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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

Survival study on teeth after successful endodontic surgical retreatment: influence of crown height, root length, crown-to-root ratio and tooth type



Studio di sopravvivenza su denti guariti a seguito di endodonzia chirurgica: influenza dell'altezza coronale, della lunghezza radicolare, del rapporto corona-radice e del tipo di dente

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KEYWORDS

Crown-to-root ratio;
Late failure;
Retrospective study;
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Abstract

Aim: To assess the influence of the crown height, root length, crown-to-root ratio, and tooth type on the survival of teeth subjected to surgical endodontic retreatment and classified as periapically healed.

Methodology: A single operator performed endodontic microsurgery interventions between 2008 and 2018 on teeth with refractory apical periodontitis. The present analysis selected the teeth classified as “complete periapical healing” according to the scale suggested by Molven. The postoperative periapical radiographs and those taken at the last recall visit were analysed by two

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PAROLE CHIAVE

Analisi di sopravvivenza;
Fallimento tardivo;
Rapporto corona-radice;
Ritrattamento
endodontico chirurgico;
Studio retrospettivo.

independent calibrated examiners, who measured crown height and root length in a blind manner. The crown-to-root ratio was calculated as the ratio of the two variables. The level of inter- and intra-operator agreement was tested with Bland–Altman plots with 95% limits of agreement. An independent statistician conducted a survival analysis using Kaplan–Meier plots and a log-rank test ($\alpha = 0.05$) to assess the significance of the differences among the subgroups defined by the following criteria: (a) crown height <median vs. >median; (b) root length <median vs. >median; (c) crown-to-root ratio <1 vs. >1; (d) crown-to-root ratio <median vs. >median; (e) single-rooted teeth vs. multi-rooted teeth.

Results: At the end of the analysis, 42 patients were evaluated, each one contributing to the study with a single tooth. The mean follow-up period was 4.2 ± 2.4 years. Survival estimates were significantly improved for the teeth with roots longer than 8 mm, in comparison with that with shorter roots ($p < 0.05$). There were no statistically significant differences among the remaining considered subgroups.

Conclusions: Under the conditions of this retrospective study, teeth with longer residual roots after apical surgery exhibited better chances of survival when compared to teeth with roots shorter than 8 mm. The other considered variables did not seem to affect the survival of apically resected teeth.

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Riassunto

Obiettivi: Valutare l'influenza dell'altezza coronale, della lunghezza radicolare, del rapporto corona-radice e del tipo di dente sulla sopravvivenza di denti sottoposti ad apicectomia e classificati come guariti a livello periapicale.

Materiali e metodi: Un singolo operatore ha svolto interventi di endodonzia microchirurgica dal 2008 al 2018 su denti con parodontite periapicale refrattaria. La presente analisi ha selezionato i denti classificati come «guarigione radicolare completa» secondo la scala di Molven. Le radiografie periapicali postoperatorie e quelle scattate all'ultima visita di controllo sono state analizzate da due operatori indipendenti e calibrati che hanno misurato in cieco altezza coronale e lunghezza radicolare. Il rapporto corona-radice è stato calcolato dal rapporto delle due variabili. Il livello di concordanza inter- e intra-operatore è stato testato con i diagrammi di Bland-Altman con limiti di concordanza al 95%. Uno statistico indipendente ha svolto un'analisi di sopravvivenza usando le curve di Kaplan-Meier e test Log-Rank ($\alpha = 0.05$) per verificare la significatività delle differenze tra i sottogruppi definiti dai seguenti criteri: altezza coronale <mediana vs. >mediana; lunghezza radicolare <mediana vs. >mediana; rapporto corona-radice <1 vs. >1; rapporto corona-radice <mediana vs. >mediana; denti monoradicoliati vs. pluriradicoliati.

Risultati: Al termine dell'analisi il campione era costituito da 42 pazienti, seguiti per $4,2 \pm 2,4$ anni, ciascuno dei quali ha contribuito allo studio con un dente. Le stime di sopravvivenza sono risultate significativamente migliori per i denti con radici più lunghe di 8 mm nel confronto con quelle di lunghezza inferiore ($p < 0.05$). Non sono emerse ulteriori differenze statisticamente significative dal confronto tra gli altri sottogruppi considerati.

Conclusioni: Nelle condizioni del presente studio retrospettivo, elementi dentari con radici residue lunghe a seguito di chirurgia apicale hanno mostrato migliori probabilità di sopravvivenza, paragonati a elementi con radici più corte di 8 mm. Le altre variabili testate non hanno influenzato la sopravvivenza dei denti sottoposti a resezione apicale.

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Introduction

When conducted in full respect of the principles of contemporary root-end surgery techniques with magnification tools, microinstruments, ultrasonic tips, and specific filling materials, surgical endodontic retreatment (SER) is a reliable and successful approach in cases root-filled teeth with chronic apical periodontitis, according to randomized controlled trials and meta-analyses.^{1–4} Indeed, SER can have higher

success rates than orthograde retreatment after 1 year, but the healing rates of the two approaches tend to be similar after 3 years.^{5–7} A possible explanation for this phenomenon is the occurrence of late failures in 5–25% of SER cases,⁸ the causes of which are only partially understood and predictable. A copious series of clinical studies has investigated the outcome of SER in the middle- and long-term^{9–17}; nonetheless, their huge methodological differences in techniques, instruments, materials, selection criteria, and follow-up

periods constitute an obstacle to synthesize and compare their data in a meta-analysis.¹⁷

During the surgical intervention, apical resection is an essential phase to remove the majority of the secondary endodontic structures¹⁸ and the infected content, where this is arduous or impossible in an orthograde way.¹⁹ However, root resection, by definition, inevitably shortens the root and may alter the biomechanical behaviour and stress distribution of the treated tooth.^{20–22} It is noteworthy that, even after complete periapical recovery, apically resected teeth continue to be exposed to occlusal loading, whose impact might be harmful, especially when the tooth is not prosthetically splinted to other abutment teeth. Although it has been suggested that the apical loss of 3 mm of root length has minimal influence in the biomechanical parameters of teeth supported by a normal periodontium,²¹ teeth undergoing SER are frequently affected by various degrees of periodontal bone loss in the clinical settings. A recent finite element analysis showed that the periodontal bone loss progressively deteriorates the biomechanical response of apically resected teeth, in comparison with a tooth with intact periodontal support.²⁰

The crown-to-root ratio (CRR) is a parameter that was invented for the evaluation of teeth eligible as abutments to support prosthetic bridges and crowns; the condition in which CRR is equal to 1:1.5 is considered optimal, while a 1:1 ratio is the minimum that can be accepted.²³ It is still unknown whether the same criteria could be valid for the teeth that have been subjected to apical resection,²⁴ since CRR was originally conceived for the assessment of the periodontal support loss at the coronal third of the root and not at the apical level. Furthermore, other biomechanical factors may – hypothetically – play a relevant role in the determination of the tooth prognosis after successful SER, crown height (CH) or root length (RL) in the first place, acting independently of CRR.

All of this considered, the aim of the present study was to assess how CH, RL, CRR, and the tooth type affect the survival of teeth subjected to apicectomy and classified as periapically healed.

Materials and methodology

The present retrospective study was conducted in full accordance with the last version of the Declaration of Helsinki (9th July 2018). Clinical data were collected from patients of the Dental Clinic of the Ospedale Maggiore, University of Trieste, Trieste, Italy. Dental records and periapical radiographs were searched exclusively from the charts of the patients that had given their approval for the handling and analysis of their data for epidemiological and scientific purposes by signing a dedicated form. Dental records of patients who underwent SER for the treatment of teeth with refractory periapical pathosis between 2008 and January 2018 were obtained. Ethical clearance was obtained by tacit approval of the Local Ethic Committee after communication of the study protocol.

Only the cases classified as “complete periapical healing” according to the scale proposed by Molven²⁵ were included in the present analysis. Teeth used as an abutment for prosthetic bridges, splinted to the surrounding teeth, or originally

affected by a lesion of combined endodontic-periodontal origin were excluded.

Surgical procedures

A single experienced endodontist performed all the surgical interventions, according to the modern principles of microsurgical endodontics. All surgical procedures were carried out using an operating microscope (M525, Leica Microsystems CMS GmbH, Mannheim, Germany). In brief, the flap was reflected after local anaesthesia with lidocaine and 1:50,000 epinephrine and an osteotomy performed with rotary burs. Inflammatory soft tissues were manually removed with a surgical curette and the root was sectioned 3 mm from its tip with a tapered fissure bur kept perpendicular to the root longitudinal axis under copious water irrigation. After having reached haemostasis applying ferric sulphate (Astal, Ogna, Muggiò, Italy), methylene blue was used to stain the resected surface to exclude the presence of visible fractures and locate the canals by using surgical micromirrors (Obtura Spartan, Fenton, MO, USA). A 3-mm deep root-end cavity was prepared with ultrasonic tips (KiS, Obtura Spartan), dried with sterile paper points (Inline, BM Dentale, Turin, Italy), and filled with SuperEBA cement (Bosworth, Skokie, IL, USA). The flap was sutured with 5-0 monofilament sutures, and a postoperative periapical radiograph was taken.

Following the routine follow-up schedule of our clinical practice, the patients were contacted by telephone every 6 months for 2 years and, after the 2 first years, annually. On every follow-up visit, the treated teeth were checked clinically and radiographically.

Radiographic examination and analysis

The periapical radiographs taken at the recall visits, as well as the immediate postoperative ones, were subjected to image analysis with dedicated software (DBSWIN, Dürr Dental, Bietigheim-Bissingen, Germany). Two independent, trained, and calibrated operators measured in a blind manner the CH, defined as the distance between the alveolar ridge and the top of the cusp, and RL, defined as the distance between the alveolar ridge and the resected apex. For each case, CRR was arithmetically calculated. The measurements were made on the postoperative (t_0) and on the last available (t_1) radiographs. The level of intra- and interobserver agreement was tested with the Bland-Altman plots with 95% limits of agreement (GraphPad Prism 7, GraphPad Software, La Jolla, CA, USA).

Statistical analysis

A statistician, who was kept blind from the study design and purpose, handled and analysed the collected data, conducting the whole analysis using statistical software (Statistical Package for Social Sciences v.15, SPSS Inc., Chicago, IL, USA). Continuous data were tested for the normality of the distribution and equality of variances by means of a Shapiro–Wilk and a Levene test, respectively. Differences in the variables of interest (CH, RL, CRR) between the two considered timepoints ($t_0 - t_1$) were assessed by means of a paired sample *t*-test. A survival analysis was performed by

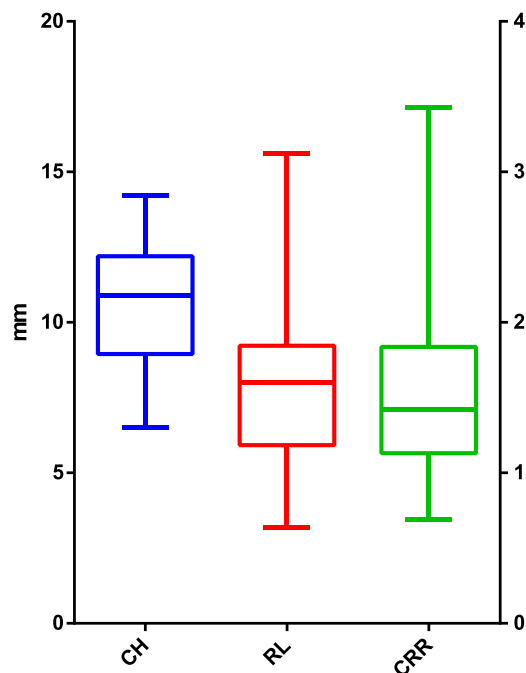


Figure 1 Box and whisker plot reporting the distribution of the variables of interest of the present study measured on the postoperative periapical radiographs, namely crown height (CH), root length (RL), and crown-to-root-ratio (CRR). The first two are reported in mm referring to the primary y-axis, CRR values are reported on the secondary y-axis.

using Kaplan–Meier plots and a log-rank test to assess the significance of the differences among the subgroups defined by the following criteria: (a) CH lower or greater than the median value; (b) RL lower or greater than the median value; (c) CRR lower or greater than 1; (d) CRR lower or greater than the median value; (e) single-rooted teeth vs. multi-rooted teeth. All types of unrecoverable SER-related late failures were considered as “event” for the analysis, including a tooth fracture, acute periradicular abscess, formation of

class III periodontal furcation defects, grade 3 tooth mobility, etc. The level of significance was set at 0.05.

Results

A minimal and not significant ($p > 0.05$) variation of the variables of interest was observed between the measurements made on the postoperative and on the last available radiographs: CH, 7.84 ± 2.51 mm at t_0 and 7.73 ± 2.48 mm at t_1 ; RL, 10.22 ± 1.95 mm at t_0 and 10.61 ± 1.91 mm at t_1 ; CRR, 1.48 ± 0.49 at t_0 and 1.52 ± 0.60 at t_1 . The complete distribution of CH, RL, and CRR values relative to the sample of patients selected for the present study is shown in the box and whiskers plot in Fig. 1. The level of inter- and intra-observer agreement was found to be fully satisfactory, as demonstrated by the Bland–Altman plots reported in Fig. 2.

Three teeth were excluded from the present study because they were not available for the evaluation, as they had been previously extracted by other dentists for prosthetic purposes. At the end of the analysis, the sample was constituted by 42 patients, each one contributing to the study with a single tooth, who were followed-up on average for 4.2 ± 2.4 years. In the sample, the mean age was 45 ± 12 years and 26 patients were female. The treated tooth types of the included patients were as follows: 20 incisors (19 maxillary), 7 canines (5 maxillary), 9 premolars (6 maxillary), 6 molars (5 maxillary).

Data distribution and survival rates are shown in Table 1. The outcome of the survival analysis is represented by means of Kaplan–Meier curves in Fig. 3. In the comparison between the teeth with the longest roots (longer than the median value, 8 mm) and those with the shortest roots, the former subgroup showed improved survival ($p < 0.05$). No statistically significant difference emerged among the remaining considered subgroups.

Discussion

The present study seems to preliminarily demonstrate that the clinical relevance of CRR in teeth successfully subjected

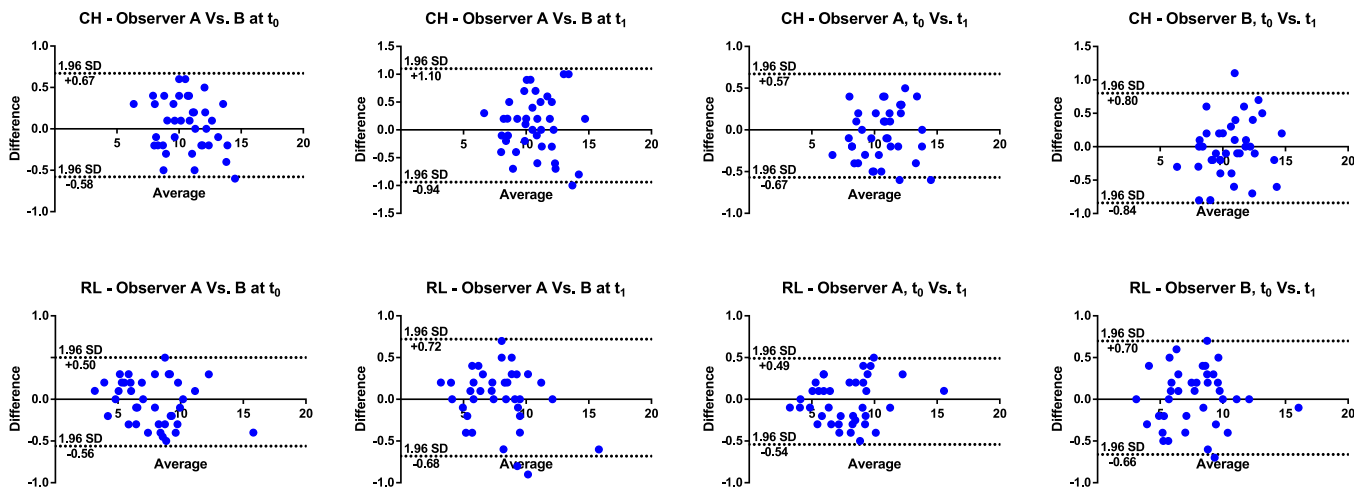


Figure 2 Bland–Altman plots reporting the mean of the two measurements as the abscissa value, and the difference between the two values as the ordinate value. Eight plots are presented for the analysis of both inter- and intra-observer level of agreement. CH, crown height; RL, root length; SD, standard deviation.

Table 1 Data distribution and univariate log-rank analysis of the treated teeth included in the present study.

Variables	No. of teeth	No. of teeth with late failure	No. of survived teeth	<i>p</i> value
Crown height				
>median value	21	1 (4.8)	20 (95.2)	0.459
<median value	21	2 (9.5)	19 (90.5)	
Root length				
>median value	21	0 (0.0)	21 (100.0)	0.028
<median value	21	3 (14.3)	18 (85.7)	
Crown-to-root ratio				
>median value	21	1 (4.8)	20 (95.2)	0.415
<median value	21	2 (9.5)	19 (90.5)	
Crown-to-root ratio				
>1	35	3 (8.6)	32 (91.4)	0.381
<1	7	0 (0.0)	7 (100.0)	
Tooth type				
Single-rooted	34	2 (5.9)	32 (94.1)	0.377
Multi-rooted	8	1 (12.5)	7 (87.5)	

Percentages of teeth are in parentheses. A significant difference is indicated by the log-rank test ($\alpha = 0.05$): comparison of the survival rate within each factor.

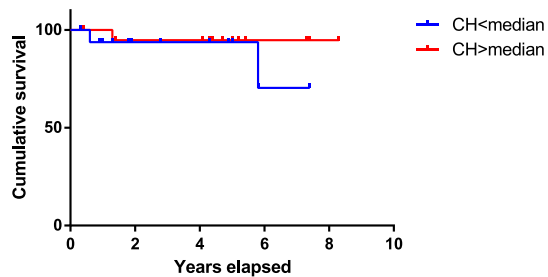
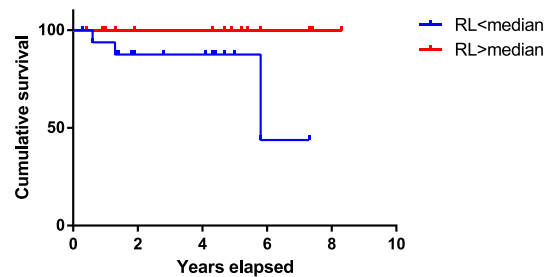
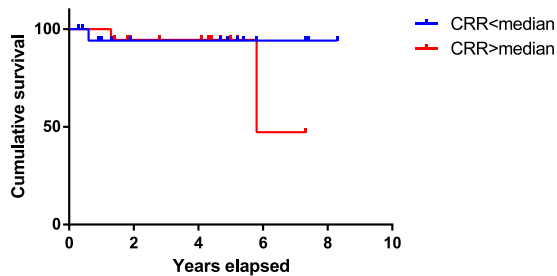
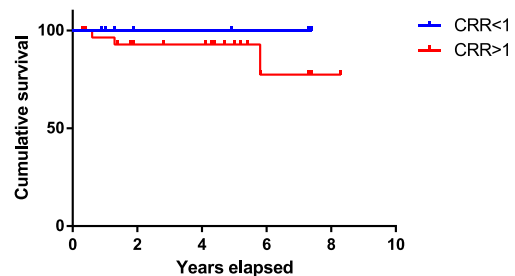
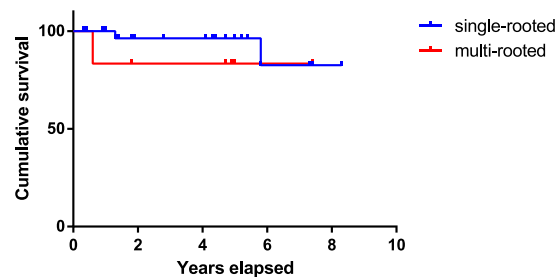
Survival proportions: CH<median Vs. CH>median**Survival proportions: RL<median Vs. RL>median****Survival proportions: CRR<median Vs. CRR>median****Survival proportions: CRR<1 Vs. CRR>1****Survival proportions: single- Vs. multi-rooted teeth**

Figure 3 Kaplan–Meier cumulative survival curves of teeth subjected to surgical endodontic retreatment in relation to the division in subgroups. CH, crown height; RL, root length; CRR, crown-to-root ratio.

to SER might be limited, despite the hypotheses of other Authors, who reported that CRR changes significantly after apical resections of 3.58 ± 1.43 mm and could play a significant role in the long-term prognosis of root-end resected teeth.²⁴ Conversely, the clinical relevance of the residual RL deserves to be further investigated, since in the present study longer roots were associated with higher survival, apparently regardless of CRR. A possible explanation for this finding is that the biomechanical behaviour of an apically resected tooth is affected only in small part by the apical loss of 3 mm of root length, while a more relevant influence is attributed to the loss of marginal periodontal bone.²⁰ In turn, this is ascribable to the little impact that the loss of a small portion of the external root surface has, compared to the attachment loss at the coronal level, where the root surface is much greater for geometrical reasons, being the root approximately cone-shaped. It is noteworthy that the majority (>75%) of the analysed teeth exhibited undesirable CRR ratios (>1). Given the high survival rates observed in this subgroup (32/35 cases, 91.4%), this finding might be preliminarily indicative that the 1:1 threshold value of CRR suggested in prosthetic dentistry may be excessively “pessimistic” when applied to teeth subjected to SER.

In the clinical setting, the assessment of treatment outcome is generally based on the subjective symptoms reported by the patient, the findings of the clinical examination, and the radiographic signs. From its introduction several years ago, the Molven's scale has been widely used for the radiographic evaluation of SER outcome in a multitude of clinical studies.^{1,3,4,6,9,11,26,27} The global acceptance of Molven's scale can be attributed to its intrinsic simplicity of interpretation and completeness in the contemplation of the possible healing patterns of a periapical defect. For the medium- and long-term follow-up of apically resected teeth, one may argue that cone-beam computed tomography should be preferred over traditional two-dimensional periapical radiography because it is known that the latter has inherent limitations such as superimposition and distortion of anatomical structures that may interfere with a correct diagnosis.^{28,29} However, the objective of the present study was to evaluate teeth whose periapical healing process had already been documented; this kind of assessment is undoubtedly more straightforward than the search for a periapical lesion for diagnostic purposes, which, differently from a surgical defect, can be limited to the cancellous bone and not easily detectable.³⁰ Although the accuracy of cone beam computer tomography is considered excellent,²⁹ the Authors strongly believe that this three-dimensional imaging technique should be used for the cases where it is diagnostically advantageous and not for routine follow-up controls, in order to minimize the radiation dose for the patient.³¹ Furthermore, the very positive outcome of the Bland–Altman analysis demonstrates that the use of periapical radiographs was a reliable analytical approach for the purpose of the present investigation.

In comparison with other previously published reports with similar research objective,^{13,14} the present study analysed a relatively small-sized sample. However, the small number of selected cases was due to the restrictive inclusion criteria that were chosen for the present study. Specifically, the exclusion of teeth adhesively or prosthetically connected to other teeth caused a relevant decrease of the number of the eligible patients but guaranteed protection against the

bias that could derive from the biomechanical impact of tooth splinting. Moreover, the present study was designed to minimise the impact and number of confounding factors, as it intentionally involved the analysis of cases treated by a single operator and following the same unvaried surgical protocol. Such decision inevitably reduced the sample size but provided a sample that is likely to be homogeneous and, thus, capable of furnishing more reliable data. Notwithstanding, some results of the present study must be interpreted with caution because some subgroups were composed of few elements, as was the case of CCR <1 and multi-rooted teeth subgroups. For better understanding of the influence of these factors, a study on a larger scale appears advisable. If a more numerous sample becomes available, the possible effect other clinical variables could be tested, considering the impact of occlusal load distribution, para-functional activities, and periodontal health in the first place.

As to teeth with more than one root, further tomographic investigations could hypothetically take into consideration the effect that the root surface area may have on tooth survival. Indeed, it may be speculated that root characteristics other than the length may contribute to improve the prognosis of root-end resected teeth, for example root shape, transversal diameters, curvature, etc. For instance, it is conceivable that a thin root may be at risk when strong occlusal forces are exerted on the apically resected tooth, especially in case of loss of other teeth, bruxism, or clenching.

Conclusions

Under the conditions of the present study, teeth with longer residual roots after apical surgery exhibited better chances of survival when compared to teeth with roots shorter than 8 mm. The other considered variables did not seem to affect the survival of apically resected teeth. Further studies are needed to confirm these findings on a larger sample of patients.

Clinical relevance

The present retrospective study preliminarily suggests that, after successful root end surgery, the residual root length might play a more relevant role than the crown-to-root ratio in determining the long-term survival of the apically resected teeth.

Conflict of interest

The authors declare that there are no conflicts of interest.

Acknowledgements

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