Clinical Outcomes and Failure Analysis of Intentional Replantation Using Fast-setting MTA and Atraumatic Extraction Forceps

: A Retrospective study

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보존과 수련 2년 동안 언제나 따뜻한 마음과 진심으로 가르쳐 주셨던 조신연 교수님과 신보경 교수님께 존경과 감사의 마음을 전합니다. 부족한 3년차지만 늘 관심을 가지고 따뜻하게 격려해 주시며 가르침을 주시는 송민주 교수님께도 감사와 존경의 말씀을 드립니다. 교수님들께 배울 수 있어 영광이었습니다.

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Complications of intentional replantation are mostly due to inadequate setting of MTA (mineral trioxide aggregate) or extraction trauma. In order to reduce failure rates due to recurrent inflammation and root resorption, fast-setting MTA (RetroMTA®) and atraumatic extraction forceps can be used during the procedures. The purpose of this study is to retrospectively evaluate the success rate of intentional replantation on teeth when these protocols were applied. Based on the analysis, this study also suggests additional considerations that may increase the success rate of intentional replantation and identifies prognostic factors that may influence treatment outcomes in the current clinical setting.

This retrospective study included 77 permanent teeth from 75 patients, who were treated intentional replantation by a single operator between January 2017 and December 2022. Based on predetermined exclusion criteria, 26 teeth were excluded from the study, and 11 teeth were lost to follow-up within one year, leaving a total of 40 teeth to be analyzed for clinical and radiographic evaluation. Interexaminer reliability for radiographic evaluation was substantial at k = 0.626 ($p<0.001$).

The mean follow-up period was 2.43 years, excluding failure cases, with failure presenting at a mean of 1.55 years postoperatively. The success rate of the treatment was 82.5% (complete 26 cases, incomplete 8 cases) according to Molven et al (1987), and the survival rate of teeth that were not extracted at follow-up was 95.0%. In this study, 36 out of 40 cases (90%) were treated within 15 minutes. In this study, there was no apical leakage due to unset MTAs among failure cases, and only 1 (2.5%) tooth extraction due to root resorption.

Keywords : Intentional replantation, outcome, failure, success rate, single operator, fast-setting MTA, atraumatic extraction forceps

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I. Introduction

As various treatment methods and dental materials for patients with apical periodontitis become available, the success rate of nonsurgical root canal treatments has significantly improved. It remains clear that both the recurrence of periapical lesions and the limitations inherent to nonsurgical root canal treatments persist. If previous treatment fails, surgical endodontic treatment such as apicoectomy or intentional replantation may be considered as a follow-up treatment prior to extraction and prosthetic treatment (Cho, 2017). The prognosis of surgical endodontic treatment is determined by a variety of factors, and predicting success rates is not straightforward given the diversity of treatment methods and tools.

Intentional tooth replantation allows for the extraction of the tooth and examination of the root surface under a microscope to identify any fractures or congenital dental anomalies that could not be accessed via conventional root canal treatment or apicoectomy, offering a relatively advantageous condition for treatment. Especially for mandibular second molars, intentional replantation is generally chosen over apicoectomy because of the thick buccal bone, difficult access, and proximity to the mandibular canal. It is also easier and more cost-effective to perform than other treatments. However, the disadvantages include the possibility of fracture of the crown or root during the extraction process and the potential for root resorption after replantation (Bender, 1993).

In a study that applied the contemporary protocol to intentional replantation, examining its success and survival rates, a 12-year cumulative retention rate of 93% and a healed rate of 77% after 3 years were reported (Cho, 2016). Additionally, a meta-analysis of studies with a minimum of 2 years follow-up showed an 88% survival rate (Torabinejad, 2015). Previous research on prognostic factors for intentional replantation indicated significant correlations between lower success rates and variables such as extraoral time, as well as the use of ProRoot MTA® for root-end filling (Jang, 2016). It was revealed that an extraoral time of less than 15 minutes acts as a predictor for complication-free healing, and the use of ProRoot MTA® significantly contributes to complications, such as persistent or increased periapical radiolucency (Cho, 2017).

Meanwhile, previous studies have indicated that using conventional extraction forceps could potentially damage the root surface during the extraction process, and the force applied by the beaks of the forceps could lead to a risk of tooth fracture. Loss of cementoblasts on the root surface can precipitate root resorption at the affected area (Oikarinen, 1996). Meanwhile, trauma-induced damage to the periodontal ligament (PDL) may lead to an exacerbated healing response, facilitating accelerated osteogenesis and raising the likelihood of ankylosis on the tooth surface (Oka, 2022).

Therefore, in earlier studies, there have been efforts to prevent traumatic extraction by loosening the periodontal ligament prior to extraction. Choi achieved occlusal contact space and orthodontic extraction using brackets and wires before extraction (Choi, 2014). Regev used elastic bands placed in the cervical region, in which the bands slide from a wide cervical to a narrower apical diameter, disrupting the periodontal fibers and causing the tooth to erupt without direct impact on the bone (Regev, 2008).

Moreover, the use of biocompatible material, such as Mineral Trioxide Aggregate (MTA), for retrofilling is a critical step in preventing the recurrence of inflammation. However, if the MTA is slow to set, it can increase the risk of the material being washed out before it hardens. Kim showed that the type of calcium silicate-based material, especially the initial setting time, affects the outcome of endodontic microsurgery (Kim, 2020). This study suggested that the use of fast-setting materials should be considered in complex clinical situations where a rapid initial setting of the material is required.

Therefore, the purpose of this study is to retrospectively evaluate the success rate of intentional replantation on teeth when the protocol is applied to improve failures due to inflammation recurrence caused by MTA setting problems and failures due to root resorption caused by extraction trauma. Based on the analysis, this study also suggests additional considerations that may increase the success rate of intentional replantation and identifies prognostic factors that may influence treatment outcomes in the current clinical setting.

Ⅱ. Materials and Methods

2.1. Subjects

This study protocol was approved by the Institutional Review Board (IRB) of National Health Insurance Service Ilsan Hospital (IRB 2023-11-033-001). The study included patients who had been treated with intentional replantation by a single operator (SY Cho) between January 2017 and December 2022.

2.2. Exclusion Criteria

This study excluded teeth (i) that were extracted using only conventional extraction forceps or had slow-setting MTA applied during root-end filling, (ii) with significant preoperative periodontal disease, characterized by a probing depth of ≥6mm at two distinct sites on the tooth or displayed +2 mobility (mobility over 1mm) (iii) that diagnosed as a cracked tooth before treatment or a cracked line was discovered during the surgery, (iv) that was treated for reasons not related to endodontic problems (dental caries, root resorption, palatal groove, perforation), and (v) from patients who were followed up for less than 1 year.

2.3. Fast-setting MTA & Atraumatic extraction forceps

In this study, RetroMTA® (bioMTA, Seoul, South Korea, Fig. 1) was selected that is a fast-setting MTA with an initial setting time of approximately 3 minutes, as the root-end filling material. This is in contrast to the conventional ProRoot MTA® (Dentsply, Tulsa, OK), which has an initial setting time in excess of 1 hour (70-74 minutes). Therefore, RetroMTA® is expected to provide more favorable results in surgical settings where bleeding contamination is a challenge.

✓ **Composition :** $CaCO_3$, SiO_2, Al_2O_3, hydraulic Ca–Zr complex

Figure 1. RetroMTA® (bioMTA, Seoul, South Korea)

For the tooth extraction, we used Dental USA's Power Elevators (Fig. 2), atraumatic forceps with a bumper-equipped beak. It works on a first-class lever principle, with one beak placed on the cervical region of the tooth and the bumper placed on the mucosa above the mucogingival junction (MGJ on the opposite side of the tooth to facilitate atraumatic extraction. This technique applies rotational force without compression, maintaining the distance between the beaks. Repeat this motion gently several times on the opposite side to luxate the tooth out of the socket. The use of these forceps has the advantage of increasing the likelihood of preserving the surrounding tissue and bone and reducing postoperative discomfort. On the other hand, the force of pressing the mucosa with the bumper may cause the mucosa to be bruise, wounded or torn, so prior notice is required and additional sutures may be necessary in case of laceration.

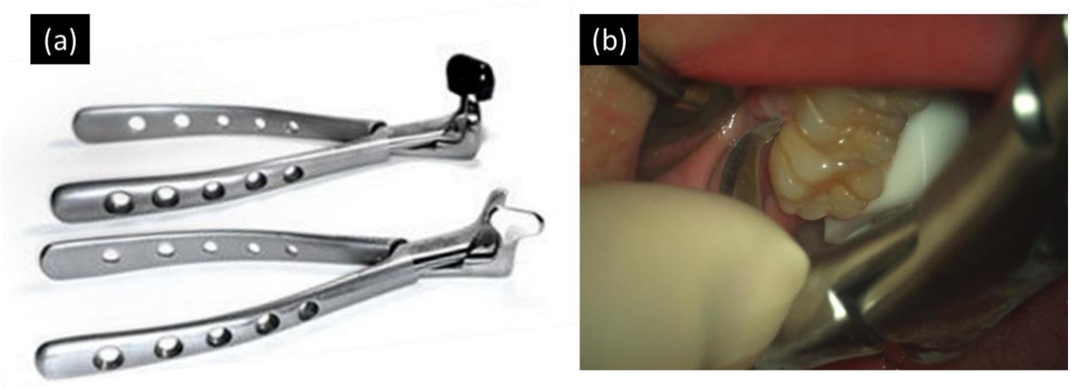

Figure 2. Atraumatic extraction forceps (a) Dental USA's Power Elevators (Dental USA, State of Illinois, USA), (b) The intraoperative use of the forceps

2.4. Treatment Procedure

All treatments were performed under a dental microscope (OPMI PICO; Carl Zeiss, Göttingen, Germany) by a single operator (SY Cho). Local anesthesia was administered using either lidocaine (1:80,000 epi.) or articaine (1:100,000 epi.) according to a predefined protocol, and the surgical site was disinfected with povidone iodine. All procedures were performed in sterile conditions. Teeth were carefully extracted using atraumatic extraction forceps (Power Elevators, Dental USA, State of Illinois, USA), followed by curettage of the extracted area and any granulation tissue, irrigation with saline, and then application of clean gauze to the extraction site. Subsequently, the root is examined under a microscope to check for any cracked lines or other defects. To avoid damaging the PDL, the root is wrapped in wet gauze, holding the end of the gauze to prevent applying pressure to the PDL during the treatment process. After identifying a point 3mm from the apex with a periodontal probe, root end resection is performed using a thin tapered diamond bur. This bur is also employed to remove 3-4mm of the GP cone from the canal, with careful attention to maintaining the integrity of the canal path. Then, irrigation and suction is performed on the extraction socket with saline solution before repositioning the tooth, and buccal bone plate is compressed. Depending on how firmly the tooth is fixed, the procedure may either proceed with gauze biting alone or require additional measures such as suturing or RWS (resin wire splint, flexible 03 SS wire). Postoperative periapical radiographs were taken to assess the repositioned tooth.

2.5. Outcome assessment

In this retrospective study, factors that may affect surgical outcomes were categorized into preoperative, intraoperative, and postoperative factors; Preoperative factors (Sex, Age, Jaw, Tooth position, Periapical radiolucency, Nonsurgical RCT quality, Preoperative symptom (percussion, mobility, periodontal pockets (≥6mm), Sinus tract), Preoperative RCT complication, MTA absorption), intraoperative factors (Tooth extraction time, Extraoral time), postoperative factors (Adequacy of MTA filling, Splinting). All data were extracted from clinical charts, surgical videos, and intraoral photographs.

In the preoperative factor, Barone reported a significantly higher healing rate of 84% in patients older than 45 years of age who underwent apical surgery, compared to

68% in younger patients (Barone, 2010). Based on this, a 45-year-old age factor was used. Number of roots included C-shaped canals in the 1 root category, and non-surgical RCT quality was determined as adequate/inadequate by considering density and length according to the RCT status at the last follow-up. In preoperative symptom, mobility was categorized as +1 degree of “present”, because teeth with mobility of +2 degrees or more were excluded. Periodontal pocket was categorized as present if it was 1 point, as teeth with more than 2 pockets of 6 mm or more were excluded. Preoperative RCT complication was categorized as present if there was a post/fracture file in the root canal or blocked pulp/overfilling.

In the intraoperative factor, several studies divided the extra-oral time into 15 minutes before and after and found significant differences(Jang, 2016, Cho, 2016). Therefore, we also divided extraoral time into 15 minutes. Few studies compared extraction time as a prognostic factor, and the median of 3 minutes was used to categorize the group.

Adequacy of MTA filling was determined by clinical photographs of apical cross-section after MTA filling taken intraoperatively, and in 2 cases out of 40 cases without clinical photographs, MTA density on periapical radiographs was unavoidably determined. Postoperative splinting was categorized as present if suture or resin-wire splinting was performed. Suture and resin-wire splinting was performed in four cases each for teeth lacking initial retention, and due to the small number of cases, both were categorized as “present” (Table 1).

Table 1. Categories of independent variables

Parameters	Categories	Explanation
Preoperative		
Age(y)	≤45 >45	
Sex	Men Women	
Jaw	Mx Mn	
Tooth position	Anterior Premolar Molar	
Periapical radiolucency	Absent Present	
Sinus tract	Absent Present	
Nonsurgical RCT quality	Adequate Inadequate	
Preoperative percussion	Absent Present	
Preoperative mobility	Absent Present	
Preoperative periodontal pockets (≥ 6mm)	Absent Present	Only 1 point was included and more than 2 points were excluded.
Preoperative RCT complication	Absent Present	"Present" category included post, fractured file, blocked pulp, and overfilling.
Intraoperative		
Tooth extraction time (minute)	< 3 ≥ 3	
Extraoral time (minute)	< 15 ≥ 15	
Postoperative		
Adequacy of MTA filling (clinical photo)	Adequate Inadequate	
Splinting	Absent Present	"Present" category included suture and resin-wire splint.

Clinical records and radiographs were used for evaluation of the cases. All of the patents were scheduled for postoperative follow-up check at 1, 3, 6 and 12 months and annually thereafter. And the patients who did not show at scheduled date were contacted by phone and rescheduled. On the every recall date, patients were performed clinical examination (symptoms or loss of function, tenderness to percussion, subjective discomfort, mobility, sinus tract formation, periodontal probing, postoperative complications) and radiographic examination (periapical view; size of periapical radiolucency, continuity of lamina dura, evidence of external root resorption).

Radiographic healing was performed by 2 examiners (K.Y.J & S.J.H) using the evaluation criteria supposed by Molven et al, 1987 (Table 2, Fig. 3) :

Table 2. Evaluation criteria for radiographic healing proposed by Molven et al.

Group	Radiographic signs
1. Complete healing	Normal remodeling of the periodontal space and lamina dura to complete bone repair with only a minor change in density or unremarkable periapical periodontal space.
2. Incomplete healing	Scar tissue; Decreased rarefaction in size or stability; the presence of internal bone structure, irregular periphery with a compact bony border, asymmetrical location around the apex, and angular connection to the periodontal space.

3. Uncertain healing	Decreased rarefaction; radiolucency greater than twice the width of the periodontal space, lamina-dura-like borders, circular or semicircular periphery, symmetrical placement around the apex with funnel-shaped periodontal space expansion, and identifiable bone structure within the cavity.
4. Unsatisfactory healing	Enlarged or unchanged rarefaction.

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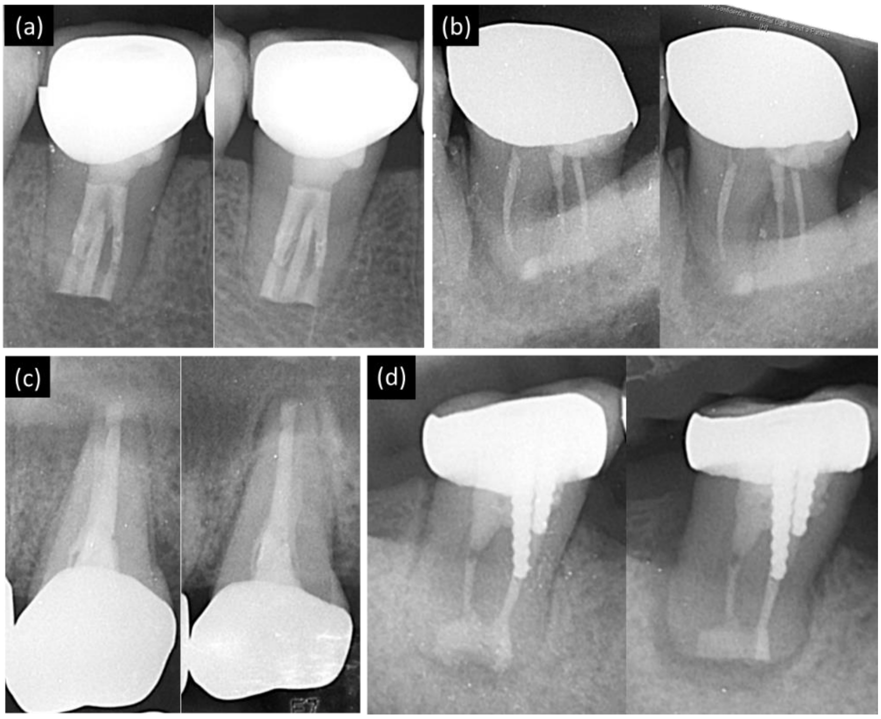

Figure 3. Representative periapical radiographs for each Molven Criteria; (a) Molven 1. Complete healing in tooth #46, (b) Molven 2. Incomplete healing in tooth #37, (c) Molven 3. Uncertain healing in tooth #27, (d) Molven 4. Unsatisfactory healing in tooth #37

Outcome evaluation was categorized as success or failure. Success was defined as the absence of clinical signs and symptoms, accompanied by either complete or incomplete healing, as evidenced radiographically. Failure was judged as the presence of any clinical signs or symptoms, or uncertain or unsatisfactory radiographic healing.

2.5. Statistical analysis

To determine the impact of various factors on the success rate, two-variate analysis was performed using both the chi-square test and Fisher's exact test. Interexaminer reliability was measured using Cohen's kappa statistics in accordance with Landis and Koch (Landis, 1977). All statistical evaluations were performed using SPSS software version 24 (IBM Corp., Somers, NY, US), and results were considered significant level of 0.05.

III. Results

This retrospective cohort study included 77 permanent teeth from 75 patients. Based on predetermined exclusion criteria, 26 teeth were excluded from the study, and 11 teeth were lost to follow-up within one year, leaving a total of 40 teeth to be analyzed for clinical and radiographic evaluation.

3.1. Clinical outcome & prognostic factor

Of 51 patients, 11 were not followed up for 1 year and were not included in this analysis (recall rate 85.7%). The mean follow-up period was 2.43 years, excluding failure cases, with failure presenting at a mean of 1.55 years postoperatively. The follow-up period for all patients ranged from 4 months to 5.6 years. The success rate of treatment was 82.5% (complete 26 cases, incomplete 8 cases) according to Molven, and the survival rate of teeth that were not extracted at follow-up was 95.0% (Fig. 4). In this study, 36 out of 40 cases (90%) were treated within 15 minutes, with a range of 4 to 16 minutes (mean 10.9 minutes), considering the extraoral time (under 15 minutes) mentioned as a prognostic factor in previous studies. When evaluating Molven scores, interexaminer reliability was substantial agreement at k = 0.626 ($p < 0.001$).

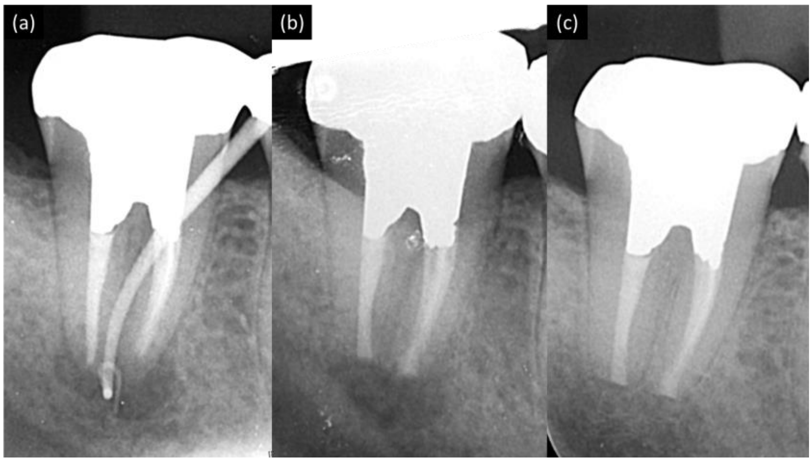

Figure 4. Successful case after intentional replantation of #47

Table 3. Two-variate analysis of success rates depending on prognostic factors

Parameters	N	Success Rate	*p value**
Age(y)			1.000
≤45	18	83.3%	
>45	22	81.8%	
Sex			**0.033**
Men	15	100%	
Women	25	72%	
Jaw			0.432
Mx	17	76.5%	
Mn	23	87.0%	
Tooth position			0.198
Anterior	1	0%	
Premolar	2	100%	
Molar	37	83.8%	
Periapical radiolucency			1.000
Absent	4	100%	
Present	36	80.6%	
Sinus tract			0.679
Absent	26	84.6%	
Present	14	78.6%	
Nonsurgical RCT quality			0.211
Adequate	22	90.9%	
Inadequate	18	72.2%	
Preoperative percussion			0.681
Absent	16	87.5%	
Present	24	78.2%	

Preoperative mobility			1.000
Absent	36	80.6%	
Present	4	100.0%	
Preoperative periodontal pockets (≥6mm)			1.000
Absent	26	80.8%	
Present	14	85.7%	
Preoperative RCT complication			0.691
Absent	25	80.0%	
Present	15	86.7%	
Tooth extraction time			1.000
< 3	23	82.6%	
≥ 3	17	82.4%	
Extraoral time (min)			0.134
< 15	36	86.1%	
≥ 15	4	50.0%	
Adequacy of MTA filling (clinical photo)			0.448
Adequate	37	83.8%	
Inadequate	3	66.7%	
postoperative splint			0.128
Absent	32	87.5%	
Present	8	62.5%	

p value* was calculated from Fisher's exact test.

3.2. Analysis of Failure (7 cases)

The following is an analysis of the failed cases. A total of 7 failed cases were analyzed, 6 cases with follow-up treatment and 1 case without follow-up treatment. All tooth numbers are written using the two-digit system prescribed by the Fédération Dentaire Internationale (FDI).

[Case 1]

The first case involved tooth #22, a dens invaginatus that had a history of apicoectomy by another operator in our clinic 2 years ago, which subsequently developed a sinus tract. After the intentional replantation, only discoloration was observed up to 2.5 years of follow-up, but periapical radiolucency (PAR) increased slightly in the third year. Therefore, endodontic treatment (RCT) was performed as a follow-up treatment. One year and nine months after the RCT, the tooth was considered healed, and follow-up was terminated. The failure of the operation is due to a missed lateral canal, which was identified on preoperative CBCT axial view (Fig. 5).

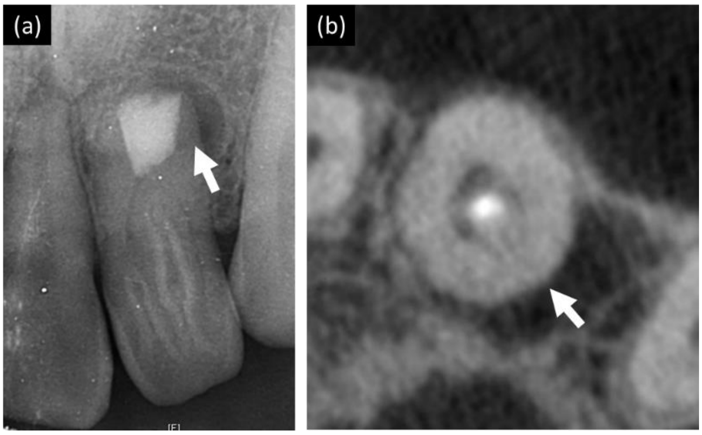

Figure 5. Detection of missing lateral canal of #22 (a) Periapical view (b) Axial view of cone-beam CT

[Case 2]

The second is tooth #36. This patient was referred to our hospital from L/C for tingling pain when touched, and initially started RCT because of discomfort with hot and cold stimulation. Afterward, root canal treatment was continued at our clinic, but the symptoms remained, so intentional replantation was planned. Immediately after treatment and until the 4-month follow-up, the patient was said to be able to masticate only soft food (ex. tofu), and pain recurred in both percussion and bite test. Therefore, re-treatment with intentional replantation was planned. During re-treatment, it was found that the isthmus of the distal root remained.

Figure 6 is from the re-treatment, along with a review of the operative findings, led to the presumption that the residual distal root isthmus was the source of the symptoms.

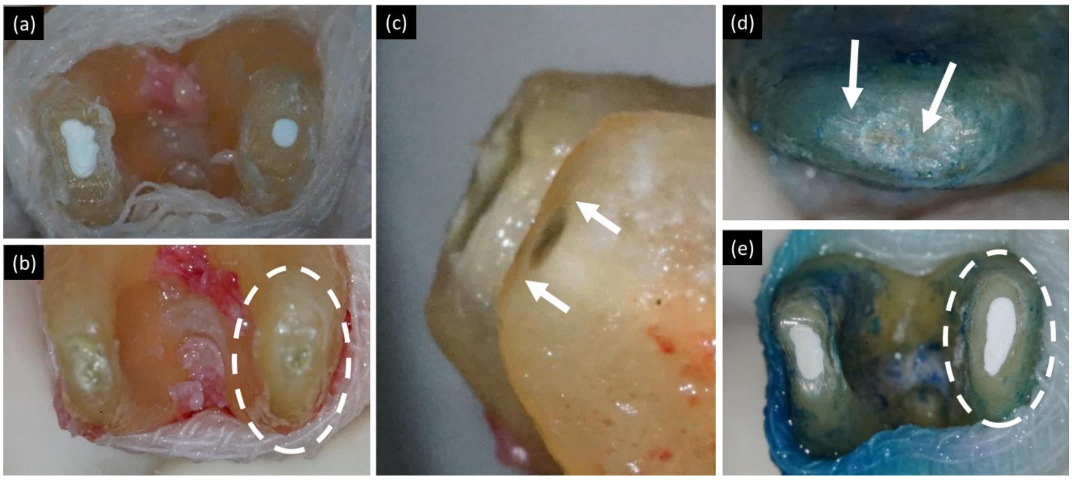

Figure 6. Intentional replantation on #36 (residual isthmus; white arrows); (a) initial intentional replantation; MTA filling, and (b) re-intentional replantation; pre-treatment status, (c) residual isthmus on distal root apex, (d) methylene blue staining, (e) residual isthmus removal and MTA filling.

[Case 3]

The third case presented with tooth #27, where the patient arrived complaining of spontaneous throbbing pain and discomfort while chewing. Periapical radiolucency (PAR) was noted. After the operation, the patient experienced no discomfort up to the 4-month follow-up, after which they were lost to follow-up.

At 3 years and 5 months postoperatively, the patient revisited, reporting that tooth #27 had begun throbbing painfully 3-4 days prior, with spontaneous pain and discomfort upon mastication. Upon examination, gingival swelling, pain upon percussion, increased discomfort with mastication, and enlarged PAR were observed, leading to the decision to extract the tooth. Pre-extraction CBCT images are available for diagnosis.

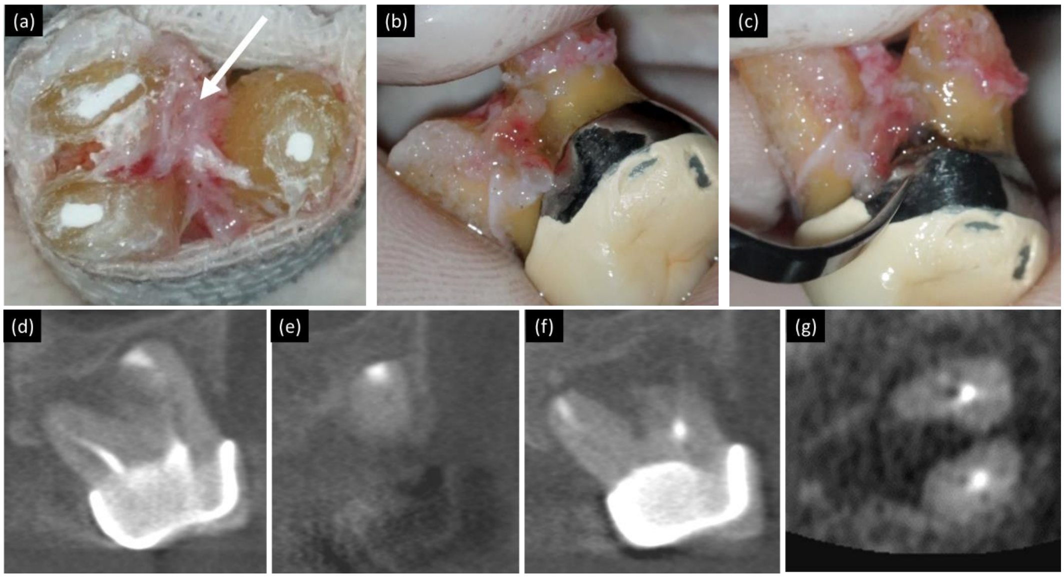

Figure 7. (a)~(c) : Extracted tooth and Diagnosis CBCT image (before extraction-bone healing of apex and bone loss on furcation) on #27; (a) furcation (granulation tissue; white arrow) (b) mesial (c) distal view, (d)~(g) : Diagnosis CBCT image; (d) mesio-buccal root apex (e) disto-buccal root apex (f) palatal root apex (g) furcation.

Observing the healing pattern, bone healing at the apex area can be confirmed (Fig 7). At the time of replantation, the furcation area had granulation tissue in place of the septum bone, suggesting the possible existence of an additional canal in this area. Therefore, the failure is presumed to be due to an additional canal in the furcation area. The reason for the missing structure is likely due to the fact that granulation tissue was not removed during replantation, preventing thorough inspection.

[Case 4]

The fourth case involved tooth #26, where the patient presented with a complaint of a pimple-like lesion, and a sinus tract was observed. For up to 5 months postoperatively, the patient reported a persistent sensation of swelling, although the periapical radiolucency (PAR) appeared to be diminishing.

The patient returned after 8 months due to the development of a new sinus tract. A plan for re-treatment through intentional replantation was made. During re-treatment, the MTA settings were good from the previous surgery, so the MTA was well maintained and does not scratch when scratched with explorer (Fig. 8(a)~(b)). Therefore, it was thought that there was another cause for the recurrence of inflammation, so the root groove area was also prepared and filled with MTA (Fig. 8(c)~(d)). The patient has been using the tooth without discomfort for 1.5 years.

The failure was presumed to be due to an additional canal in the root groove area causing apical leakage. In retrospect, the presence of additional canals could have been confirmed with methylene blue staining during the initial treatment.

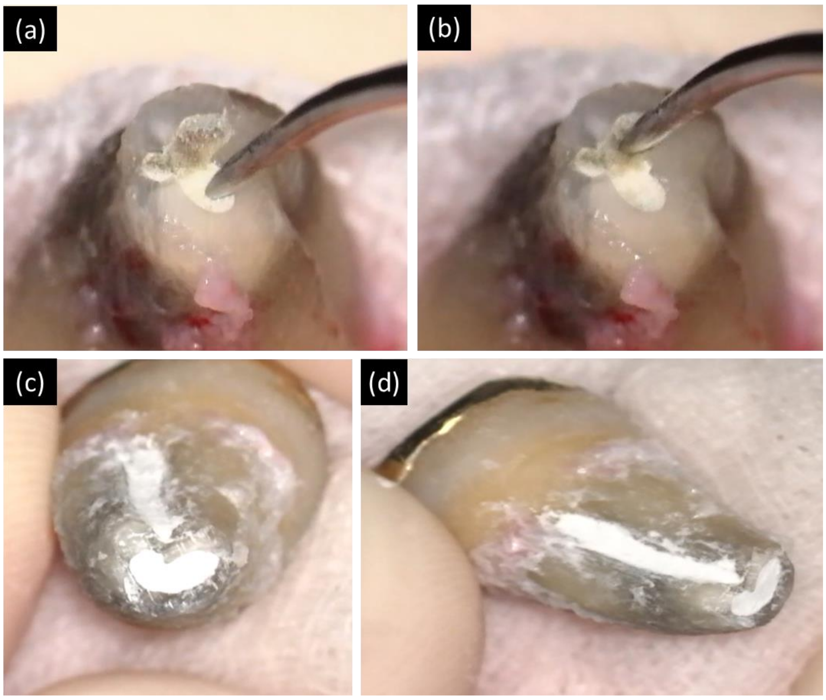

Figure 8. Re-intentional replantation on #47; (a)~(b) : The MTA filling from the previous surgery is well maintained and did not scratch when scratched with the explorer. (c)~(d) : MTA filled in the apex and root groove

[Case 5]

The following case involves tooth #48, where the patient presented with a complaint of a noticeable protrusion on #48 buccal gingiva, and a sinus tract was observed upon clinical examination. From immediately after treatment to the 10-month follow-up, the patient consistently reported discomfort while chewing, along with persistent percussion pain and PAR remaining evident. Starting from the 10-month check, a +2 mobility was noted, leading to a diagnosis of the tooth as hopeless and the decision for extraction.

Radiographic observation in the periapical view showed root resorption (Fig. 9(a)~(d)), and 8it is speculated that this occurred in the area where, during replantation, the root was locked in the alveolar bone and subjected to pressure, as seen in video videos of the surgery (Fig. 9(e)~(i)). Therefore, it is hypothesized that damage to the PDL from pressure during replantation led to the root resorption.

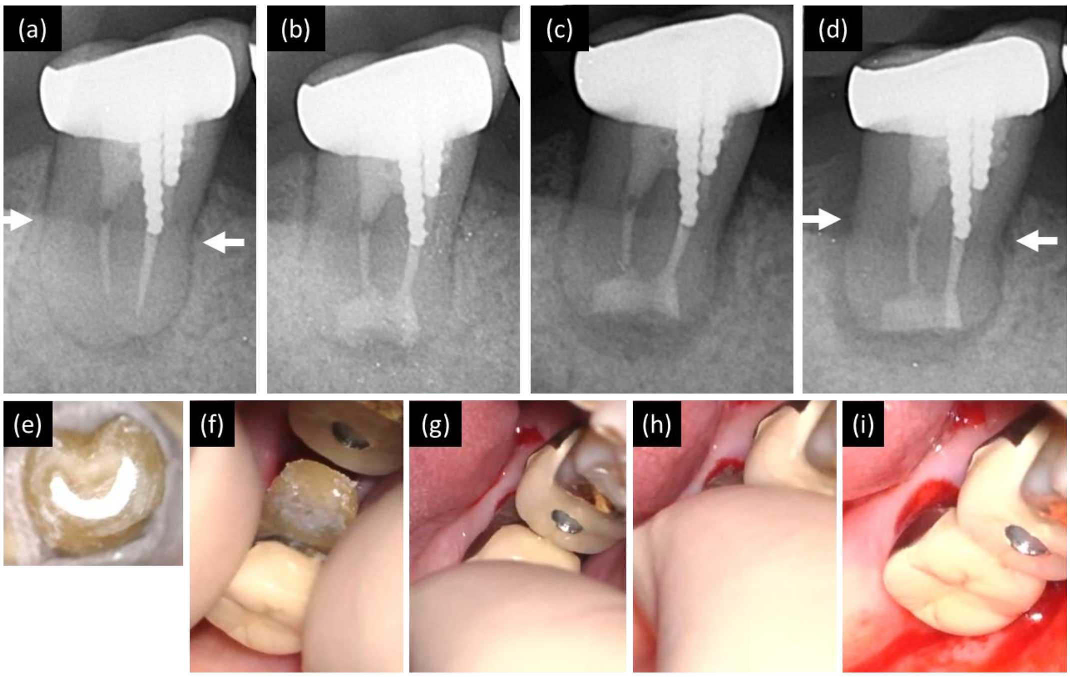

Figure 9. (a)~(d) Periapical view on #47; (a) Preoperative (b) Immediately after surgery (c) 1 month follow-up (d) 10 months follow-up (failure), external root resorption (white arrows). **(e)~(i) Root-end filling and repositioning on #47;** (a) Successfully performed root-end filling with MTA, (b) Insertion of tooth, (c) The root that locked in the alveolar bone, (d) Finger press, and (e) Tooth in place

[Case 6]

The 6th patient presented with the complaint that 'Tooth #17 throbs even when still and hurts too much to chew,' and severe percussion pain and pain upon chewing were reproduced.

The symptoms were absent for up to 2 months after treatment, but after 9 months, the patient complained of night pain and pain upon percussion and chewing. The PAR had decreased, so a check-up was planned for 1 week later. At the next visit, no clinical signs were observed, leading to a decision to check again in 3 months, at which time a sinus tract was observed, prompting a plan for re-RCT. The patient has been in follow-up for 10 months after subsequent treatment, with no change in the size of the PAR, but it appears to be incomplete healing.

Surgical photos of replantation (Fig. 10(a)~(c)) show that granulation tissue was observed in the furcation and mid 1/3 area after extraction, but only the furcation area was removed, and the rest was replanted as is. There appears to be the possibility of additional canal in the area, which may have caused the lesion to recur due to apical leakage.

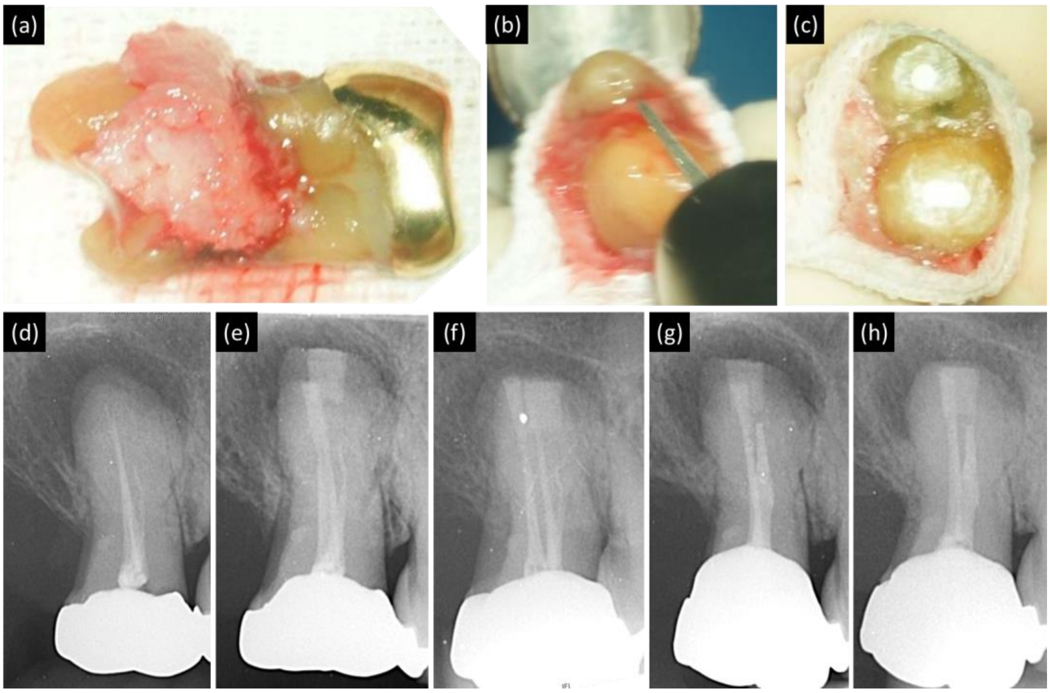

Figure 10. Intentional replantation on #17; (a) Pre-treatment state (Granulation tissue was observed in the furcation and mid 1/3 area), (b) Root end resection, and (c) Just before repositioning (Only the granulation in the furcation area was removed and the remaining granulation in the mid 1/3 area was left intact. (d)~(h) Periapical view on #17; (d) Preoperative, (e) Immediate postoperative, (f) 9-month follow-up, (g) 1-year follow-up (Increased PAR), and re-RCT (h) 9-month follow up (incomplete healing)

Figure 10(d)~(h) are periapical radiographs. The preoperative lesion is visible, and up until the 9-month check post-surgery, the lesion appeared to have reduced in size.

However, at the 1-year check, an increase in the size of the lesion was confirmed. After re-RCT, bone healing was observed.

[Case 7]

This is the last case, where symptoms persisted but no additional treatment was provided. The patient presented with complaints that 'tooth #36 has been hot and throbbing with pain even when still for the past 3 days.' Percussion pain was present, and a periapical radiolucency (PAR) was observed on CBCT. From immediately after treatment to the 1-year and 8-month follow-up, the patient reported an improvement over the initial condition but mentioned an inability to chew comfortably, although there were no records of percussion pain or pain upon chewing. At the 1-year and 2-month follow-up, tenderness in both masseter muscles suggested myofascial pain, and the patient was instructed on masseter muscle massage, but records indicate no improvement in symptoms. The patient was informed that further symptom improvement was unlikely, and follow-up was concluded. Based on photographic records (Fig. 11) from the time of the replantation surgery, it is presumed that symptoms persisted due to the residual isthmus between the buccal and palatal canals.

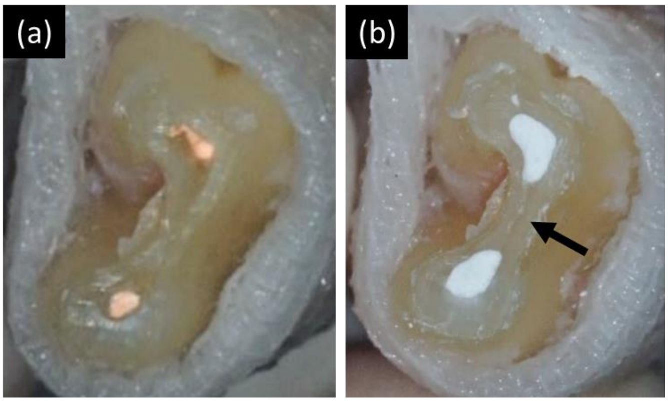

Figure 11. The residual isthmus between the buccal and palatal canals (black arrow).

Failure was analyzed in 6 cases with subsequent treatment and 1 case without subsequent treatment (Table 4). There were 3 main causes of failure, among which root resorption was 1 case, and the incidence of root resorption accounted for 2.5% of the total 40 cases. The remaining 6 cases can be considered as failures due to the presence of undetected structures. Among them, there were 4 cases of failure related to presumed additional root canals, three of which were root furcation and root groove sites, which were difficult to control intraoperatively. Failure to remove granulation tissue of the furcation site and failure to use methylene blue were considered as improvements. Residual isthmus was present in 2 cases, which may be the cause of persistent pain after the procedure, and the use of methylene blue may also be recommended.

The average time to failure was 1.55-year, including only those cases that were subsequently treated. Three cases were uncomfortable from the immediate postoperative period until failure, and a total of four cases failed within one year, including one case that complained of discomfort from 6 months after surgery. One case that was not subsequently treated also complained of discomfort from the immediate postoperative period. The remaining 2 cases had failures after 3 years. Although this study is limited by the small total number of teeth treated, we could recommend a minimum follow-up period of 1 year.

It is a classification of the 6 cases that received subsequent treatment. They are divided into 2 cased each for RCT or re-RCT, re-replantation, and extraction. Based on this, the survival rate, considering extraction as the outcome, can be viewed as 95%.

Table 4. Information of failure cases

Order	Sex	Age	Tooth	Cause of failure	Discomfort	Time to Failure	Subsequent treatment
1	16	F	#22	Lateral canal	3-year	3-year	Root canal treatment
2	56	F	#36	Residual isthmus	Immediately after surgery	4-month	Re-intentional replantation
3	56	F	#27	Possibility of Additional canals (Furcation site)	3.5-year	3.5-year	Extraction
4	26	F	#47	Possibility of Additional canals (Root groove area)	Immediately after surgery	8-month	Re-intentional replantation
5	61	F	#48	Root resorption	Immediately after surgery	10-month	Extraction
6	60	F	#17	Possibility of Additional canals (Residual granulation tissue on furcation)	6-month	1-year	Re-root canal treatment
7	43	F	#36	Residual isthmus	Immediately after surgery	(Survival)	No additional treatment

IV. Discussion

4.1. Atraumatic extraction forceps

In intentionally replanted teeth, root resorption and ankylosis due to periodontal ligament damage is a major cause of failure (Messkoub, 1991). Most of the previous studies have focused on cases extracted using conventional extraction forceps. Cho reported that out of 159 teeth that treated intentional replantation, 5 cases (5.7%) were extracted due to root resorption (Cho, 2016). In this study, 1 (2.5%) of the failure cases were due to root resorption. This is a significantly lower rate compared to previous studies.

Conventional forceps consist of a pair of first-class levers connected by a hinge. the handle is the long side (force point) of the lever, the hinge acts as a fulcrum, and the beaks in contact with the tooth act as the short side (action point) of the lever. The force applied to the handles is thus magnified, resulting in a large grasping force. However, this force is not used to extract the tooth; rather, it can crush or fracture the tooth. The force exerted by the handles of the forceps helps to grasp the tooth, but does not mechanically assist in extracting the tooth (Misch, 2008). Conventional forceps can damage the cementum in the cervical area of the buccal and lingual (palatal) because they grip tightly, and the beaks can damage the PDL by slipping during the extraction process.

Atraumatic forceps, on the other hand, maintain the spacing between the beaks and work on the principle of first class lever mechanics (Fig. 12 (c)). One beak is placed in the cervical area (action point) and the bumper beak is placed on the mucosa of the alveolar bone area on the opposite side (fulcrum) to dislocate the tooth from the extraction canal by rotational force of a handle (force point). Therefore, damage to the cementum or PDL can be minimized during the extraction process, and the probability of preserving the surrounding tissue or bone is increased.

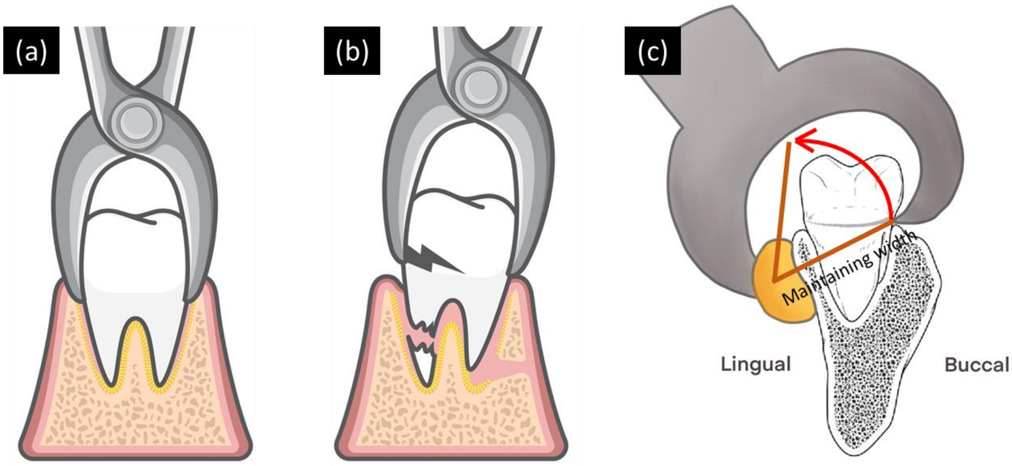

Figure 12. Conventional extraction forceps; (a) Damage on the PDL and (b) Possibility of crown/root/bone fracture, (c) atraumatic extraction forceps; first class lever mechanics.

El-Kenawy (2015) analyzed the complications of simple extractions performed with conventional forceps or atraumatic extraction forceps. In the conventional forceps group (Fig. 12 (a),(b)), crown fracture occurred in 10%, buccal bone fracture in 7%, and root fracture in 16.6%. In contrast, the group of atraumatic extraction forceps had 3% crown fracture, 3% buccal bone fracture, and 8.5% root fracture. Atraumatic extraction forceps can be used to achieve predictable results in difficult tooth extraction cases, reducing crown, root, and buccal bone plate fractures and preserving surrounding structures.

This study included 12 teeth (30%) with divergent roots or teeth with three roots, as shown in the figure, and root fracture occurred in two of the cases. In both cases, the root apex was broken and the tooth retention was not an issue. So treatement was proceeded as normal. There was one case of buccal bone fracture, a maxillary second molar, in which the buccal bone was very thin and fractured by a periapical lesion. Of the total 40 cases, there was 1 case (2.5%) of buccal bone plate fracture and 2 cases (5.0%) of root fracture. The results are similar to those of the previous study, and most importantly, this complication did not affect the success rate of this treatment (Fig. 13).

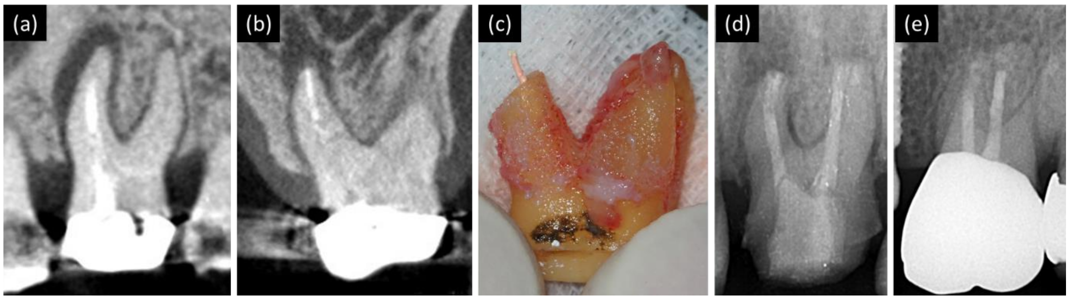

Figure 13. Successful case of a tooth #26 with root fracture during extraction; (a)~(b) Preoperative CBCT view, (c) Palatal root fracture during extraction, (d) Immediately after surgery, and (e) 2.5-year follow-up (complete healing)

4.2 Fast-setting MTA - RetroMTA®

The RetroMTA® used in this paper is classified as a hydraulic bioceramic material, which is composed of fine, hydrophilic particles that harden upon contact with water, forming a durable and impermeable seal. The material uses a hydraulic calcium zirconia complex as a contrast agent. The setting time is 150 seconds, which is a fast-setting material. Existing research has shown that the mechanical and biological properties of new fast-setting calcium silicate–based materials(CSMs) are very similar to those found in conventional slow-setting CSMs (Kim, 2020).

In intentional replantation, the tooth is extracted, treated, and then replanted into the extraction socket, which is filled with blood. In addition, because the tooth is somewhat moving in the socket, some pumping action is exerted on the treated root apex from the initial stage of healing (Cho, 2016). This may interfere with the setting of the MTA used as root end filling materials, so the initial setting time of the MTA has a significant role in the success of the treatment. The aforementioned study by Cho (2016) of teeth with intentional replantation used ProRoot MTA with a slow-setting time, and 7 cases (12.7%) of the teeth with MTA for root-end filling did not show periapical healing, possibly resulting from the inadequate sealing of the root canal bacteria by the retrofilling. In our study, no cases failed due to apical leakage caused by poorly set up MTA.

The exact mechanism is unknown, but it is reported that blood contamination interferes with the hydration of the MTA, preventing its normal setting. Song studied the effect of blood contamination on MTA setting and microhardness using specimens filled with MTA in molds of 2 and 4 mm length (Song, 2016). Blood contamination could adversely affect the surface microhardness of all MTA specimens, and normal setting was hindered in 2 mm specimens, whereas all 4 mm specimens were set. RetroMTA® has been shown to set in both saline and blood environments, even in 2mm restorations. To Prevent surface washout is of primary importance in the setting of MTA, but the intraoral environment is more challenging than the study conditions because the teeth are constantly moving. Therefore, in intentional restorations with relatively favorable visualization, retro-preparation as deep as possible (about 4mm) with minimal loss of tooth structure and restoration with RetroMTA® may provide an advantage in the unfavorable bloody environment with pumping action. In this study, we also filled the RetroMTA® after 3-4 mm of retro-prep, and as mentioned earlier, there were no failure cases due to MTA setting problems.

In this study, there were no significant prognostic factors for success rate for several factors. The previous study found that extraoral time (<15 minutes) and whether MTA was used were significant prognostic factors for success rate, but in our study, all procedures were performed by a single experienced endodontist and all but 4 cases (90%) had an extraoral time within 15 minutes (mean 10.9 minutes). The MTA used in the previous paper (Jang, 2016) was ProRoot MTA®, which showed unfavorable results compared to other materials due to slow initial setting time, but in this study, RetroMTA® was used as a single material, so these two factors could not be factors affecting the success rate in this study. The small sample size may also have affected these results.

On the other hand, there were a few cases that were poor in the non-surgical RCT quality factor (Table 3). The patients were mostly patients who had persistent symptoms after RCT at the local clinic and came to our clinic for subsequent treatment. Of 18 patients with poor RCT quality, just 1 case decided to undergo surgery due to persistent symptoms after normal endodontic treatment at our clinic, 4 cases had post after treatment at a local clinic, 3 cases had fractured file, 5 cases had severe calcification, 1 case had c-shaped canal, and 2 cases had apicoectomy history. This is because operator prioritized replantation in cases where the success rate of re-RCT is expected to be low, such as the presence of inserted post or separated file, c-shaped canal, or severe calcification, regardless of the quality of canal filling.

The study has several strengths compared to previous intentional replantation research. We included all patients who consented to the study in the study which reduced bias in the data, and all patients were treated by a single operator (SY Cho), which has the advantage of consistency in all procedures. Almost all cases had video or clinical photographs of the surgical procedure, allowing for detailed analysis of failure cases despite the retrospective design of the study. The extraoral time, which has been suggested as a significant prognostic factor in previous studies, was within 15 minutes in most procedures. The use of fast-setting MTA for the initial setting ensured relatively favorable conditions in an environment susceptible to bleeding contamination. In addition, the use of atraumatic extraction forceps reduced the likelihood of root resorption due to PDL damage, a complication of intentional replantation, allowing us to focus on the impact of other parameters on the success rate. Furthermore, there have been few studies of intentional replantation using both novel extraction instruments and surgically favorable fast-setting MTA, as in this study. The survival rate in this study treated as such was quite high, at 95%.

The presence of undetected structures was the cause of failure in 85.7% (six of total

7 cases) of the cases described above. In 1985, Cambruzzi introduced the use of 1-2% methylene blue dye in endodontic surgery. Methylene blue does not dye hard tissue, but soft tissue such as the pulp, which can help detect isthmus, accessory canals or root fracture, that have not been accessed. In our clinic, it was difficult to use it due to material supply problems, but if it is used in the future, the success rate will increase significantly. In addition, in one case of root resorption, it is recommended to pay attention not only to intraoperative PDL damage but also to damage during the repositioning process.

V. Conclusion

In this study, the success rate of treatment was 82.5% and the survival rate of teeth that were not extracted at follow-up was 95.0%. This study, different from previous studies, presents a low-complication and effective procedure for intentional replantation using atraumatic forceps and fast-setting MTA. Although the sample size is limited in this study, no failures were seen due to root resorption resulting from extraction trauma or MTA setting problems. With the use of the latest instruments and materials and thorough intraoperative inspection, including the use of intraoperative methylene blue, better surgical outcomes can be expected.

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Abstract (In Korean)

비외상성 발치겸자와 경화속도가 빠른 MTA를 이용한 의도적 재식술의 임상적 결과와 실패케이스 분석 : 후향적 연구

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치의학과

(지도교수 정일영)

의도적재식술의 부작용은 MTA 경화 부족 또는 발치 중 외상으로 발생한 경우가 대부분이다. 본 연구는 이러한 원인으로 발생하는 근단부병소의 재발이나 치근 흡수 문제를 개선하기 위해, 근단부 역충전 시 빠른 경화시간을 가진 MTA(RetroMTA®)를 사용하였고, 발치과정에서 비외상성 발치겸자를 사용했다. 이 연구의 목적은 이러한 프로토콜을 적용했을 때 치아에 의도적재식술의 성공률을 후향적으로 평가하는 것이다. 또한 이 분석을 바탕으로 이 연구는 의도적 재식술의 성공률을 높일 수 있는

추가 고려 사항을 제안하고 현재 임상 환경에서 치료 결과에 영향을 미칠 수 있는 예후 인자를 식별하고자 한다.

이 연구에는 2017 년 1 월부터 2022 년 12 월까지 한 명의 술자에 의해 의도적재식술을 받은 75 명의 환자의 77 개의 영구치가 포함되었다. 미리 정해진 제외 기준에 따라 26 개의 치아는 연구에서 제외되었고, 11 개의 치아는 1 년 이내에 추적 관찰로 제외되어 총 40 개의 치아를 임상 및 방사선학적 평가를 위해 분석했다

평균 추적관찰 기간은 실패 증례를 제외하고 2.43 년이었고, 실패한 증례들은 수술 후 평균 1.55 년만에 실패를 보였다. 치료 성공률은 Molven(1987)에 따라 82.5 % (complete 26 incomplete 8)였고, 생존률은 95.0% 였다. 본 연구에서 36 증례 (90%)에서 15 분 이내로 치료가 진행되었다. 방사선 사진 평가에 대한 연구자간 신뢰도는 k = 0.626 으로 “상당한(substantial)” 값을 보였다. 본 연구에서는 실패 증례 중 경화되지 않은 MTA 로 인한 근단부 누출은 없었고, 치근흡수으로 인한 발치는 단 1 건(2.5%)이었다.

핵심되는 말 : 의도적 재식술, 결과, 실패, 성공률, 단일술자, 빠른 경화시간 MTA, 비외상성 발치겸자