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3 **Survival of molar teeth after resective periodontal therapy – A**  
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5 **retrospective study**  
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10 **Abstract**

11 **Aim:** To study outcomes of molar teeth after resective therapy performed with the  
12 intention to prolong the lifespan of teeth having one or more unsaveable roots, and  
13 without which tooth extraction would be the only other treatment option.  
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16 **Material and Methods:** Clinical records of 149 subjects who had undergone  
17 resective therapy were retrieved. Demography and dental history were recorded, and a  
18 recall examination was undertaken. Cox regression models were performed.  
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23 **Results:** Of the 149 resective therapies, 132 (88.6%) were performed for periodontal  
24 reasons. 89 (59.7%) teeth subjected to resective therapies had been extracted by the  
25 time of recall a mean of 10 years post-resection. The median survival period was 74  
26 months. Factors significantly associated with shorter survival duration of teeth  
27 subjected to resective therapy were: age at resective therapy; preoperative  
28 radiographic bone height of the remaining root(s) <50%; pre-treatment mobility II or  
29 above; and not being splinted to neighbouring teeth nor incorporated as a bridge  
30 abutment.  
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43 **Conclusions:** There was increased risk of tooth loss with older patient age at  
44 resection, grade II mobility or above, and reduced preoperative radiographic bone  
45 heights around roots to remain. Splinting of a resected tooth to neighbouring teeth  
46 appeared to confer a protective effect towards its survival.  
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## Clinical relevance

*Scientific rationale for the study:* Furcation involvements commonly occur in multi-rooted teeth affected by periodontitis. Resective periodontal therapies provide clinicians with a possible therapeutic strategy in managing such affected teeth, and may often be applied as a 'last resort' to salvage a tooth, as in this study. Quantitative data on prognosis prediction for resective therapies as a 'last resort' form of therapy are lacking.

*Principal findings:* Older age at time of resection, pre-treatment tooth mobility II or above, pre-treatment radiographic bone height <50% on root(s) to remain were all associated with reduced survival of resected molars, while periodontal splinting conferred protection against tooth loss.

*Practical implication:* The risk indicators identified may assist clinicians' decision-making processes and facilitate appropriate patient management when resective periodontal therapy is applied as a 'last resort' for furcation-involved molars.

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3 Molars affected by periodontal disease consequently developing furcation  
4 involvement usually respond less favourably to treatment compared with  
5 single-rooted teeth or molar teeth without furcation involvement (Nordland et al.  
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10 1987; Loos et al. 1989; Wang et al. 1994). Such furcation involved molars are at  
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12 greater risk of loss following non-surgical periodontal therapy (Ekuni et al. 2009), an  
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14 outcome possibly related to anatomical features, such as root concavities  
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16 (Al-Shammari et al. 2001), **cervical enamel projections** (Chiu et al. 1991; Hou et al.  
17  
18 1994), and limited furcation entrance widths for access (Bower 1979). These can  
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20 certainly impact upon the treatment of furcation involved molars in Asian populations  
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22 (Hou & Tsai 1987 & 1997a; Zee et al. 1991).  
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25 Various therapeutic approaches had been suggested as definitive treatment for  
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27 different degrees of furcation involvement (Carnevale et al. 2008, Walter et al. 2011).  
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29 The effect of periodontal therapy on the survival of multi-rooted teeth with furcation  
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31 involvement has been systematically reviewed (Huynh-Ba et al. 2009), and this  
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33 review concluded that good long-term survival rates could be achieved. For  
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35 furcations with advanced degree of involvement, resective therapy, such as root  
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37 resection/amputation or hemisection, is a relatively common treatment. There has  
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39 been a great variation reported for the survival data of teeth after resective treatment  
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41 (Bergenholtz 1972; Hamp et al. 1975; Klavan 1975; Langer et al. 1981; Erpenstein  
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43 1983; Buhler 1988; Basten et al. 1996; Blomlof et al. 1997; Carnevale et al. 1998;  
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45 Dannewitz et al. 2006). The survival rates reported have ranged from less than 10%  
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47 to up to 90% in various studies after varying periods of observation. The case  
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49 selection, different resective procedures, quality of the endodontic therapy, the  
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51 incorporation or not of the resected tooth in a fixed dental prosthesis, the type of  
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53 restoration provided after resective treatment, and the caries susceptibility of the  
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3 studied patients have all varied among the studies reported. It seems caution has to  
4 be applied in the comparison of the results from these studies. The systematic  
5 review concluded that vertical root fractures and endodontic failures were the most  
6 frequent complications following resective procedures (Huynh-Ba et al. 2009).  
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11 Amputation of roots of teeth was originally introduced as “radical and heroic”  
12 (Farrar 1884) and resective therapy is still often used as a ‘last resort’, as in the  
13 current study population. In the current study, resective therapy was performed  
14 simply to prolong the lifespan for the tooth if the tooth involved was not a second  
15 molar, if the position of the furcation was not situated far apically on the tooth, and if  
16 there was anticipated accessibility for homecare following resection (Hamp et al.  
17 1975). Additional factors to be considered in evaluating respective treatment  
18 outcomes are the remaining periodontal support, occlusal antagonism, strategic value,  
19 patient’s age and health conditions (Carnevale et al. 2008). This “last resort”  
20 treatment approach is actually favoured by Chinese patients who in general prefer  
21 tooth preservation over extraction (Razak et al. 1990). The aim of this study was to  
22 investigate retrospectively if various factors, including patients’ demographic, oral  
23 health behaviour, supportive care, dental, periodontal and occlusal factors, may be  
24 associated with survival of root resected molar teeth in patients treated according to  
25 this approach.  
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## 50 **Material and Methods**

### 51 **Subjects**

52 Patients whose clinical files indicated that they had undergone root  
53 resection/amputation or hemisection therapy in the dental teaching hospital on or  
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3 before December 31, 2006, which yielded at least one year post-resective therapy  
4 history, were included. To be included in this study the patient record must have  
5 shown that non-surgical mechanical therapy had been carried out before the resective  
6 therapy. Also, the record must have revealed that the resective surgery was carried  
7 out by either a teaching staff member of the Periodontology Clinic, or by a  
8 periodontology trainee under the supervision of a staff member. In brief,  
9 non-surgical mechanical periodontal therapy was performed on all Periodontology  
10 Clinic subjects, under local anesthesia when applicable. These cases were reviewed  
11 after a period of three-to-six months, typically, followed by a second round of  
12 non-surgical therapy, if needed. Patients were then carefully re-evaluated for residual  
13 pockets and determination of individual tooth prognosis. If molars with furcation  
14 involvement showed unfavorable or doubtful prognosis a discussion with the patient  
15 for consideration of extraction or retention of the tooth was conducted. For subjects  
16 favoring the latter treatment option, standard access flaps should be raised after  
17 endodontic treatment and proper direct coronal restoration of the tooth involved (Fig.  
18 1) or a clear plan that endodontic treatment would be carried out shortly after the  
19 surgery. Upon exposing the involved root and furcation, root separation, extraction of  
20 the resected portion, root surface debridement of remaining roots, bevelling and/or  
21 smoothing to minimize plaque retention and enable homecare, all would be routinely  
22 performed. In keeping with the prime aim of prolonging the lifespan of the tooth,  
23 the resected tooth would not regularly have been prepared for extra-coronal  
24 restoration nor was ostectomy performed. Along the same lines, maxillary molars  
25 with residual furcation involvement would not receive root separation, rather the  
26 patient would be informed and instructed how to clean the furcation during homecare  
27 procedures. A small proportion of the included case were referrals from within the  
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3 hospital or from private practise regarding respective therapy due to other reasons  
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5 such as failed endodontic treatment or root fracture. In brief, these subjects would  
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7 receive non-surgical periodontal therapy or endodontic treatment as needed, and then  
8  
9 resective therapy as described above.  
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11 For treated periodontal patients, structured supportive periodontal care (SPC)  
12  
13 was normally provided by the Periodontology Clinic, in which the patients would be  
14  
15 followed up at least twice a year for careful oral hygiene instructions and professional  
16  
17 periodontal debridement provided by academic staff and/or trainee periodontists  
18  
19 assisted by dental hygienists. The local water is fluoridated (Wong et al. 2006) hence  
20  
21 the Periodontology Clinic does not routinely deliver professionally applied fluoride,  
22  
23 unless a clear indication for remineralization of early lesion is apparent. Patients  
24  
25 under SPC would be discharged if they declined further treatment, which to some  
26  
27 extent happened when their responsible clinicians left the hospital, typically on  
28  
29 completion of their education and/or training. Other patients who had received  
30  
31 resective treatment were referred from the private sector or other divisions of the  
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33 hospital, and these patients were instructed to receive supportive periodontal care  
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35 from their referral sources.  
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40 The resected tooth needed to have been endodontically treated before, or within  
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42 one month after, the resective therapy. Both pre-resective therapy and post-resective  
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44 radiographs needed to be available in the patients' records. Non-Chinese patients and  
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46 patients with medical conditions suggesting a need for antibiotic prophylaxis were  
47  
48 excluded. For subjects who had more than one tooth with root resection,  
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50 chronologically the first one in the record fulfilling the recruitment criteria was  
51  
52 selected. A total of 379 patients were recorded as having had resective procedures  
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54 performed. Forty two patients were excluded because required radiographs were not  
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3 available. One hundred patients could not be contacted, and 88 patients declined to  
4 participate. One hundred forty nine patients (62.9%) agreed to participate. Data  
5 collection, by one designated examiner (KLL), was finished by December 2007. All  
6 of the patients who had declined to attend were subsequently surveyed through  
7 telephone calls regarding the survival of their resected tooth.  
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14 A two-part questionnaire collected data on educational level, family income,  
15 occupation, smoking, diet habit - particularly hard food consumption, oral hygiene  
16 habits, denture wearing, general health status, compliance with dental recalls  
17 (cross-checked with hospital dental records, if available and a history of private  
18 supportive periodontal care would be confirmed by contacting the patients' private  
19 practitioners), and subjective tooth mobility (Fleszar et al. 1980) of the resected tooth.  
20 The time and reasons for any loss of resected teeth and self-reported survival duration  
21 were recorded. The tooth loss data, whenever possible (in subjects who received SPC  
22 in the Periodontology Clinic, or check-ups in other clinics of the dental hospital, or  
23 whose tooth of concern was extracted in the teaching hospital), was cross checked  
24 against the hospital records. For teeth of concern extracted elsewhere, the  
25 self-reported information was considered accurate and was used in this study.  
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### 43 **Pre-resective therapy clinical records**

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45 The following pre-root resection clinical records were retrieved from each patient's  
46 file:  
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49 *Pre-treatment tooth mobility:* recorded according to Miller's classification  
50 (1938).  
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54 Pre-treatment paralleling periapical radiographs were used for assessment of the  
55 following aspects: *Root trunk length:* relative distance from radiographic furcation to  
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3 cemento-enamel junction (CEJ) (Hou et al. 2005). *Root divergence angle*: the angle  
4  
5 between the coronal intercepts of long axes of the resected root and the remaining  
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7 root(s). Greater than or equal to 15 degrees was considered as 'divergent'. In upper  
8  
9 molars measurement was only possible between mesio-buccal and disto-buccal roots.  
10  
11 *Remaining bone level*: subcategorised into 75%, 50-74% and <50% presented as the  
12  
13 mean between mesial and distal aspects of the remaining root(s). When more than one  
14  
15 root remained, radiographic bone levels at mesial and distal aspects of both or all  
16  
17 roots were averaged. *Crown-root ratio*: All values for mesial and distal aspects of all  
18  
19 roots were averaged to yield the final data per tooth. For the parameters root trunk  
20  
21 length, remaining bone level and crown-root ratio, the measurements were recorded  
22  
23 by a Schei ruler after radiographic identification of the cusp tip of concern, the CEJ,  
24  
25 and the appropriate root apex. For teeth which had received extra-coronal  
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27 restorations, the crown margin was use in lieu of the CEJ. If there was extensive  
28  
29 direct restoration having proximal margins beyond the CEJ, the restoration's gingival  
30  
31 margin would be used as the reference point. For any case with altered reference  
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33 points, restorations altering cusp tips, covering the CEJs at proximal restoration  
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35 margin, at any stage when data collection was needed, data was be excluded.  
36  
37 *Endodontic treatment quality*: Intra-radicularly - dichotomised into 'good' or 'not  
38  
39 good' according to the Consensus Report of the European Society of Endodontology  
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41 (2006) based on quality of root filling and/or over-preparation. *Pre-treatment*  
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43 *radiographic apical lesion size*: categorised arbitrarily according to radiographic  
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45 widest diameter of lesion size:  $\leq 2.0\text{mm}$ ; 2.1-4.0mm;  $\geq 4.1\text{mm}$ . Clinical decision for  
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47 root(s) removal was not recorded nor considered in the current study. Rather, only the  
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49 exact number and location of the root(s) resected and hence the root(s) being retained  
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51 were considered.  
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### Post-resective therapy clinical records

The following early post-root resection clinical records were retrieved from each patient's file:

*Quality of root resection:* Any radiographic ledges, furcation lips, residual root fragments or concavities created during the resective procedure were considered as unsatisfactory resective treatment (Newell 1991). *Caries:* if there was any sign of clinical (reported in record) and/or radiographic caries found on any root surface. *Restorative status after resective therapy:* simple direct (bonded amalgam or posterior composite) restoration, or coronal coverage restorations, bridge abutment, or splinted to neighbouring tooth/teeth. *Presence of post and core:* yes: either cast or prefabricated; or no. *Occlusal factors:* The antagonistic units were categorised into: i) Fixed units- tooth or tooth or implant borne crown or bridge unit; ii) Removable denture units; or iii) No antagonist. Number of occlusal pairs for resected tooth: premolar size antagonists were considered as a single unit pair; molar-sized occlusion was counted as a double-unit (Kayser 1981).

### Clinical examinations

These examinations were performed by one examiner (KLL). Plaque - presence or absence, bleeding on probing (BOP), recession (REC), probing pocket depth (PPD) and probing attachment level (PAL) were measured at six sites (mesio-buccal, mid-buccal, disto-buccal, mesio-palatal, mid-palatal and disto-palatal) on each tooth except third molars and retained roots. PCP-UNC 15 probe (Hu-Friedy, Chicago, IL) was used. The measurement of REC, PPD, and PAL was performed according to

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3 a reported protocol (Pilgram et al. 2000), and tooth sites associated with tooth  
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a reported protocol (Pilgram et al. 2000), and tooth sites associated with tooth  
impaction or having the CEJ indeterminable were excluded.

A paralleling periapical radiograph was taken if the resected tooth was still  
present. Similar radiographic measurements as for the pre- and earlier post-resective  
therapy radiographs were recorded. In addition, any increase in the size of any apical  
lesion, change in radiographic density of root canal fillings, and widening of  
periodontal ligament space was recorded.

### **Data analysis**

Standard descriptive statistical analysis was conducted to synthesize the raw data. The  
association between the dependent variable, the survival of the resected tooth at recall,  
to the various pre- or earlier post-treatment independent variables was assessed. The  
independent variables were: age at the time of resective therapy, gender, educational  
level, smoking, dietary habits, denture wearing, compliance with dental check-up, oral  
hygiene practice, pre-treatment tooth mobility, root morphology, type of remaining  
root(s), quality of resective therapy, endodontic treatment quality, pre-treatment  
periapical lesion size, radiographic bone level on the remaining root(s), radiographic  
crown-root ratio, the restorative status after root resection, and any splinting of  
resected tooth to neighbouring teeth. Similarly, univariate analysis between period of  
resected tooth survival and various independent variables was performed using  
Kaplan-Meier analysis/log-rank test to detect which decisive variables would be  
significantly associated with period of resected tooth survival without consideration of  
confounding variables. In brief the independent variable were: age at root resection  
and at recall, gender, smoking, regular dental check-up, tooth type, pre-resection tooth  
mobility, the following parameters at recall - PI%, BOP%, full mouth mean PPD,

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3 missing teeth, denture wearing, and any parameters found significantly associated  
4 with missing resected tooth at recall. Univariate analysis of association between  
5 period of resected tooth survival and various independent variables was calculated  
6 according to the Kaplan-Meier product limit estimation. Time zero was defined as the  
7 date when the resective treatment was carried out. The surviving resected teeth data  
8 and self-reported survival data regarding the lost resected teeth were recorded on the  
9 recall data collection visit. The calculated survival curve was the 'maximum  
10 likelihood' estimate of the true survival curve. **Multivariate Cox regression model**  
11 **was then constructed, based on the above predetermined independent variables and**  
12 **those appearing to be significantly associated with i) survival of resected teeth at**  
13 **recall, and ii) period of survival of resected tooth from the Kaplan-Meier analysis.**  
14 Significance level of 0.05 was adopted. All data were analysed using the Statistical  
15 Package for Social Science, version 16.0 (SPSS, Chicago, IL, USA).  
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## 37 **Results**

38 The majority (88.6%) of patients receiving resective therapy in the Periodontology  
39 Clinic had suffered from severe attachment loss such that the resective treatment was  
40 the only viable option to prolong the lifespan of the involved tooth. Hence the  
41 indication for root resection had not changed during the period of patient treatment  
42 under consideration which was a median of 9.0 and a mean of  $9.0 \pm 5.7$  years.  
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50 **Only seventeen (11.4%) of the 149 patients were non-periodontitis cases. Out**  
51 **of the 132 periodontal patients, 87 (65.9%) of them had received at least biannual**  
52 **SPC, 72 (54.5%) at the Periodontology Clinic and 15 (11.4%) from private dental**  
53 **practitioners. The others (n=45 periodontitis patients, and 17 non-periodontitis**  
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3 patients), despite having been recommended, as is routine, to seek regular SPC from  
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5 private dentists, had in reality attended less than twice per year.  
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8 Among the teeth of interest, 70 had Degree I furcation(s), 79 had Degree II or III  
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10 furcation(s) involvement recorded, however many furcation involvements recorded as  
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12 Degree I on the basis of the clinical examination were found on surgical exploration  
13  
14 to be more severely involved in terms of furcation involvement or in terms of  
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16 advanced attachment loss localised to one root. Furcation status of other molars was  
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18 not noted for this study because it was not always possible to compare every furcation  
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20 entry in the clinical notes against a corresponding intra-oral radiograph.  
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23 Hemisection had been carried out in 23 teeth (15.4% patients), while root  
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25 amputation/resection had been performed for the remaining 126 teeth. Of the teeth  
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27 which had undergone resective therapy, 76 (51.0 %) were upper first molars, 13  
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29 (8.7%) were upper second molars, 43 (28.9%) were lower first molars and 17 (11.4%)  
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31 were lower second molars. For upper first and second molars, resection of  
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33 mesiobuccal, distobuccal, both buccal, or palatal root(s) accounted for 15 (10.1%), 21  
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35 (14.1%), 7 (4.7%) and 46 (30.9%) cases, respectively. For lower molars, resection of  
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37 mesial or distal root both individually accounted for 30 (20.1%) cases. Furcation  
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39 involvement remained present between the standing roots of 39 resected upper molars.  
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41 Forty eight (32.2%) of the resected teeth received extra-coronal restoration.  
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45 Mean age of patients when they had undergone resective therapy was 47.3 years  
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47 (range 19-83 years) and the mean age at recall was  $57.3 \pm 10.6$  years. Demographic  
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49 data and habits of participants are summarized in Table 1. Overall tobacco exposure  
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51 of the 34 smokers and ex-smokers was  $19.5 \pm 14.5$  pack-years. The observation  
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53 period of resected teeth ranged from 1 to 24 years, categorized as: 1-5 years (31.5%);  
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55 6-10 years (28.9%); 11-15 years (24.8%); and  $\geq 16$  years (14.8%).  
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3 The mean ( $\pm$ SD) and the median survival of resected teeth were 73 ( $\pm$ 58.9) and  
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5 74 months, respectively. Eighty nine (59.7%) of the resected teeth had been lost prior  
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7 to re-evaluation. Of these, clear indications for 73 (82.0%) tooth extractions could be  
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9 determined, while for the rest ( $n = 16$ ) the reasons for extraction were self-reported.  
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11 The total reported reasons for loss were: periodontal causes ( $n = 66$ , 74.2%), fractured  
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13 root ( $n = 14$ , 15.7%), endodontic problems or root resorption ( $n = 6$ , 6.7%), and caries  
14  
15 ( $n = 3$ , 3.4%). In total 931 first and second molars, including the subject teeth, were  
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17 present in the 149 subjects at baseline (Table 2). Those reporting regular SPC had  
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19 lost a mean of 0.6 first or second molars, while those reporting non-adherence to  
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21 regular recalls lost a mean of 1.0 first or second molars. Tobacco exposure was not  
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23 associated with survival of resected teeth at recall.  
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28 The reported survival period of the 89 lost resected teeth was between: 0-3 years  
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30 for 40 (44.9%); 4-6 years for 24 (27.0%); 7-9 years for 7 (7.9%); 10-12 years for 11  
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32 (12.4%); and >12 years for 7 (7.9%). For the 40 teeth lost in the first 3 years, 30 teeth  
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34 (75%) were reported lost due to periodontal reasons or excessive mobility, 5 (12.5%)  
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36 due to root fracture and the remaining 5 (12.5%) due to endodontic problems.  
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38 Eighteen (45%) out of these 40 teeth were assessed as having bone level <50 % on  
39  
40 remaining roots from the post-resective radiograph.  
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44 For the 88 patients who were contacted by phone or mail but declined to  
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46 participate in the clinical study, all were subsequently contacted by telephone. 41  
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48 (response rate 46.6%) agreed to answer questions about the status of their resected  
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50 tooth. Their mean age at resection was  $46.1 \pm 10.0$  years and at telephone contact was  
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52  $60.7 \pm 9.3$  years. Twenty-four (58.5%) resected teeth were reported as surviving over  
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54 the mean period of 14.6 years.  
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3 Background characteristics of all subjects are as shown in Table 1. For those  
4  
5 subjects self-reporting or verified through hospital records as having regular dental  
6  
7 check-ups professional fluoride application was not noted. Subjects who reported  
8  
9 using interdental brushes daily were found to have lower PI% and BOP% ( $p \leq 0.021$ ).  
10  
11 Preliminary univariate analysis indicated that patients with resected tooth present at  
12  
13 recall: i) were younger than those who had lost the resected tooth, and ii) reported  
14  
15 regular dental check-ups. No significant association was detectable between the  
16  
17 subjects' gender, systemic disease status, economic factors, educational level,  
18  
19 smoking, dietary plus oral hygiene habits and the survival of the resected tooth (Table  
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25 The tooth type of the resected tooth, pre-treatment tooth mobility, root  
26  
27 morphology, endodontic treatment quality did not significantly correlate with survival  
28  
29 at recall. There was no significant correlation of any pre-treatment periapical  
30  
31 radiographic lesion size with resected tooth survival. The location of remaining  
32  
33 root(s), antagonistic occluding units, quality of root resection, post-resective treatment  
34  
35 did not significantly associate with resected tooth survival at recall. Pre-resection  
36  
37 tooth support, post-resection restoration status, including post and core usage,  
38  
39 appeared to associate with resected tooth survival at recall. Not wearing denture(s),  
40  
41 having fewer decayed (DT) or filled teeth (FT), and less full-mouth mean recession at  
42  
43 re-examination appeared to be associated with survival of resected tooth at recall  
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47 (Table 3).

49 The median (50%) estimated survival of the resected molars was 74 months.  
50  
51 According to the Kaplan–Meier plot (data not shown), one-half of the resected teeth  
52  
53 were lost after six years. The estimated 10-year post-resection survival was 39%.  
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3 The variables found to have significant correlation (without controlling for the  
4 confounding variables) with resected tooth survival are summarised in Table 4.  
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6 Reduced bone height  $\leq 50\%$ , and mobility  $\geq M II$  were associated with reduced  
7 survival while use as a bridge abutment or being splinted was associated with  
8 increased survival. Based on the above, a multivariate Cox proportional hazards  
9 regression model was developed (Table 5). Only teeth with  $>75\%$  bone level had a  
10 significantly longer survival period ( $p < 0.001$ ) compared to those with  $<50\%$  bone  
11 level in the adjusted Cox regression model. There was more than four times  
12 increased risk in tooth loss of for teeth with  $<50\%$  bone, compared to those with  
13  $>75\%$  bone. Teeth presenting with MII or greater pre-treatment mobility were at a  
14 three-fold higher risk of tooth loss than non-mobile teeth. Significant decrease, by  
15 74%, was found in the risk of tooth loss for splinted resected teeth compared to those  
16 teeth restored with unsplinted restorations. Patients' older age at time of resective  
17 treatment was found to be significantly associated with poorer survival. Harrell's C  
18 of 0.6924 indicates that one can correctly order survival times for pairs of patients  
19 approximately 70% of the time on the basis of the variables in the model (Harrell et al.  
20 1996).  
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## 45 Discussion

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47 The results from the current study indicate that for molar teeth with hopeless root(s)  
48 mostly with extensive periodontal damage, several factors appear to positively or  
49 negatively affect the tooth survival after resective periodontal therapy. These are:  
50 pre-treatment radiographic bone level on the root(s) to remain, pre-treatment mobility,  
51 coronal protection and splinting. Such information may assist clinicians in treatment  
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3 planning resective therapy as well as in designing post-operative management  
4 strategies in an attempt to prolong the life of a tooth treated by a resective approach as  
5 a last resort intervention for a furcation involved tooth, or a multi-rooted tooth with an  
6 endodontic mishap or root fracture affecting only one root.  
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11 Similar to an earlier local report (Leung et al. 2006), the majority (53.1%) of the  
12 total first or second molar teeth lost over the post-treatment period in these patients  
13 were from subjects (42.1%) not complying with SPC advice. Due to the limitations  
14 of the retrospective study design, it was not possible to retrieve reliable further data to  
15 compare exactly first and second molar tooth loss according to SPC compliance,  
16 smoking, treatment type received (non-surgical and/or surgical) for resected versus  
17 non-resected molar survival in the current patient cohort.  
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27 More severely involved teeth may not be retained or treated, with 44% of all  
28 teeth with furcation involvement being extracted as part of initial treatment in one  
29 study (Hamp et al. 1975). Resective therapy may be performed as a definitive  
30 treatment approach (Carnevale et al. 1991; Carnevale et al. 1998), or it may be  
31 performed as a last resort type of therapy to extend the functional survival of teeth  
32 having one root with advanced attachment loss, as in this study. It is difficult to  
33 compare different study outcomes unless the treatment approaches adopted and  
34 treatment goals set are reported in sufficient detail. The clinical decision for root(s)  
35 removal before, based upon pre-treatment clinical examination and plain radiography,  
36 or during the root resective surgical procedure, based on direct appreciation of the  
37 clinical defect/problem (Walter et al. 2009,) was not studied.  
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52 By the nature of this retrospective study, some of the patients who had received  
53 resective therapy could not be recalled because their contacts were no longer valid or  
54 because they had passed away. Some of the patient information retrieved from the  
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3 patient clinical files did not satisfy the inclusion criteria. A fair proportion of those  
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5 who had received resective therapy, refused to participate in this project as it involved  
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7 a recall visit to the dental teaching hospital. All of those who refused to participate but  
8  
9 who were willing to answer questions were interviewed by telephone. They were  
10  
11 older than those who participated this project and reported a longer resected tooth  
12  
13 survival period. Thus non-attendance by potential patients may have suggested less  
14  
15 favourable survival than actually experienced. The number of patients successfully  
16  
17 recalled, 149, is comparable to a similar Hong Kong study on treatment outcomes  
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19 (Leung et al. 2006).  
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23 A range of clinical factors may influence treatment decisions for periodontally  
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25 involved molars (Svardstrom & Wennström 2000), as may dentists' treatment  
26  
27 preferences (Zitzmann et al. 2011). In the present study, 89% of the patients  
28  
29 receiving resective therapy had suffered from severe attachment loss not affecting all  
30  
31 roots to a similar extent. The alveolar bone support on the remaining root(s) was not  
32  
33 optimal in every case. Around half of the resected teeth in this study presented with  
34  
35 pre-treatment <75% radiographic bone support, with 20% having only <50%. The  
36  
37 median survival of a resected tooth with pre-treatment <50% remaining radiographic  
38  
39 bone support was only 2.1 years (data not shown). Reduced bone height might  
40  
41 constitute a possible reason why 40 of the 89 extracted resected teeth were lost in the  
42  
43 first 3 years. The attempt to prolong the life of some teeth with questionable prognosis  
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45 having minimal bone height on roots to remain by respective therapy as a 'last ditch'  
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47 form of therapy may explain the relatively high failure rate of this treatment approach  
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49 in this study. Another study of root resection therapy in an Asian population also  
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51 concluded that the roots to remain should have sufficient bone support (Park et al.  
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60 2009).

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3 Complicating respective therapeutic approaches for lower first molars in the  
4 Chinese is a high prevalence, up to 21%, of an extra disto-lingual root (Walker &  
5 Quackenbush 1985; Huang et al. 2007; Tu et al. 2007). This study however did not  
6 show any significant association between any particular type of resected tooth and  
7 post-resection survival, which is in agreement with an earlier study (Blomlof et al.  
8 1997).

9  
10  
11 This study found that there was no significant association between resected tooth  
12 survival and reported consumption of hard foods, including the chewing of bones.  
13 Recommendations that remaining roots on resected molars be subjected to only the  
14 lightest loads possible (Langer 1996) cannot in practice work in a population in which  
15 masticatory activities such as the chewing of bones is commonplace.

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18 In the present study, periodontal causes/excessive mobility was the major reason  
19 for failure, accounting for 75% of the resected tooth loss. Fractured root was the  
20 second commonest mode of failure, accounting for 15% of resected teeth lost, not  
21 dissimilar to the proportion of resected teeth lost due to fracture (18.6%) in another  
22 Asian study (Park et al. 2009).

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25 The teeth which were most commonly resected, as a last resort therapy, in this  
26 study in descending order were: upper first molars, lower first molars, lower second  
27 molars and upper second molars. A higher prevalence of furcation involved molars  
28 has been reported in the maxilla (Hirschfeld & Wasserman 1978; McFall 1982;  
29 Svardstrom & Wennström 1996) possibly due to differences in the number of  
30 furcation entrances or differences in accessibility of furcation entrances for plaque  
31 control.

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34 Only one-fifth of patients in this study had undergone resective therapy on  
35 second molars. A higher prevalence of unfavourable anatomical features in upper  
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3 second molars in the Chinese race, long root trunks and fused roots (Hou & Tsai  
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5 1997b), often preclude successful resective therapy. It has been reported that  
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7 extraction was indicated two-times more commonly for periodontally involved second  
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9 molars than for first molars (Müller et al. 1995).  
10

11  
12 Root resected teeth are often subsequently subjected to various types of  
13  
14 restorative treatment, which may further complicate the interpretation of results of the  
15  
16 respective therapeutic approach itself. Some studies (Carnevale et al. 1991; Carnevale  
17  
18 et al. 1998) showed a remarkably high survival rate (93%) over 3-11 years, but 62%  
19  
20 of the treated teeth were treated with root separation and not root resection, while the  
21  
22 prosthetic plan for 87% of the treated teeth was splinting through incorporation as  
23  
24 abutments for fixed dental prostheses. The longevity of endodontically-treated, which  
25  
26 teeth treated by resective therapies invariably become, has been the focus of several  
27  
28 recent studies. Endodontically-treated molars with maximum coronal tooth structure  
29  
30 remaining after endodontic access can be restored without crown placements, yielding  
31  
32 fair long-term survival (median >7.9 years), irrespective of type of direct restoration  
33  
34 material (Nagasiri & Chitmongkolsuk 2005). However another retrospective study  
35  
36 showed that endodontically-treated teeth which were not crowned were at a 6-fold  
37  
38 greater risk to be lost than a crowned root treated tooth (Aquilino & Caplan 2002)  
39  
40 while crowned endodontically-treated teeth have been shown to have similar survival  
41  
42 rates as crowned teeth with vital pulps (Valderhaug et al. 1997). However his study  
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44 showed that splinting of resected teeth offered protection.  
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50 Fifty eight percent of patients in this study reported biannual dental check-ups,  
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52 not a common reported practice among the general population of Hong Kong (Oral  
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54 Health Survey 2001) or in treated periodontitis patients in Hong Kong (Leung et al.  
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56 2006). However on the basis of the multivariate analysis, regular dental recalls in the  
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3 Periodontology Clinic and/or at patients' own general dentists did not seem to be  
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5 associated with better post-resection molar survival (Table 4). Considering the  
6  
7 potential differences between the quality of SPC provided by the Periodontology  
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9 Clinic compared to the quality of the supportive care delivered in general dental  
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11 practices, and the difficulties for those attending private dentists to remember exactly  
12  
13 what services had been offered and availed of, no attempt was made to analyse the  
14  
15 effect of quality of preventive treatment received during dental check-ups on resected  
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17 molar survival. Nevertheless, regularity of maintenance has been shown to be  
18  
19 significant in terms of preservation of teeth with furcation lesions (Rosling et al. 1976;  
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21 Nyman et al. 1977; Checchi et al. 2002; Pretzl et al. 2008) and should thus be  
22  
23 routinely recommended.  
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### 30 **Conclusion**

31  
32 The present study investigated retrospectively factors which may be associated with  
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34 the clinical survival of resected molar teeth in a teaching hospital-based periodontal  
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36 patient pool. Most of the resective treatment was carried out for teeth with one, or  
37  
38 more, hopeless root(s), mostly with extensive periodontal damage, in an attempt to  
39  
40 prolong the life of the teeth. Several factors were demonstrated to affect molar tooth  
41  
42 survival after resective periodontal therapy: younger age at resection and splinting of  
43  
44 resected teeth to neighbouring teeth conferred significant positive effects, while teeth  
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46 with reduced pre-treatment radiographic bone levels on the root(s) to remain and teeth  
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48 with pre-resective treatment mobility of Degree II or above were at risk of earlier loss.  
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50 Findings from the present study could therefore provide clinicians with guidance in  
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52 managing a periodontally involved molar with advanced attachment loss, for which  
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3 resective therapy may be considered so as to avoid tooth extraction and extend the  
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5 functional longevity of the tooth.  
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20 analysis.  
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## Legend

*Fig. 1.* A case of a 41 year-old female with combined periodontal-endodontic lesion at lower left first molar (tooth 36) requiring distal root resection in lieu of extraction. a) radiographic presentation of lesion before and b) after root canal therapy; c) lingual and d) buccal views of lower left mandibular posterior region before root resection while shortly after non-surgical periodontal therapy and root treatment; e) resective surgery on 36 distal; f) radiographic presentation, g) lingual and h) buccal views of 36 at recall, i.e. 25 months post-resection and regular SPC.

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Table 1. Background characteristics of study participants

Characteristics	Categories	Resected tooth status		Test	Statistics	p-value
		Missing (n = 89)	Present (n = 60)			
Age (Mean ±SD, year)	At recall	59.2 ± 10.0	54.6 ± 11.0	t	2.639	0.009
	At tooth resection	47.3 ± 9.9	47.3 ± 12.2	t	-0.035	NS
Gender	Male	52 (58.4)	30 (50.0)	$\chi^2$	1.028	NS
	Female	37 (41.6)	30 (50.0)			
Monthly household income (HK\$) <sup>a</sup>	< 10000	35 (39.3)	15 (25.0)	$\chi^2$	3.350	NS
	10000-19999	24(27.0)	19 (31.7)			
	≥ 20000	30 (33.7)	26 (48.3)			
Educational level	No/Primary	24 (27.0)	14 (23.3)	$\chi^2$	1.705	NS
	Secondary	44 (49.4)	26 (43.3)			
	Post-secondary	21 (23.6)	20 (33.3)			
Smoking	Non-smoker	67 (75.3)	48 (80.0)	$\chi^2$	0.453	NS
	Ex-Smoker/Smoker	22 (24.7)	12 (20.0)			
Pack-year (Mean ± SD)	Ex-Smoker	20.9 ± 18.2	8.8 ± 6.1	t	1.421	NS
	Smoker	22.2 ± 14.2	23.0 ± 11.5	t	0.103	NS
Systemic disease	No	55 (61.8)	46 (76.7)	$\chi^2$	3.628	NS
	Yes	34 (38.2)	14 (23.3)			
Dietary habits	Hard food consumption	No	48 (53.9)	$\chi^2$	0.108	NS
		Yes	41 (46.1)			
Snacking	No	54 (60.7)	33 (55.0)	$\chi^2$	0.475	NS
	Yes	35 (39.3)	27 (45.0)			
Daily soft drink consumption	No	72 (80.9)	45 (75.0)	$\chi^2$	0.739	NS

	Yes	17(19.1)	15 (25.0)			
Oral Hygiene habits						
Tooth brushing habit	≤ 1 time daily	76 (85.4)	50 (83.3)	$\chi^2$	0.117	NS
	≥ 2 times daily	13 (14.6)	10 (16.7)			
Interdental brushing	No	20 (22.5)	10 (16.7)	$\chi^2$	0.751	NS
	Yes	69 (77.5)	50 (83.3)			
Regular dental check-up	No	45 (50.6)	17 (28.3)	$\chi^2$	7.9579	0.019
	Yes: private	9 (10.1)	6 (10.0)			
	Yes: hospital	35 (39.3)	37 (61.7)			

Results are Number (%) unless otherwise indicated; NS = not significant.

<sup>a</sup>HK\$7.8 = US\$1 (and pegged at that exchange rate)



Table 2. Status of first and second molars in study participants

	Baseline (n = 149)	At recall <sup>a</sup>		With SPC <sup>b</sup> (n = 87)		p-value <sup>c</sup>
		No SPC(n = 62)		With SPC <sup>b</sup> (n = 87)		
		Extracted	Standing	Extracted	Standing	
Subject tooth	149	45	17	44	43	0.011
Other first/second molars	782	65	274	53	390	0.007
Total	931	110	291	97	433	

<sup>a</sup>overall p <0.001, Chi-square test

<sup>b</sup>including SPC at dental hospital and private dental practises

<sup>c</sup>Chi-square test

Table 3. Dental status of study participants

Characteristics	Categories	Resected tooth status		Test	Statistics	p-value
		Missing (n = 89)	Present (n = 60)			
<b>Pre-resective therapy records</b>						
<i>Clinical data</i>						
Tooth type	Maxillary first molar	49 (55.1)	27 (45.0)	$\chi^2$	3.030	NS
	Maxillary second molar	9 (10.1)	4 (6.7)			
	Mandibular first molar	23 (25.8)	20 (33.3)			
	Mandibular second molar	8 (9.0)	9 (15.0)			
Tooth mobility <sup>a</sup>	M0	26 (29.2)	28 (46.7)	$\chi^2$	5.731	NS
	MI	45 (50.6)	26 (43.3)			
	MII or above	18 (20.2)	6 (10.0)			
<i>Radiographic data</i>						
Root morphology						
Trunk length	Cervical 1/3	42 (47.2)	30 (50.0)	$\chi^2$	0.113	NS
	Cervical 1/2 and 2/3	47 (52.8)	30 (50.0)			
Divergence angle <sup>b</sup>	< 15°	42 (47.2)	34 (56.7)	$\chi^2$	1.288	NS
	≥ 15°	47 (52.8)	26 (43.3)			
Tooth support						
Remaining bone level	≥75 %	23 (25.8)	28 (46.7)	$\chi^2$	19.042	< 0.001
	74-50%	38 (42.7)	30 (50.0)			
	<50%	28 (31.5)	2 (3.3)			
Crown-root ratio	(Mean ± SD, %)	1.90 ± 1.25	1.25 ± 0.53	t	4.350	< 0.001
Endodontic treatment quality <sup>c</sup>	Not good	11 (12.4)	10 (16.7)	$\chi^2$	0.251	NS
	Good	78 (87.6)	50 (83.3)			
Pre-treatment apical lesion size (mm)	≤ 2.0	63 (70.8)	43 (71.7)	$\chi^2$	2.815	NS
	2.1 - 4.0	17 (19.1)	15 (25.0)			

	$\geq 4.1$	9 (10.1)	2 (3.3)			
<b>Post-resective therapy records</b>						
<i>Clinical data of resected tooth</i>						
Remaining root(s)						
Type						
Maxillary	MB+DB	32 (36.0)	14 (23.3)	$\chi^2$	9.715	NS
	DB+P	10 (11.2)	5 (8.3)			
	MB+P	13 (14.6)	8 (13.3)			
	P	3 (3.4)	4 (6.7)			
Mandibular	M	17 (19.1)	13 (21.7)			
	D	14 (15.7)	16 (26.7)			
Restorative status	Simple restoration	71 (79.8)	30 (50.0)	$\chi^2$	14.572	< 0.001
	Coronal coverage	10 (11.2)	16 (26.7)			
	Bridge abutment/splinted	8 (9.0)	14 (23.3)			
Caries <sup>f</sup>	No	87(97.8)	55 (91.7)	$\chi^2$	2.965	NS
	Yes	2 (2.2)	5 (8.3)			
Antagonistic occluding units	None	5 (5.6)	5 (8.3)	$\chi^2$	1.126	NS
	Removable denture	7 (7.9)	7 (11.7)			
	Fixed <sup>d</sup>	77 (86.5)	48 (80.0)			
Number of occluding pairs	(Mean $\pm$ SD)	8.12 $\pm$ 3.50	8.57 $\pm$ 3.26	t	-0.779	NS
<i>Radiographic data</i>						
Quality of root resection <sup>e</sup>	Not good	14 (15.4)	7 (10.9)	$\chi^2$	0.211	NS
	Good	75 (84.6)	53 (89.1)			
Presence of post and core	No	87 (97.8)	53 (88.3)	$\chi^2$	5.603	0.018
	Yes	2 (2.2)	7 (11.7)			

**Dental status at recall***General*

PI%		0.52 ± 0.27	0.45 ± 0.26	t	1.769	NS
BOP%		0.32 ± 0.23	0.27 ± 0.24	t	1.289	NS
REC		1.61 ± 0.85	1.18 ± 0.81	t	3.141	0.002
PPD (mm)		1.44 ± 0.64	1.56 ± 0.62	t	-1.091	NS
PAL (mm)		3.06 ± 1.17	2.74 ± 1.17	t	1.652	NS
MT		0.57 ± 1.43	0.50 ± 1.02	t	0.342	NS
DT		7.27 ± 5.06	3.55 ± 3.74	t	5.160	< 0.001
FT		3.99 ± 3.80	5.85 ± 5.26	t	-2.356	0.020
DMFT		11.83 ± 6.08	9.90 ± 6.53	t	1.846	NS

Denture wearing	No	57 (64.0)	49 (81.7)	$\chi^2$	5.421	0.020
	Yes	32 (36.0)	11 (18.3)			

*Clinical data of resected tooth*

Tooth mobility <sup>a</sup>	M0	NA	40 (66.7)
	MI	NA	15 (25.0)
	MII or above	NA	5 (8.3)

Results are Number (%) unless otherwise indicated; D = distal; DB = distobuccal; M = mesial; MB = mesiobuccal; NA = not applicable; NS = not significant; P = palatal.

<sup>a</sup>Mobility– classified according to Miller's classification (Miller 1938).

<sup>b</sup>Divergence for maxillary molars - only between mesiobuccal and distobuccal roots.

<sup>c</sup>Intra-canal treatment quality - classified according to the Consensus Report of the European Society of Endodontology (2006).

<sup>d</sup>Fixed units - tooth or tooth or implant borne crown or bridge unit.

<sup>e</sup>Quality of root resection - classified according to Newell (1991).

<sup>f</sup>Diagnosis aided radiographically.

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Table 4. Kaplan–Meier analysis on variables showing significant associations with period of resected tooth survival

Characteristics	Categories (1–3)	N (%)	Median survival (months)	95% Confidence interval (months)	Log-rank Chi-square p-value	Between categories survival
Remaining bone level	≥75 % (1)	51 (34.2)	156	94.4 - 217.6	<0.001	1 > 3
	74-50% (2)	68 (45.6)	106	69.5 - 142.4	<0.001	2 > 3
	<50% (3)	30 (20.1)	25	2.6- 47.4		
Pre-resection tooth mobility <sup>a</sup>	M0 (1)	54 (36.2)	123	84.9 - 161.1		
	MI (2)	71 (47.7)	62	51.3–72.7	0.009	1 > 2
	MII or above (3)	24 (16.1)	39	0.0 – 81.3	0.009	1 > 3
Restoration status	Simple restoration (1)	101 (67.8)	63	51.3 - 74.7		
	Coronal coverage (2)	26 (17.4)	156	88.2 - 223.8	0.006	1 < 2
	Bridge abutment/splinted (3)	22 (14.8)	227	-	0.006	1 < 3

Independent variables considered in Kaplan–Meier analysis but at the end not significant: age at root resection and at recall, gender, smoking, regular dental check-up (no/yes: private vs. hospital), tooth type, presence of post and core, and the following parameters at recall - PI%, BOP%, PPD, REC, DT, FT, denture wearing. Crown-root ratio was not incorporated because of possible confounding with remaining bone level.

<sup>a</sup>Mobility– Classified according to Miller’s classification (Miller 1938).

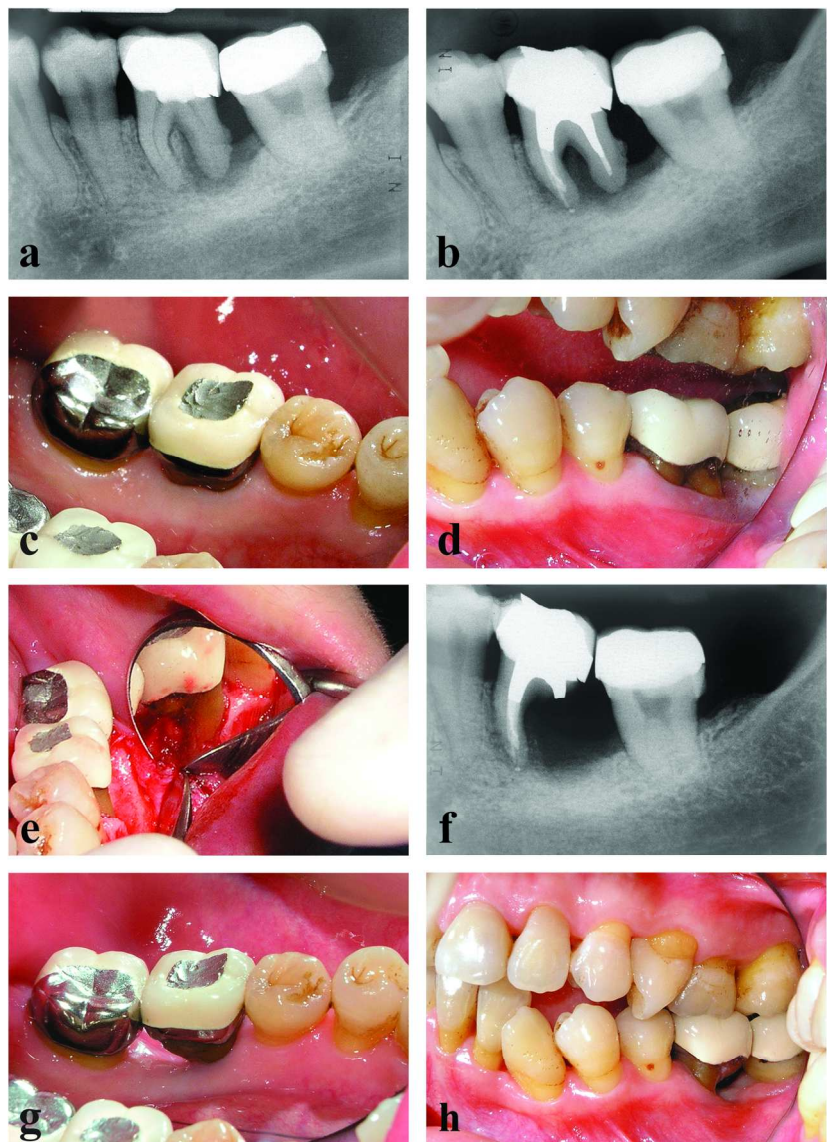
Table 5. Multivariate Cox proportional hazards regression model for period of resected tooth survival

Variable	Parameter estimate (B)	Standard Error (SE)	p-value	Hazard ratio (95% CI)
Age at resective treatment	0.02	0.01	0.04	1.021(1.001-1.040)
Bone height				
>75%				1
74-50%	0.49	0.28	0.08	1.626 (0.943-2.807)
<50%	1.51	0.31	<0.001	4.515 (2.460-8.287)
Pre-resection toothmobility <sup>a</sup>				
M 0				1
M I	0.19	0.26	0.47	1.211 (0.724-2.026)
M II or above	1.11	0.35	0.001	3.033(1.534-5.997)
Restoration status				
Simple restoration				1
Coronal coverage	-0.43	0.35	0.22	0.651 (0.329-1.289)
Bridge abutment/splinted	-1.34	0.42	0.002	0.263 (0.115-0.603)

Result simplified from analysis of independent variables including age at recall, gender, smoking, regular dental check-up (no/yes: private vs. hospital), tooth type, presence of post and core, and the following parameters at recall - PI%, BOP%, PPD, REC, DT, FT, and denture wearing which were found not significantly associated with period of resected tooth survival. Crown-root ratio was not incorporated because of possible confounding with remaining bone level.

<sup>a</sup>Mobility– Classified according to Miller's classification (Miller 1938)

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