if the space was greater than double the width of the PDL space in other areas surrounding the root.

Outcome was determined according to the guidelines for radiographic assessment of root canal treatment established by the European Society of Endodontology.[36] Treatment was considered successful if the PDL space was normal and possible preoperative root resorption, if present, had ceased. Treatment was considered to show no evidence of failure if possible preoperative root resorption had ceased but a preexisting periapical lesion had remained the same or only decreased in size and not completely resolved. Treatment was considered to have failed if a periapical lesion or root resorption developed subsequent to endodontic treatment, if a preexisting periapical lesion had increased in size, or if possible preoperative root resorption appeared to continue after endodontic treatment.

Statistical analyses—For purposes of analyses, each individual tooth root was considered an experimental unit, in accordance with human studies.[14-17,25,28,29] Only the outcome at the most recent follow-up examination (ie, the longest follow-up period) was considered. Tooth roots classified as having no evidence of failure were grouped with tooth roots in which treatment had failed to minimize false-positive misclassification of outcome. The χ^2 test of homogeneity was used to compare the distribution of outcome (success vs failure) by factor levels. A failure-time (rate) analysis was performed with the Cox proportional hazards regression model. To avoid confounding by country of origin, all models were adjusted by including a regression variable for country, and effect modification by country was evaluated by use of likelihood ratio tests. Factors studied were breed, weight group (small, 1 to 10 kg; medium, 11 to 24 kg; large, ≥ 25 kg), age, and sex of the patients; tooth type; indication for root canal treatment; whether there was evidence of preoperative root resorption; whether there was evidence of a preoperative periapical lucency; preoperative pulp vitality; treatment staging (1-stage vs 2-stage treatment); method of obturation; quality of obturation (voids); and whether there was evidence of overfill. Values of $P < 0.05$ were considered significant. Results are presented as **incidence rate ratios (IRR)** and 95% **confidence intervals (CI)**.

Results

Medical records of 222 dogs that underwent root canal treatment during the study period were identified. However, only 64 dogs returned for 1 or more follow-up evaluations and were included in the study. The cases included in the study did not differ from the entire treated population with regard to age, sex, or affected tooth type.

The 64 dogs included in the study represented 32 breeds. Twenty-six (41%) were female, and 38 (59%) were male. Mean age at the time of endodontic treatment was 4.8 years (range, 1 to 12 years). Root canal treatments were performed on 81 teeth in these 64 dogs, including 2 (2%) first incisors, 5 (6%) second incisors, 5 (6%) third incisors, 41 (51%) canines, 24 (30%) maxillary fourth premolars, 1 (1%) mandibular fourth premolar, and 3 (4%) mandibular first molars. In total, root canal treatment was performed on 127 tooth roots, including 99 roots treated at the University of California and 28 roots treated at the University of Helsinki. Indications for root canal treatment included pulp exposure secondary to abrasion, fracture, or caries (118 roots) and pulp necrosis or periapical pathosis without pulp exposure (9). Follow-up time ranged from 1 to 60 months (mean, 13 months). Follow-up time was ≤ 3 months for 39 roots, 4 to 11 months for 51 roots, 12 to 23 months for 54 roots, and ≥ 24 months for 16 roots.

Overall, treatment was classified as successful for 87 (69%) roots, as showing no evidence of failure for 33 (26%) roots, and as having failed for 7 (6%) roots. The 33 roots classified as showing no evidence of failure included 11 roots for which a preexisting periapical lucency had remained the same and 22 roots for which a preexisting periapical lucency had decreased in size but had not resolved. Outcome did not appear to be associated with follow-up time (**Fig 1**). In addition to the endodontic failures, 7 roots fractured, which led to the loss of 3 teeth.

A preoperative periapical lucency was seen in association with 56 roots (**Table 1**). Preoperative pulp necrosis was evident in association with 18 roots, and 14 roots had evidence of preoperative root resorption.

Figure 1—Outcome of root canal treatment as a function of follow-up time in dogs (n = 127 tooth roots).

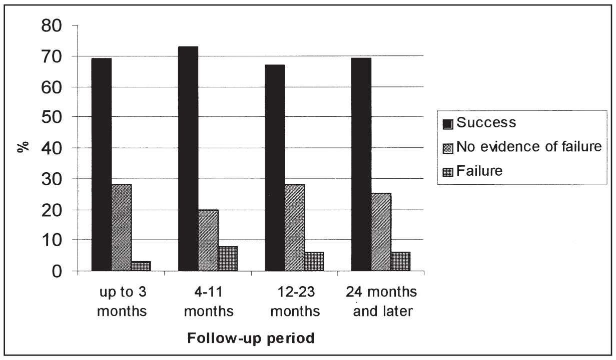

Table 1—Analysis of factors potentially associated with outcome of root canal treatment in dogs

Factor	Total No. of tooth roots	No. successful	Percentage successful
Preoperative periapical lucency			
Detected	56	24	43*
Not detected	71	63	89
Preoperative pulp vitality			
Necrosis	18	8	44*
Vital	18	15	83
Not recorded	91	64	70
Preoperative root resorption			
Yes	14	7	50
No	113	80	71
Treatment			
Single visit	99	69	70
Two visits with intracanal medication	28	18	64
Treatment of teeth with a preoperative periapical lucency			
Single visit	39	16	41
Two visits	17	8	47
Obturation method			
Lateral compaction	58	39	67
Single cone heated gutta-percha	55	41	75
Vertical compaction with heated gutta-percha	8	3	38
Not recorded	3	1	33
Apicoectomy in addition to orthograde obturation	3	3	100
Voids in obturation			
None	15	10	67
Small voids	28	22	79
Large voids	84	55	65
Overfill			
Yes	27	18	67
No	100	69	69
Tooth			
Maxillary fourth premolar	67	52	78
Canine	41	23	56
Mandibular fourth premolar or first molar	7	3	43
Incisor	12	9	75

*Success rate significantly ($P < 0.05$) different between levels of factor (excluding roots with vitality not recorded).

Of the 56 roots with a preoperative periapical lucency, 17 were treated with a 2-stage procedure, and 39 were treated with a 1-stage procedure. The obturation methods were as follows: lateral compaction (58 roots), single-cone thermoplastic gutta-percha (55), and vertical compaction with thermoplastic gutta-percha (8). In 3 roots, the method of obturation was not mentioned. Three roots underwent apicoectomy in addition to orthograde obturation. One was obturated with single-cone thermoplastic gutta-percha, and 2 were obturated with lateral compaction prior to apicoectomy. Eighty-four roots had large voids in the obturation, 28 had small voids, and 15 did not have any voids. Sealer or gutta-percha was detected in the periapical area of 27 roots. Twenty of these 27 roots with overfill had been obturated with a single-cone thermoplastic gutta-percha method, and treatment was successful in 14 of the 20. Lateral and vertical compaction had been used to obturate 4 and 3 roots, respectively, with overfill, and treatment was successful for 2 obturated with each method.

Evidence of a preoperative periapical lucency was associated with an increased risk of failure (IRR, 9.50; 95% CI, 3.89 to 23.16; $P < 0.001$), as was evidence of preoperative root resorption (IRR, 2.30; 95% CI, 0.99 to 5.33; $P = 0.05$). The P value for evaluation of whether evidence of preoperative pulp necrosis was associated with an increased risk of failure was close to the cutoff for significance (IRR, 3.60; 95% CI, 0.94 to 13.77; $P = 0.06$). There was no statistical evidence that the effect of these risk factors on the risk of treatment failure differed among countries.

Age had no apparent effect on the outcome of root canal treatment. For each 1-year increase in age, the IRR was 1.06 (95% CI, 0.93 to 1.20; $P = 0.40$). There was also no strong evidence that sex played an important role in risk of failure. Comparing males with females, the IRR was 1.58 (95% CI, 0.80 to 3.14; $P = 0.19$). No single breed was represented in sufficient numbers to allow comparison. Compared with small dogs, the risk of failure was neither significantly increased nor significantly decreased for medium-sized (IRR, 0.38; 95% CI, 0.11 to 1.28; $P = 0.12$) and large (IRR, 1.18; 95% CI, 0.53 to 2.65; $P = 0.68$) dogs.

Only 2 indications for root canal treatment occurred in sufficient numbers to allow statistical analysis, namely complicated crown fracture (77 roots) and complicated crown-root fracture (38). The risk of failure was not significantly different between these 2 groups (IRR, 0.97; 95% CI, 0.45 to 2.09; $P = 0.94$).

Compared with maxillary fourth premolars, mandibular fourth premolars and first molars combined had an increased risk of failure (IRR, 4.86; 95% CI, 1.54 to 15.33; $P = 0.007$), as did canines (IRR, 2.35; 95% CI, 1.11 to 4.97; $P = 0.025$).

Discussion

Results of the present study suggest that root canal treatment offers a viable option for salvage of periodontally sound but endodontically diseased teeth in dogs, with an overall success rate of 69%. Evidence of a preoperative periapical lucency, preoperative pulp necrosis, and preoperative root resorption decreased the success rate, and the success rate was lower for canines than for maxillary fourth premolars. The use of a 2-stage process with intracanal medication did not appear to be necessary, even for roots with a preoperative periapical lucency, and the method and quality of obturation did not appear to play a major role in the outcome of the treatment. However, these findings should be studied in a larger population to increase the statistical strength. Results of this study did indicate that failures could be detected within a relatively short time after endodontic treatment; however, tooth roots without evidence of failure shortly after endodontic treatment should be followed up for a longer period to determine ultimate outcome.

In human studies,[9-11,14,17,22,23,30-32] between 11 and 81.8% of patients (mean, 54.8%) were available for follow-up evaluation, whereas in the present study, 29% (64/222) of the patients were returned for a follow-up examination. The reasons why more dogs were not returned for a follow-up examination were not investigated, but our clinical impression was that the need and cost of another anesthetic episode combined with the lack of clinical signs of failure were the most important causes of the low follow-up rate. However, dogs for which follow-up information was available were similar to the entire treated population. Importantly, failure of root canal treatment could be detected at a relatively early stage; therefore, a follow-up protocol consisting of an initial follow-up evaluation at 3 months and subsequent evaluations at 1 year and annually thereafter seems justifiable.

Even though radiographic findings are seen as the single most important indication of success,[1,39] a lack of clinical signs, such as pain, is also included in the definition of success in human dentistry.[36] We selected radiographic criteria, because clinical signs associated with failure of endodontic treatment are often vague or nonexistent in dogs[1] and may be more difficult to evaluate in dogs than in humans. Only 1 dog in the present study was returned for a follow-up examination because of signs of pain noticed by the client.

In the present study, radiographs were evaluated by 2 individuals, using a standardized method, to increase the reliability of diagnosis.[40,41] It was realized that early pathologic changes might not be detected radiographically and, on the other hand, that the initial stages of bone healing were not necessarily evident radiographically.[32]

To our knowledge, there are no published reports of the success rate of root canal treatment in dogs. In a previous study,[42] the pulp of 39 teeth in 2 dogs was experimentally exposed.[42] All pulp cavities were cleaned 9 months later and sealed either without any root filling or following obturation with gutta-percha or silver points. Twenty-nine of the 39 teeth had developed a radiographically apparent periapical lucency before treatment. Dogs were followed up for 18 months, after which the teeth and periapical areas were studied radiographically and histologically. Exact success rates were not given, but it was concluded that root resorption occurred consistently in teeth with a periapical lucency but was only rarely seen on radiographs. Root canal débridement and occlusal sealing alone led to cessation of the increase in size of the periapical lucency. Underfilling of the canal was preferable to overfilling.

The success rate of root canal treatment for dogs in the present study was comparable to success rates reported for humans; however, studies[7-32] of root canal treatments in humans report highly variable success rates. The variable results are partially attributable to different ways to define success and partially attributable to multiple other factors, such as preoperative status of the pulp and method of treatment. Contrary to criteria used in the present study, some reports did not require the PDL width to be normal for a case to be considered successful. In these studies,[9,10,18,20,22,23,29,32] all patients in which size of a preoperative periapical lucency was static or smaller at the time of follow-up examination were considered to have a successful outcome, with reported success rates ranging from 76 to 92%. In studies[7,11,13,14,17,21,24-26] that use the same definition of success as in the present study, success rates of 62 to 88% were reported. A less-stringent definition of success would have dramatically changed results of the present study. For instance, if treatment had been considered successful in dogs with periapical lesions that remained the same or decreased in size, the success rate would have been 95%, and none of the factors examined would have been significantly associated with outcome. On the contrary, if treatment had been considered a failure for teeth with nonendodontic failure and teeth lost because of failure of 1 root, the success rate would only have been 62%. It has been stated that the most common cause for extraction of endodontically treated teeth in humans is another fracture, not failure of the endodontic treatment.[43] In our study, only 3 teeth (7 roots altogether) were extracted because of a new fracture following endodontic treatment. This was equal to the number of roots lost because of failure of endodontic treatment.

The factors most commonly mentioned as being associated with outcome of root canal treatment in humans include evidence of a preoperative periapical lucency,[14,15,22,23,25,29,32] preoperative pulp necrosis,[11,13,14,22,28,32] voids in the apical part of the root filling,[10,13,15,16,18,28,31] and periapical extension of filling material (overfill).[7,11,13-15,28] Our study indicated that root canal treatment was significantly less likely to be successful in roots with a preoperative periapical lucency than in roots without any preexisting periapical lucency. Our stringent definition of success probably decreased the success rate, because treatment was considered to have failed in all roots with a detectable periapical lucency, even if the size of the lucency was decreasing. It is likely that most of these lucencies would eventually have healed, if monitored longer.[17,21] In people, for instance, periapical healing is most often detected 1 year after endodontic treatment, but it may take as long as 4 years for periapical lesions to heal completely.[19] Treatment should be considered to have failed in patients in which a periapical lucency has not healed within 4 years, and such patients should be treated accordingly.[36]

Nonvital pulp and root resorption were also related with lower success rates in the present study. However, the method and quality of obturation did not seem to play an important role in the outcome of root canal treatment in these dogs. Voids may be caused by incomplete débridement, incorrect shaping, or incomplete obturation.[5] In dogs in the present study, voids were more likely to have been caused by suboptimal shaping or obturation, as great care was taken to achieve complete débridement, and incomplete débridement would likely have resulted in more failures. Contrary to results of 1 study[42] involving dogs and many studies[7,11,13,15,29] involving humans, treatment was as likely to be successful in overfilled roots in the present study as in roots without periapical extension of sealer or gutta-percha. Most overfills were associated with obturation with a single cone of thermoplastic gutta-percha and may have been caused by the single wide cone pushing sealer through the apical delta.

Intracanal administration of calcium hydroxide is the most common method to reduce the number of bacteria in the pulp cavity; it has been shown to increase the success rate of root canal treatments in humans, especially in patients with a preexisting periapical lucency and patients for which results of bacterial culture of a sample obtained when cleaning is completed are positive.[20,24,27,43,44] However, use of intracanal medication is controversial, and the current trend in endodontics is to complete root canal treatments in a single session.[8,22,27,34,45,46] In the present study, intracanal medication did not seem to increase the success rate, even for roots with a preoperative periapical lucency. Samples were not obtained for bacterial culture.

Factors that have less commonly been suggested to be associated with outcome of root canal treatment in humans include tooth type,[10,11,13-15,29,47] age and sex of the patient,[11,13-15,29,32,47] and whether a prosthetic crown restoration is performed.[13,14] Also, the experience of the endodontist has been reported to influence the outcome.[15,47] There was a marked difference in outcome of root canal treatment performed on maxillary fourth premolars versus canines in the present study. It may be hypothesized that complete débridement is more difficult to achieve in the long pulp cavities of canine teeth. The success rate of root canal treatment performed on mandibular fourth premolars or mandibular first molars was found to be significantly lower than that for treatment performed on maxillary fourth premolars; however, this finding should be interpreted with caution, as the former group was small. Age and sex have not been found to affect the success rate of root canal treatment in humans,[47] and results of the present study were similar. In addition, size of the dog was not associated with outcome in the present study. Only 9 teeth (all canine teeth) in the present study were restored with a metal crown. Treatment was successful in 8 of the 9. Even though treatments were performed by various individuals, they were all supervised by a qualified faculty member. Therefore, it was assumed that the technical quality was comparable in all cases.

[a]Thermafill, Dentsply Tulsa Dental, Tulsa, Okla.
[b]Successfil, Hygiene, Coltene Whaledent, Mahwah, NJ.
[c]Ultrafil, Hygiene, Coltene Whaledent, Mahwah, NJ.
[d]Kodak Ultra-Speed, Eastman Kodak Inc, Rochester, NY.
[e]Peak Scale Lupe 7x, Tokyo, Japan.

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