Original Article

A Comparison of Pulp Necrosis and Root Resorption After Auto-transplantation Between Immature Teeth and Apicoectomized Mature Teeth

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Abstract

Success in pulp revascularization after autotransplantation tends to happen in a tooth with an incomplete root formation, while a tooth with a complete root formation needs a root canal treatment. However, recent studies showed that apicoectomy facilitated the repair and revascularization process with promising outcomes. This study aimed to compare the incidences of pulp necrosis and root resorption of autotransplanted teeth with a complete root formation which underwent apicoectomy and teeth with an incomplete root formation. Patients with a history of autotransplantation received clinical and radiographic follow-up examination. The autotransplanted teeth were divided into two groups, the incomplete root formation group and the extraoral apicoectomized complete root formation group. Pulp and periradicular outcomes (pulp healing, pulp necrosis and presence of root resorption) were determined with an additional of cone-beam computed tomography investigation. The incidence of each outcome and prognostic factors were statistically compared. The result showed that the incomplete root formation group presented 40 % (4 of 10) pulp necrosis and 10 % (1 of 10) root resorption, while the extraoral apicoectomized complete root formation group presented 77.8 % (7 of 9) pulp necrosis and 66.7 % (6 of 9) root resorption. The periradicular status between the two groups was significantly different. No prognostic factor was found to be related to pulp outcome, however apicoectomy and recipient socket were found to be related to the periradicular outcome. Autotransplanted teeth with complete root formation undergoing extraoral apicoectomy increased the risk of pulp necrosis and root resorption. A totally prepared recipient socket without remaining periodontal ligament was also found to be related to root resorption.

Keywords: Apicoectomy, Autotransplantation, Cone beam computed tomography, Revascularization, Root resorption

Received Date: Jun 17, 2022 **Revised Date:** Aug 8, 2022 **Accepted Date:** Sep 26, 2022
doi: 10.14456/jdat.2023.1

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Introduction

Tooth autotransplantation is a surgical transposition of a tooth by extraction and replantation into another site in the same patient's mouth, also known as a controlled, aseptic avulsion and re-implantation.[1] It is one of the treatment options for patients to replace missing teeth and is preferred in children due to its adaptation to growth and developmental changes.[2]

Wound healing in autotransplantation is dependent on PDL healing, bone healing, pulp regeneration and root development.[3] Pulp revascularization is expected in an immature and developing transplanted tooth without the need for root canal treatment[4], while it is recommended that a tooth a with complete root development should undergo root canal treatment within 2 weeks after tooth transplantation to prevent root resorption.[5] According to Andreasen[6,7], 1 mm is the critical diameter of apical foramen which led to successful revascularization, while increasing the stage of root development[8] and the stage of eruption was found to be related to root resorption. However, recent case reports showed that apicoectomy of fully developed tooth facilitated the revascularization process and prevented subsequent endodontic treatment.[9,10] These were consistent with studies of extraoral apicoectomized mature teeth in dogs which showed the repair process via the ingrowth of connective tissue and pulpal revascularization.[11,12] Moreover, a recent retrospective study of extraoral root-end resection of mature teeth showed promising outcomes with a single root canal and uncomplicated root morphology.[13]

Although autotransplantation has been successfully performed for several years, only one clinical study has investigated the survival and complication of immature and root-end resected mature autotransplanted teeth.[13] Therefore, this study aimed to compare the incidence of pulp necrosis and root resorption of autotransplanted teeth with incomplete root formation and extraoral apicoectomized complete root formation at the Faculty of Dentistry, Chulalongkorn University. The finding might suggest the possibility of pulp revascularization in different root types, expand the potential applicability and create the protocol for root canal treatment in autotransplanted teeth.

Materials and methods

Patient recruitment

The Human Research Ethics Committee of Chulalongkorn University, Bangkok, Thailand (HREC-DCU 2020-070) approved the study protocol. Patients who had received tooth autotransplantation from January 2011 to May 2018 at the Faculty of Dentistry, Chulalongkorn University, were recruited and assessed via dental record history.

Inclusion criteria:

1. Patients with a history of autotransplantation and a minimum postoperative period of 1 year.

2. The patients' dental records with presurgical radiographs or immediate postsurgical radiographs.

3. At the time of surgery, the donor tooth was classified as incomplete root formation (stage 0-4 of Moorrees classification[14]) or complete root formation (stage 5-6 of Moorrees classification[14]) and underwent apicoectomy during surgery.

Data collection

Patients were divided into two groups according to donor tooth at the time of surgery as follows: (1) Teeth with incomplete root formation, (2) Teeth with complete root formation and underwent apicoectomy during surgery. Teeth with complete root formation and underwent intentional root canal treatment were excluded from this study.

The patients' demographics were collected from the hospital records. The following variables which may influence the outcome were recorded; donor tooth type, stage of root development, recipient socket, cause of tooth loss, and eruption status of donor tooth. The recipient socket was classified as a partially prepared socket, if a permanent tooth was extracted from the recipient site and the donor tooth was placed into the socket within the same visit and only need some additional socket preparation, while a totally prepared socket referred to

the recipient socket from an edentulous area or a primary tooth extraction, which operator needed to establish a new recipient socket without any remnant PDL. If the donor tooth received root canal treatment after auto-transplantation, the cause of root canal treatment was identified according to the treatment records.

Clinical and radiographic evaluation

Patients who met the inclusion criteria were contacted via phone and invited to take part in the follow-up examination from September 2020 to July 2021. A clinical examination was performed by one examiner (PM). Subjective symptoms and clinical parameters including tooth mobility[15], percussion sound, pain on percussion, sensibility test (electric pulp test and Endo-Frost), gingival index[16], periodontal pocket, soft tissue appearance (presented of sinus fistula or swelling), and restoration condition were recorded.

Two different angles of parallel periapical radiographs were taken to examine obliteration of pulp cavity, periapical lesion, the integrity of periodontal space and signs of root resorption. Patients who agreed to additional radiograph were subjected to cone beam computed tomography (CBCT) [Accuitomo 170 (J. Morita USA)] with a limited field of view (FOV) of 4x4 cm. The CBCT images were assessed using One Volume Viewer software. All examiners were reminded of the salient features of resorption lesions using sample radiographs and CBCT images before images analysis. The periapical and CBCT images were evaluated by two examiners (PM and CR) at two-week intervals.All discrepancies were resolved by a consensus between the two examiners.

Determination of pulp and periradicular outcomes

The outcomes of pulp status were categorized as pulp healing and pulp necrosis

• *Pulp healing* was defined by teeth which include all the following criteria: positivity to sensibility test (EPT or thermal) *, absence of tenderness to percussion, absence of sign and symptom of pathosis (abscess, swelling, sinus), together with a radiographic presentation of partial pulp obliteration or continue root formation (in a tooth with incomplete root formation).

* If the teeth showed any radiographic evidence including pulp obliteration or continue root formation, the teeth would be assumed as successful in pulp healing despite having a negative response to the sensibility test.[17]

• *Pulp necrosis* was defined by teeth which radiographically presented periapical radiolucency, and/or infection-related root resorption[18] with or without a response to pulp sensibility test or teeth which did not fulfill all criteria for pulp healing.

The outcome of periradicular status was to be categorized as no resorption, external inflammatory resorption, replacement resorption and external cervical resorption.

• No resorption: A tooth presented physiologic mobility with normal percussion sound. CBCT radiograph showed no sign of resorption or presented surface resorption.[19]

• External replacement resorption (ERR): CBCT radiograph showed an absence of periodontal space together with continuous replacement of loss of root substance with bone and no radiolucency.[20]

• External inflammatory resorption (EIR): CBCT radiograph showed loss of root substance, bowl-shaped resorption with adjacent periradicular radiolucency in bone.[20]

• External cervical root resorption (ECR): CBCT radiograph showed extensive irregular radiolucency extending from the cervical area into the crown and projected over the root canal outline.[21]

Statistical Analysis

Incidences of pulp necrosis and root resorption were reported by descriptive analysis as frequencies and percentages. The comparison of the incidence of each treatment outcome between teeth with incomplete root formation and teeth with complete root formation undergoing extraoral apicoectomy prior to transplantation were investigated by chi-square test or Fisher exact test as appropriate.

Quantitative prognostic factors between each treatment outcome were tested by independent *t*-test or Mann-Whitney U test. Qualitative prognostic factors between each treatment outcome were tested by chi-square

test or Fisher exact test. A *P* value < 0.5 was considered statistically significant. Statistical analysis was calculated using IBM SPSS statistics for Windows, version 22 (IBM, Armonk, New York).

Results

A total of 26 patients with 28 transplanted teeth met the inclusion criteria according to the hospital database from January 2011 to May 2018. Nine patients could not be contacted due to changing phone number or relocation. Seventeen patients with 19 transplanted teeth received follow-up examinations with an additional CBCT radiographs. Nine patients with 10 transplanted teeth were categorized in the teeth with incomplete root formation group, while 8 patients with 9 transplanted teeth were categorized in the extraoral apicoectomized complete root formation group.

The patient's demographic data and tooth variables between the two groups were not significantly different. (Table 1) The average follow-up time of incomplete root and extraoral apicoectomized complete root groups was 6.02 years and 4.72 years, respectively.

Table 1 *Patient's demographic data and tooth variable*

		Incomplete root formation	Extraoral apicoectomized complete root formation	*P*-value[†]
Gender				0.37
	Male	3	5	
	Female	7	4	
Donor tooth type				0.277
	Anterior	0	2	
	Premolar	5	4	
	Molar	5	3	
Donor root type				1
	Single root	6	5	
	Multi root	4	4	
Eruption status				0.981
	Fully erupted	6	5	
	Partial erupted	2	2	
	Unerupted	2	2	
Recipient socket				0.141
	Partially prepared socket	5	1	
	Totally prepared socket	5	8	
Age				0.115
	Mean age	16.6	20.56	
Follow up time				0.153
	Mean	6.02	4.72	

[†]*The chi-square test/Fisher exact test.*

[*]*Significant difference (p<.05).*

The incomplete root formation group presented 40 % (4 of 10) pulp necrosis, while the extraoral apicoectomized complete root formation group presented 77.8 % (7 of 9) pulp necrosis. The outcome of pulp status between the two groups was not statistically different. (Table 2)

The incomplete root formation group presented 10 % (1 of 10) root resorption. The root resorption type was defined as external cervical root resorption (Fig.1), while the external inflammatory root resorption and replacement resorption were not found in this group. The extraoral apicoectomized complete root formation group presented 66.7 % (6 of 9) root resorption. All 5 of 7 pulp necrosis teeth developed external inflammatory root resorption. (Fig.2 and 3) External cervical root resorption was also found in one tooth. (Fig.4) The periradicular status between the two groups was significantly different. (Table 2)

Table 2 *Outcome of pulp and periradicular status*

	Incomplete root formation	Extraoral apicoectomized complete root formation	*P*-value[†]
	n (% of total)	n (%) of total	
Pulp status			0.17
Pulp healing	6 (60%)	2 (22.2%)	
Pulp necrosis	4 (40%)	7 (77.8%)	
Periradicular status			0.02*
No resorption	9 (90%)	3 (33.3%)	
Root resorption	1 (10%)	6 (66.7%)	
Type of root resorption			0.286
External inflammatory resorption	-	5 (83.3%)	
External cervical resorption	1 (100%)	1 (16.7%)	
Replacement resorption	-	-	
Need of endodontic treatment			0.35
No treatment needed	5 (50%)	2 (22.2%)	
Treatment needed	5 (50%)	7 (77.8%)	

[†]*The chi-square test/Fisher exact test.*

[*]*Significant difference (p<.05).*

Figure 1 *Straight on (a.) and horizontal tube shift (b.) periapical radiographs of tooth 28 (left maxillary third molar) transplanted to 36 (left mandibular first molar) area at 9 years follow-up showed pulp obliteration with diffused radiolucent area in the crown. CBCT images (coronal (c.), sagittal (d.) and axial (e.)) exhibited an ECR in the reparative phase*[22]

Figure 2 *Periapical radiographs of teeth in the extraoral apicoectomized complete root formation group with external inflammatory resorption (a.) Tooth 34 (left mandibular first premolar) transplanted to 44 (right mandibular first premolar) area at 4.42 years follow-up (b.) Tooth 14 (right maxillary first premolar) transplanted to 44 (right mandibular first premolar) area at 4.17 years follow-up (c.) Tooth 24 (left maxillary first premolar) transplanted to 34 (left mandibular first premolar) area at 3.75 years follow-up (d.) Tooth 47 (right mandibular second molar) transplanted to 16 (right maxillary first molar) area at 4.67 years follow-up (e.) Tooth 48 (right mandibular third molar) transplanted to 16 (right maxillary first molar) area at 4.08 years follow-up*

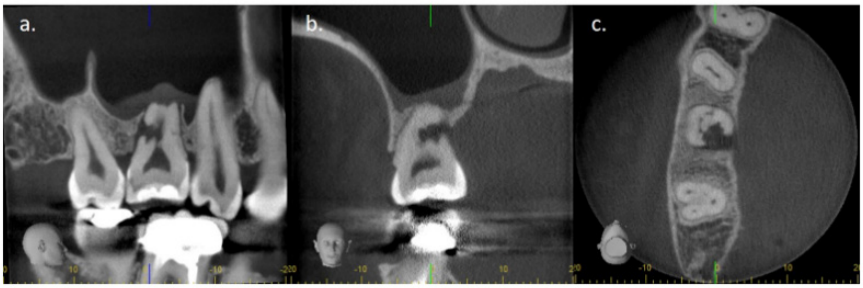

Figure 3 *CBCT radiographs of extraoral apicoectomized complete root formation tooth with external inflammatory resorption. Sagittal (a.) coronal (b.) and axial (c.) images showed extensive external inflammatory resorption. Tooth was indicated to be extracted*

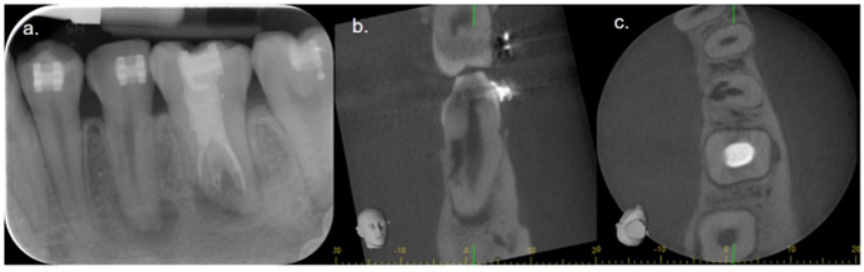

Figure 4 *Periapical radiograph (a.) and CBCT images (coronal (b.) and axial (c.)) of tooth 23 (left maxillary canine) transplanted to replace prolonged left mandibular second primary molar at 5.17 years follow-up. Extensive external cervical resorption was observed. The tooth was indicated to be extracted*

No prognostic factor (patient demographic, donor tooth type, donor root type, stage of root development, recipient socket, cause of tooth loss, eruption status of donor tooth and apicoectomy) was found to be related to pulp outcome, while apicoectomy and recipient socket were found to be related to the periradicular outcome. (Table 3)

Table 3 *Descriptive data and univariate analysis of the relationship between each prognostic factor and outcome of pulp and periradicular status*

Factor	Pulp status		*P*-value†	OR (95% CI)	Periradicular status		*P*-value†	OR (95% CI)
	Pulp healing n (% of total)	Pulp necrosis n (% of total)			No resorption n (% of total)	Root resorption n (% of total)		
Age			1	1.714 (0.228-12.89)			0.617	2.25 (0.308-16.411)
0-20	6 (46.2%)	7 (53.8%)			9 (69.2%)	4 (30.8%)		
>20	2 (33.3%)	4 (66.7%)			3 (50%)	3 (50%)		
Gender			0.059	0.082 (0.007-0.926)			0.074	0.133 (0.016-1.085)
Male	1 (12.5%)	7 (87.5%)			3 (37.5%)	5 (62.5%)		
Female	7 (63.6%)	4 (36.4%)			9 (81.8%)	2 (18.2%)		
Donor tooth type			0.237				0.906	
Anterior	1 (50%)	1 (50%)		reference	1 (50%)	1 (50%)		reference
Premolar	2 (22.2%)	7 (77.8%)		3.5 (0.145-84.694)	6 (66.7%)	3 (33.3%)		0.5 (0.023-11.088)
Molar	5 (62.5%)	3 (37.5%)		0.6 (0.027-13.582)	5 (62.5%)	3 (37.5%)		0.6 (0.027-13.582)
Donor root type			0.181	0.225 (0.032-1.584)			1	1.050 (0.159-6.924)
Single root	3 (27.3%)	8 (72.7%)			7 (63.6%)	4 (36.4%)		
Multiroot	5 (62.5%)	3 (37.5%)			5 (62.5%)	3 (37.5%)		
Eruption status			0.238				0.659	
Fully erupted	3 (27.3%)	8 (72.7%)		reference	6 (54.5%)	5 (45.5%)		reference
Partially erupted	3 (75%)	1 (25%)		0.125 (0.009-1.723)	3 (75%)	1 (25%)		0.4 (0.031-5.151)
Unerupted	2 (50%)	2 (50%)		0.375 (0.035-3.999)	3 (75%)	1 (25%)		0.4 (0.031-5.151)
Stage of root development			0.079				0.064	
Stage 2	2 (100%)	0		reference	2 (100%)	0		reference
Stage 3	4 (57.1%)	3 (42.9%)		0.417 (0.030-5.708)‡	6 (85.7%)	1 (14.3%)		1.167 (0.074-18.346)‡
Stage 4	0	1 (100%)		0.167 (0.006-4.515)‡	1 (100%)	0		0.667 (0.025-18.059)‡
Stage 5	1 (100%)	0		0.667 (0.025-18.059)‡	1 (100%)	0		0.667 (0.025-18.059)‡
Stage 6	1 (12.5%)	7 (87.5%)		0.083 (0.005-1.294)‡	2 (25%)	6 (75%)		0.143 (0.010-1.995)‡
Apicoectomy			0.17	5.250 (0.698-39.476)			0.02*	18 (1.496-216.62)
Yes	2 (22.2%)	7 (77.8%)			3 (33.3%)	6 (66.7%)		
No	6 (60%)	4 (40%)			9 (90%)	1 (10%)		
Cause of tooth loss			0.664	1.667 (0.251-11.071)			1.0	1.5 (0.195-10.032)
Agenesis	3 (37.5%)	5 (62.5%)			5 (62.5%)	3 (37.5%)		
Caries	5 (50%)	5 (50%)			7 (70%)	3 (30%)		
Recipient socket			0.319	0.222 (0.028-1.754)			0.044*	8.0 (0.78-82.052)‡
Partially prepared socket	4 (66.7%)	2 (33.3%)			6 (100%)	0 (%)		
Totally prepared socket	4 (30.8%)	9 (69.2%)			6 (46.2%)	7 (53.8%)		

†*The chi-square test/Fisher exact test.*

**Significant difference (p<.05).*

‡*Haldane's modification23 was used in sets containing zero.*

Discussion

This retrospective study was designed to compare the incidence of pulp necrosis and root resorption between an autotransplanted tooth with incomplete root formation and an autotransplanted tooth with complete root formation which underwent apicoectomy. The period of patient recruitment was from January 2011 to May 2018, due to the homogeneity of treatment protocols, before the involvement of 3D digital printing technology which improved the treatment outcome by facilitating the recipient site preparation, reducing donor tooth extra-alveolar time and avoiding PDL damage.[24] The requirement of the minimum postoperative period of 1 year is indicated because root resorption usually develops within the first year after replantation.[20] No significantly different variable was found between the two group. The average follow-up time for both groups was 5.4 years, which was enough to detect any pathology. However, the recall rate was 70 % due to loss of contact.

The transplantation was performed by residents under the supervision of maxillofacial staff. Although this led to the lack of treatment procedure homogeneity, the main concept of minimizing periodontal trauma and extra-alveolar time was still maintained. All the apicoectomy cases were supervised by KD. A tooth with a cone-shaped root was cut to achieve 1 mm. of apical foramen width, which is believed to facilitate the revascularization process.[6] In some cases, the donor's root length was longer than the recipient socket depth, the donor root had to be cut to fit into the recipient site.

Detection of apical periodontitis can be difficult, if the cortical bone was not involved.[25] Two-dimensional periapical radiograph may not detect bone changes in the cancellous bone due to its lower sensitivity compared to CBCT.[26] Cone beam computed tomography (CBCT) is a three-dimensional imaging technique that has been recommended as an additional radiograph. American Association of Endodontists and American Academy of Oral and Maxillofacial Radiology (AAE and AAOMR) joint position statement has suggested using limited FOV CBCT as an imaging modality for endodontic diagnosis and detection of periapical lesions. The statement has also suggested CBCT imaging in the localization and differentiation of inflammatory resorption defects to determine appropriate treatment and prognosis.[27] CBCT also presented superior accuracy in detecting root resorption than periapical radiograph.[28,29] This study chose the smallest FOV possible, 4x4 cm, that covered anatomical area of interest. Smaller FOV produces higher spatial resolution images with lower radiation doses compared to large FOV.[27] The benefit of using CBCT radiograph in this study is to confirm the diagnosis, type of root resorption and extent of the lesion in addition to periapical radiographs.

Pulp necrosis was found in teeth with a complete root formation which underwent apicoectomy more than in teeth with an incomplete root formation, but was not statistically significant in this study. Root development together with apical foramen diameter were known as important factors related to pulp necrosis.[30] Tooth with apical foramen larger than 1 mm. has a low risk of pulp necrosis.[6] The process of apicoectomy might enlarge apical foramen size and facilitate the ingrowth of connective tissue and blood vessel as seen in the histological study.[11,12] However, from our study, an extraoral apicoectomized tooth still achieved less pulp healing than a tooth with an incomplete root formation. This might be due to the complexity of the autotransplantation procedure. This procedure is a highly sensitive technique with several prognostic factors involved.[31] Factors affecting healing of transplanted teeth include sex[6], age of the patients[6],storage media[32], length of extra-alveolar period[32], stage of root development[7], stage of eruption[7], distance from apical foramen to pulp horn[30], and subsequent orthodontic movement[7]. In addition, stem cells from the apical papilla (SCAP) which are believed to play an important role in the healing process[33] are absent in a tooth with a complete root formation. In the previous clinical study, all the un-complicated single canal autotransplanted tooth (n=4) achieved pulp canal obliteration which was presumed as a sign of pulp healing.[34] The author suggested that the

apicoectomy technique in a single root canal gave promising outcomes.[13] In contrast with our study, 2 teeth that achieved pulp healing were a canine and a molar, while the other single canal tooth developed pulp necrosis. The contrary between the 2 studies might be inconclusive due to the small sample size. However, the previous study did not perform CBCT imaging in all samples, which might affect the interpretation of outcome since CBCT yield additional information.

This study showed the relationship between periradicular status and apicoectomy. Root resorption was statistically higher in teeth with a complete root formation which underwent the apicoectomy than in teeth with an incomplete root formation. The only case of root resorption found in the incomplete root formation group was external cervical root resorption in tooth 28 (left maxillary third molar), which was transplanted to 36 (left mandibular first molar) recipient area. Due to its divergent palatal root and insufficient bucco-lingual bone width, palatal root amputation and MTA retrograde filling were performed extraorally. The patient was unable to complete the follow-up appointment after 7 months. At 9 years follow-up examination, CBCT radiograph classified the resorption as 2Cp according to Patel classification.[35] The surgical procedure was assumed to cause a defect at the cementoenamel junction and initiated the resorptive process. (Fig. 1) The unmatched donor tooth and recipient socket could lead to endodontic complications. This can be prevented nowadays by the use of digitalized approaches such as CBCT, 3D-printed guiding templates and replicas.[24]

A tooth with pulp necrosis in an incomplete root formation group did not show any sign of inflammatory root resorption in contrast to the extraoral apicoectomized complete root formation group. In the latter group, 5 of 7 pulp necrotic teeth presented features of external inflammatory resorption. Four teeth were successfully treated and remained functional, while another didn't attended annual follow up and presented extensive root resorption at 4 years. (Fig. 2) After additional investigation with CBCT, the tooth was extracted. (Fig. 3) The risk of root resorption was found to be related to the increasing stage of root development.[7,36,37] Incomplete formed root is usually covered with thick follicle and required less traumatic force in extraction than a complete formed root with a firm attachment of the periodontal ligament.[7] Damage to the root surface together with inflammatory stimulus from necrotic infected pulp result in external inflammatory root resorption.[38] If the root surface is injured without infection, the repair process by osteoclasts and osteoblasts will replace the radicular dentin with bone which results in external replacement resorption.[39]

Another root resorption case in the extraoral apicoectomized complete root formation group was external cervical resorption. Embedded tooth 23 (left maxillary canine) was transplanted to the recipient site after tooth 75 (left mandibular second primary molar) extraction. The detection of the resorptive lesion was delayed and the tooth was extensively destructed. At 5 years follow-up, CBCT radiograph showed the resorption as 3Ap according to Patel classification[35] After a discussion with the patient's orthodontist, the tooth was extracted. (Fig. 4)

No replacement resorption was found in both groups which was assumed to result from good management of the donor tooth during surgery. The donor tooth was removed with atraumatic surgical technique and handling via its crown to preserve the PDL. The tooth was also kept in its socket during the recipient site preparation with minimal extra-alveolar time. Replacement resorption is known for its relation to the extra-alveolar period and dry storage.[32]

Due to the limitation of the retrospective study design, information about the surgical period, extra-alveolar time and storage media were not recorded. Another limitation of this study is the small sample size because apicoectomy is a novel technique in autotransplantation.[13] The incidence of pulp necrosis, root resorption and the analysis of the relationship between each prognostic factor may have a large proportion difference between the two groups, but not statistically significant due to the limitation of the small sample size. We suggest further

prospective cohort studies with a larger sample size and 3D printing technology which facilitate the surgical procedures, reduce complications from surgical techniques and control other confounding factors.

Interestingly, the recipient socket was another factor that was found to be associated with root resorption. The recipient socket was prepared slightly larger than the donor tooth by an implant drill kit or an external cooling bur. The donor tooth was periodically placed into the socket with light pressure to ensure proper fit. All teeth presented with root resorption were founded in a totally prepared socket. A tooth that was transplanted into a freshly extracted socket with partial preparation demonstrated a better outcome compared to socket preparation from the edentulous area or primary tooth extraction. Assuming some vital PDL might still be present in the former socket. Despite the importance of PDL viability on the root surface, PDL on the socket wall also facilitated the healing process as seen in the animal studies.[40,41] However, the amount of remaining PDL in a partially prepared socket in this study was inconclusive due to a lack of data.

Even though some extraoral apicoectomized complete root formation autotransplanted teeth successfully healed without any complication. This method showed more undesirable outcomes than teeth with incomplete root formation. Our study found that 80 % of an extraoral apicoectomized group without presurgical/ postsurgical root canal treatment needed more additional endodontic treatment subsequently than teeth with incomplete root formation due to pulp necrosis and root resorption, but not statistically significant. (Table 2) Root canal treatment performed in the canal with wide apical foramen or root resorption is complicated. Therefore, we suggest that extraoral apicoectomized transplanted teeth should be closely followed up.

Conclusion

Autotransplanted teeth with complete root formation undergone extraoral apicoectomy increased the risk of root resorption than autotransplanted teeth with incomplete root formation. In addition, the development of root resorption was related to a totally prepared recipient socket, which had no periodontal ligament.

Acknowledgements

This study was supported by a grant from the Faculty of Dentistry, Chulalongkorn University. The authors thank Dr. Soranun Chantarangsu and Dr.Pagaporn Pisarnturakit for statistical advice and the Faculty of Dentistry, Chulalongkorn University for research funding. The authors denied any conflicts of interest related to this study.

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