Clinical outcomes after apical surgery on the palatal root of the maxillary first molar using a palatal approach

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Abstract

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In the previous studies of apical surgery, few studies have discussed about the apical surgery on the palatal root of the maxillary first molar using a palatal approach. This study aimed to investigate the outcomes and complications associated with apical surgery on the palatal root of the maxillary first molar using a palatal approach. We searched for patients who underwent apical surgery with a palatal approach on the palatal root of the maxillary first molar between March 2010 and September 2017 by a single operator. A total of 46 teeth from 46 subjects were included, and they were examined at 6 and 12 months after surgery, and, annually, thereafter. Of the 46 treated cases, 11 were lost to follow-up. Thus, 35 cases were included in the analysis (recall rate 76%, average follow-up time 3.5 years). Success was considered achieved in 32 cases; 30 cases showed complete healing and two had incomplete healing. Three cases resulted in failure, all occurring within 1 year following surgery. To evaluate whether there was nerve damage on the surgical side, a pinprick test and cotton swab test were used with a 0-10 numerical rating scale (NRS), and the results were statistically compared using the Wilcoxon signed-rank test. The pinprick test results showed that all the NRS scores were higher than 7, and the responses on the surgical site were not statistically different from those on the contralateral site (P=0.109). All subjects showed normosensitivity to the cotton swab test. The success rate of apical surgery on the palatal root of the maxillary first molar using a palatal approach was 91.5%, which is similar to that observed in apical surgery performed on the other roots. Use of the palatal approach had an advantage in terms of accessibility and visibility, and the number of complications resulting from artery and nerve damage was minimal.

Keywords: Apical surgery, greater palatine artery, greater palatine nerve, maxillary first molar, nerve damage, palatal approach, palatal root

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I. INTRODUCTION

The success rate of endodontic surgery has improved since the introduction of microsurgery (Friedman, 2011; Setzer, et al., 2012; Setzer, et al., 2010; Wang, et al., 2017). Apical surgery is the first option in most situations, and intentional replantation is considered in cases with difficult surgical accessibility, such as those involving the second molars (Cho, et al., 2017; Cho, et al., 2016; Rouhani, et al., 2011). With modern apical surgery and intentional replantation, clinicians are able to manage almost all roots in the mouth with high success rates. A significant amount of research has demonstrated the usefulness and reliability of these modalities. However, few studies have focused on the palatal root of the maxillary first molar. Existing papers concentrating on apical surgery do not refer to the palatal root separately, while most papers on intentional replantation predominantly focus on the second molars. (Cho, et al., 2017; Cho, et al., 2016; Song, et al., 2011)

Apical surgery on the palatal root of the maxillary first molar was introduced using a buccal approach on the upper section of the maxillary first molar (Kalender, et al., 2013; Rigolone, et al., 2003). This type of surgery accessed the palatal root through a buccal vestibule and the inside of the sinus and, therefore, was named transantral endodontic surgery (Wallace, 1996). Some studies reported that the palatal roots of the maxillary first molar frequently protruded into the sinus (29 – 45% of cases) (Kalender, et al., 2013; Kang, et al., 2015; Tian, et al., 2016), and the buccal approach often resulted in the removal of a part of the sinus in the course of the penetration into the apex of the palatal root. Complications include sinusitis and oro-antral fistula, and the time to recover the sinus membrane and physiologic function after surgery was approximately five months (Benninger, et al., 1989). In terms of the horizontal distance, palatal roots are located 9.73 - 12.16 mm from the buccal cortical bone (Kalender, et al., 2013; Kang, et al., 2015; Rigolone, et al., 2003). This distance is sufficient to interfere with proper visualization and instrumentation during root apex management.

The studies, which performed the buccal approach on the maxillary first molar, have warned risks when the approach was conducted palatally; greater palatine arterial injury, the greater palatine nerve damage, iatrogenic sinusitis(Wallace, 1996; Kalender, et al., 2013; Rigolone, et al., 2003). Despite the possibility of those complications, there are few studies that have reported those complications in practice. Several dental surgeries are performed in the palatal area, such as cleft palate recovery and oro-antral fistula recovery (operated in the oral and maxillofacial surgery part) (Anavi, et al., 2003; H. Y. Kim, et al., 2014; Parvini, et al., 2018) and connective tissue graft and free gingival graft (performed in the periodontal part) (Aguirre-Zorzano, et al., 2017; Rojo, et al., 2018; Tavelli, et al., 2019). In these studies, the greater palatine artery and nerve damage could be avoided by incision considering the anatomical location of the artery and nerve, and elevation of a full thickness flap considering the fact that the artery and nerve were located inside the palatine masticatory mucosa.

Within the limitation of our knowledge, only one case report study has reported on the use of the palatal approach in apical surgery performed on the palatal root of the maxillary molar (Giacomino, et al., 2018). Therefore, this study aimed to investigate the outcomes and complications associated with apical surgery on the palatal root of the maxillary first molar using the palatal approach.

II. MATERIALS AND METHODS

1. Subjects

The Institutional Review Board approved the study protocol (IRB No. 2018-0106-001). We searched for patients who underwent apical surgery with a palatal approach on the palatal root of the maxillary first molar between March 2010 and September 2017 by a single operator (I. Y. Jung) at the Department of Conservative dentistry, Yonsei University Dental Hospital, Seoul, Korea. This study included teeth with a chronic apical abscess or symptomatic apical periodontitis in which orthograde retreatment failed or was judged impractical. Informed consent was obtained from each subject at the time of the treatment, after the nature of the procedure and its risks were explained. A total of 46 teeth from 46 subjects were included in this study.

2. Surgical procedure

Before surgery, an alginate impression was taken, and a cast model was made with yellow stone. On the cast model, the wafer margin was marked 3mm below the buccal marginal gingiva and the whole palate. The wafer was fabricated of a 1 mm plastic sheet using Pro-Vac vacuum former (Keystone Industries, Gibbstown, NJ, USA) for hemostasis after surgery (Fig 1. H).

All surgical procedures were performed with an operating microscope (OPMI PICO; Carl Zeiss, Göttingen, Germany), excluding incisions, flap elevation and suturing. Patients were anesthetized with 2% lidocaine with 1:80,000 epinephrine. Sulcular incisions were conducted from the upper first premolar to second molar, and vertical incisions were placed from the mesio-palatal line angle of the upper first premolar or disto-palatal line angle of the canine within a 10-mm length from the cementoenamel junction (CEJ) of the tooth depending on the length of the palatal root. After considering the anatomical location of the greater palatine artery and nerve, a full-thickness periosteal flap was elevated to avoid blood vessel and nerve damage. Osteotomy was performed with a #4 round bur using a low-speed straight handpiece. Then, the 3-mm root tip was resected with a 170-tapered fissure bur. After the sinus membrane was checked for perforation with a periodontal probe and the Valsalva maneuver, periradicular curettage was conducted with a Columbia 13–14 curette (G Hartzell and Son Inc, Concord, CA) and 34/35 scaler (G Hartzell and Son Inc). Cotton pellets soaked in 0.1% epinephrine (Bosmin; Jeil Inc, Seoul, Korea) and/or ferric sulfate (Astringedent; Ultradent Products, Inc, South Jordan, UT) were used for hemostasis. The root end was stained with methylene blue and inspected with a micromirror under 25X magnification. The 3-mm deep root-end cavity was prepared using a KiS ultrasonic tip (Obtura Spartan, Fenton, MO) and filled with RetroMTA (BioMTA, Seoul, Korea) and ProRoot MTA(Dentsply, Tulsa, OK). The root-end and filled cavity was confirmed with a micromirror under 25X magnification, and the flap was repositioned and sutured (Fig 1).

After surgery completion, pressure dressing with gauze was applied on both buccal and palatal flap and initial hemostasis was confirmed. Then the pre-fabricated wafer was delivered and remained in place for about 7-10 days. After wound-site healing, the wafer was removed (Fig 1).

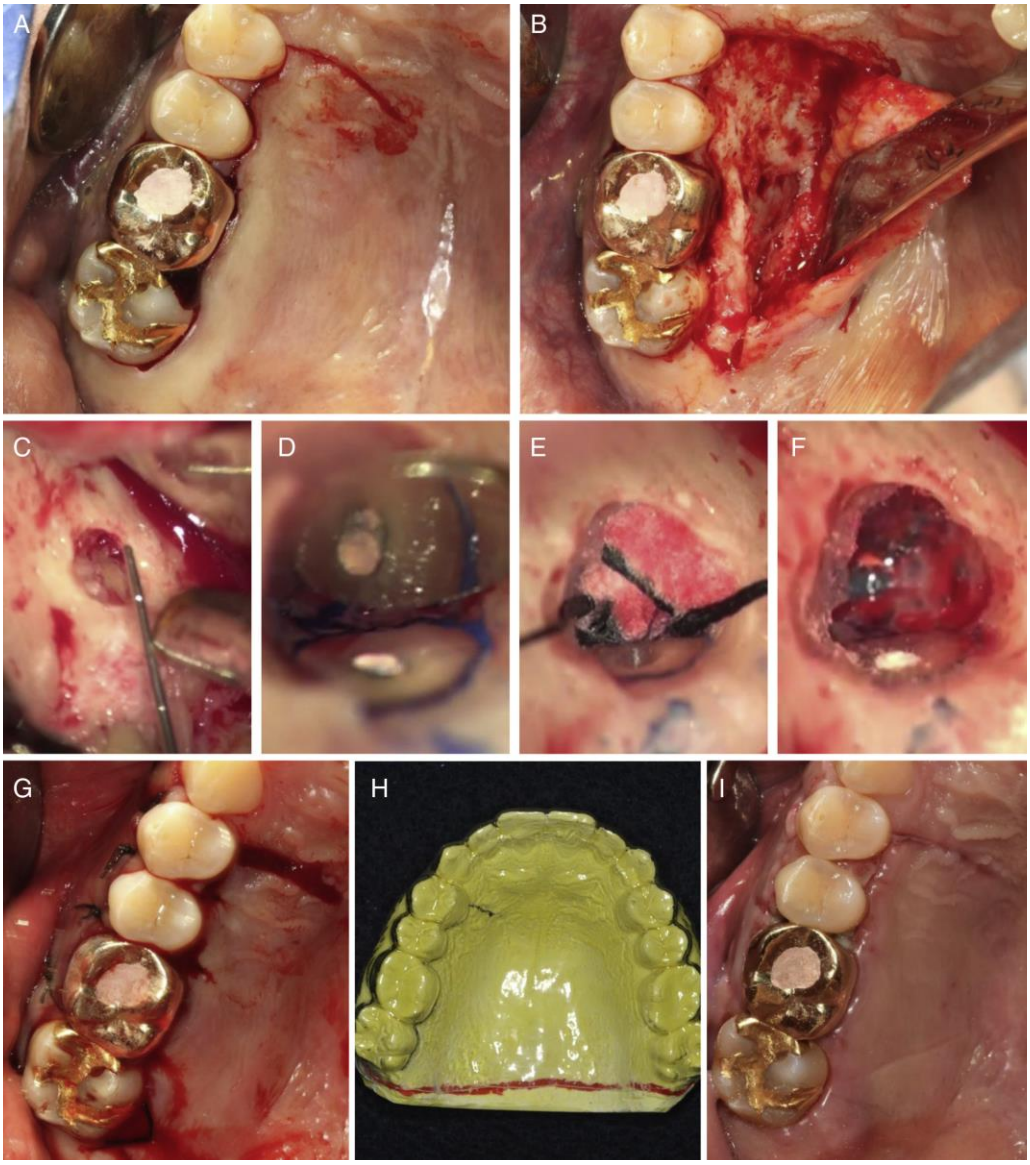

Figure 1. Clinical photographs showing the palatal approach procedures. A) Vertical incision was placed from the mesio-palatal line angle of the upper first premolar. B) Elevation and reflection of the full thickness flap. C) Osteotomy was performed. D) Inspection of the resected root surface after root-end resection. E, F) root-end cavity preparation and filling. G) The flap was repositioned. H) Pre-fabricated wafer. I) Wound healing state one week after surgery.

3. Radiographic evaluation

Preoperative cone-beam computed tomographic (CBCT) images (Alphrad 3030; Asahi Roentgen Ind Ltd, Kyoto, Japan) were obtained for every patient. Four measurements were obtained from the sagittal and axial views of the CBCT images: (1) the distance from the buccal surface of the buccal cortex bone to the buccal surface of the palatal root 3 mm below the apex (the root resection level), (2) the distance from the palatal surface of the palatal cortex bone to the palatal surface of the palatal root 3 mm below the apex (the root resection level), (3) the status of the sinus connection with the palatal root or lesion of palatal root origin, and (4) the status of the sinus pneumatization between the palatal root and buccal root(Fig 2).

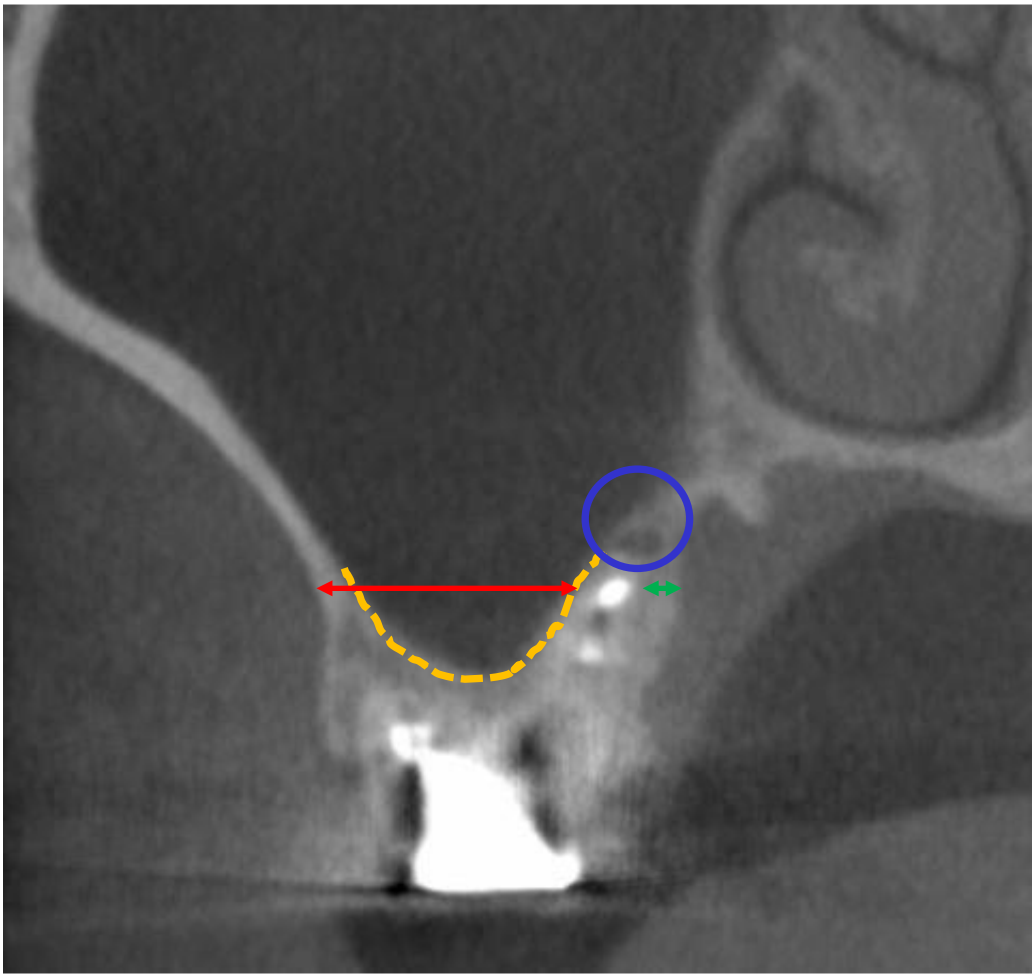

Figure 2. Preoperative cone-beam computed tomographic (CBCT) image. (red arrow) the distance from the buccal surface of the buccal cortex bone to the buccal surface of the palatal root 3 mm below the apex (the root resection level), (green arrow) the distance from the palatal surface of the palatal cortex bone to the palatal surface of the palatal root 3 mm below the apex (the root resection level), (blue circle) the status of the sinus connection with the palatal root or lesion of palatal root origin, and (yellow dotted line) the status of the sinus pneumatization between the palatal root and buccal root.

4. Clinical evaluation

Subjects were scheduled for follow-up examinations at 6 and 12 months following surgery and annually, thereafter. On every recall visit, two horizontally-shifted periapical radiographs (straight and 20-degree mesial or distal) were taken, and routine examinations were performed to identify signs and/or symptoms, tenderness to percussion or biting, tooth mobility and periodontal probing depth.

5. Neurologic evaluation

Sensory nerve tests were added as needed after the initial recall exam had been performed. We could evaluate only 12 subjects for the possibility of greater palatine nerve damage during surgery. To evaluate the presence of nerve damage on the surgical side, the following sensory nerve tests were utilized to conduct comparisons between the surgical and contralateral sides. (1) Pinprick test: The examiner poked the palatal mucosa of the first premolar and the first molar with a dental explorer, and asked the patient to describe the pain using a 0-10 numerical rating scale (NRS). (2) Cotton swab test: The examiner rubbed the palate with a cotton swab head on the surgical site and compared the senses with those on the control palate. Patients were asked if they felt: the same sensations on both sides (normosensitivity), a weaker sensation on one side than the other (hyposensitivity), or a stronger sensation on one side than the other (hypersensitivity) (Svensson, et al., 2012).

6. Outcome assessment

Two examiners independently evaluated the radiographs according to Molven's criteria for periapical healing, which were classified as follows: (1) complete healing, (2) incomplete healing, (3) uncertain healing, and (4) unsatisfactory healing (Table 1)(Molven, et al., 1987). Each outcome was assessed using combined clinical and radiographic criteria. The outcome was considered successful when the teeth showed no signs and/or symptoms, no increased mobility, no increased probing depths, and a radiographic assessment of complete or incomplete healing. Teeth that showed any of the aforementioned events or a radiographic assessment of uncertain or unsatisfactory healing were regarded as failure cases. Inter-examiner reliability was determined with Cohen Kappa statistics in accordance with Landis and Koch (Landis and Koch, 1977).

Table 1. Molven's criteria

Classification	
Complete healing after endodontic surgery	(A) Re-formation of periodontal space of normal width and lamina dura to be followed around the apex. (B) Slight increase in width of apical periodontal space, but less than twice the width of non-involved parts of the root. (C) Tiny defect in the lamina dura (maximum 1 mm ~) adjacent to the root filling. (D) Complete bone repair; bone bordering the apical area does not have the same density as surrounding non-involved bone. (E) Complete bone repair; no apical periodontal space can be discerned.
Incomplete healing (scar tissue) after endodontic surgery	The rarefaction has decreased in size or remained stationary, and is characterized by one or more of the following findings. (A) Bone structures are recognized within the rarefaction; the periphery of the rarefaction is irregular and may be demarcated by a compact bone border; the rarefaction is located asymmetrically around the apex; the connection of the rarefaction with the periodontal space is angular. (B) Isolated scar tissue in the bone with findings also shown in (A).
Uncertain healing after endodontic surgery	The rarefaction has decreased in size, and with one or more of the following characteristics; the radiolucency is larger than twice the width of the periodontal space; is bordered by lamina-dura like bone structures; has a circular or semicircular periphery; is located symmetrically around the apex as a funnel-shaped extension of the periodontal space; bony structures are discernible within the bony cavity. A collar-shaped increase in width of lamina dura coronal to the radiolucency may also be found.
Unsatisfactory healing after endodontic surgery	The rarefaction has enlarged or is unchanged.

7. Analysis

Subjects who had undergone at least a one-year follow-up and those whose teeth showed failure within one year were included in the analysis. The outcomes were tabulated and statistically analyzed with a chi-square test. Sensory nerve responses were statistically compared between the surgical and contralateral sites with a Wilcoxon signed-rank test. SPSS v.23.0 software (IBM Corp, Somers, NY) was used for all the analyses, and a significance level of 0.05 was set.

III. RESULTS

1. Characteristics of patients

The included subjects were characterized by the variables listed in Table 3. Of the 46 treated cases, 11 were lost to follow-up. Thus, 35 cases were included in the analysis, and the recall rate was 76%. The follow-up period ranged from one year to 8.1 years, with an average of 3.5 years (Table 2). There were twice as many female patients (n=23) as male patients (n=12). Sixteen subjects were aged ≤ 40 years, and 19 were aged > 40 years, with a mean age of 43 years.

Table 2. Distribution of Cases according to the Follow-up Period

Follow-up period	No. of cases
Less than 1 year (failed)	3
1-2 years	7
2-3 years	12
3+ years	13
Total	35

Table 3. Characteristics of the Included Subjects and Bivariate Associations between the Investigated Variables and Outcomes

Variables	**Total *N***	**Success *N* (%)**	**Failure *N* (%)**	***P* value**
Sex				.536
Male	12	12 (100%)	0 (0%)	
Female	23	20 (87.0%)	3 (13.0%)	
Age				1.000
≤ 40 years	15	14 (93.3%)	1 (6.7%)	
> 40 years	20	18 (90.0%)	2 (10.0%)	
Right vs. Left				.603
Right first molar	17	15 (88.2%)	2 (11.8%)	
Left first molar	18	17 (94.4%)	1 (5.6%)	
Surgical site				.536
P root only	12	12 (100%)	0 (0%)	
Both B and P roots	23	20 (87.0%)	3 (13.0%)	
Sinus-lesion involvement				.582
Involved	16	14 (87.5%)	2 (12.5%)	
Not involved	19	18 (94.7%)	1 (5.3%)	
P root protrusion to sinus				.234
Protruding	19	16 (84.2%)	3 (15.8%)	
Not protruding	16	16 (100%)	0 (0%)	
Periapical diagnosis				1.000
Symptomatic apical periodontitis	24	22 (91.7%)	2 (8.3%)	
Chronic apical abscess	11	10 (90.9%)	1 (9.1%)	
Previous treatment				0.460
Initial treatment	5	5 (100%)	0 (0%)	
Retreatment	30	27 (90%)	3 (10%)	

B, buccal; P, palatal

2. Preoperative Radiographic Measurements

The average distance from the buccal surface of the buccal cortex bone to the buccal surface of the palatal root at the level of 3 mm below the apex was 10.1±1.6 mm, and the average distance from the palatal surface of the palatal cortex bone to the palatal surface of the palatal root was 1.5±0.7 mm. The sinus floor extended below the palatal root apex in 19 of 35 cases, and was connected with the palatal root or its lesion in 16.

3. Outcome after apical surgery

The inter-examiner agreement regarding periapical healing was 0.77, suggesting good agreement. Of the 35 recall cases, success was considered achieved in 32; 30 had complete healing (Fig 3) and two had incomplete healing. In three cases, failure was observed; all the failure events occurred within one year after surgery. No factors were observed that significantly affected outcomes.

Figure 3. Cases with complete healing

(A-1) Preoperative radiograph of tooth with large cast post and periapical radiolucency on the palatal root. (A-2) Preoperative cone-beam computed tomographic (CBCT) showed periapical radiolucency on the palatal root and significant mucosal swelling in the maxillary sinus. (A-3) Postoperative radiograph. (A-4) A radiograph 4 years after the surgical treatment showed complete healing around the apex of the palatal root.

(B-1) Preoperative radiograph. (B-2) Postoperative radiograph. (B-3) Radiograph 7 years after treatment showed complete healing of apical radiolucency. (B-4) Preoperative CBCT showed periapical radiolucency on the palatal root apex and mucosal swelling in the maxillary sinus. (B-5) CBCT 7 years after treatment showed complete healing around the apex of the palatal root and resolution of mucosal swelling in the maxillary sinus.

4. Neurologic evaluation and other complication

Of the 12 subjects examined with sensory nerve tests, three reported a lower NRS score to the pinprick test on the surgical sites. However, all the NRS scores were higher than 7, and the responses on the surgical site were not statistically different from those on the contralateral site (*P*=0.109). All subjects displayed normosensitivity to the cotton swab test (*P*=1.000) (Table 4). None of the subjects showed intraoperative bleeding due to palatal artery damage and two cases suffered delayed bleeding on fifth and eighth days each.

Table 4. Comparison of the Sensory Nerve Responses between the Surgical Site and Contralateral Site using a Wilcoxon Signed-rank Test

	Pinprick test	**Cotton swab test**
	median (Q1, Q3)	median (Q1, Q3)
Surgical site	10 (9.25, 10)	10 (10, 10)
Contralateral site	10 (10, 10)	10 (10, 10)
P value	0.109	1.000

Q1, first quartile; Q3, third quartile

IV. DISCUSSION

In this study, we investigated 35 cases with apical surgery performed on the palatal root of the maxillary first molar using a palatal approach with an average recall rate of 3.5 years. Thirty-two cases showed clinical and radiological success and only three teeth were extracted within one year of surgery. The success rate was 91.5%, which is similar to that observed in apical surgery performed on the other roots (Song, et al., 2011; Song and Kim, 2012; Wang, et al., 2017). Palatal roots are predominantly straight, and their canals are single, round or oval without an isthmus (Marceliano-Alves, et al., 2016). This simple configuration helps clinicians easily manage apical canals. Inter-examiner agreement on the periapical healing was 0.77 which suggested good agreement but was slightly lower than previous apical surgery studies (Song, et al., 2011; Song and Kim, 2012; Wang, et al., 2017). Palatal roots are more difficult to evaluate on periapical radiographs because they are frequently superimposed on maxillary sinus.

Of the three cases that showed failure in this study, vertical root fractures were identified in two. The author failed to detect the fractures in both cases during the surgery as they were located on the buccal surface of the palatal root. The tooth from the other failure case was extracted in another hospital due to persistent pain. The patient had the same complaint before surgery, and it is unlikely that the symptom was related to the tooth. As the causes of the failures in these three cases did not seem to be associated with surgical procedure-related limitations or errors, the management of the palatal root using a palatal approach is predictive and valid.

Apical surgery on the palatal root of the maxillary first molar was first reported on using a buccal approach in previous studies (Kalender, et al., 2013; Rigolone, et al., 2003; Wallace, 1996). Those studies reported that the major limitations associated with the palatal approach were a risk of bleeding from injury to the greater palatine artery, numbness from damage to the greater palatine nerve, and iatrogenic sinusitis. However, several studies have investigated oral surgery in the palatal area performed for the avoidance of injuries to the greater palatine artery and great palatine nerve (Aguirre-Zorzano, et al., 2017; Anavi, et al., 2003; H. Y. Kim, et al., 2014; Parvini, et al., 2018; Rojo, et al., 2018; Tavelli, et al., 2019). Based on those studies, flaps can be designed to avoid damage to the greater palatine bundles during surgery conducted using a palatal approach. In addition, iatrogenic sinusitis is a complication that can occur when the buccal approach is used because it is a transantral surgery. Studies using the buccal approach measured the distance from the buccal cortical bones to the buccal surface of the palatal root with computed tomography (CT) data. In studies by Kalender et al. (Kalender, et al., 2013) and Rigolone et al. (Rigolone, et al., 2003), the measurement level from the root tip was 2 mm, and the distances were 9.9 mm and 9.73 mm, respectively (Kalender, et al., 2013; Rigolone, et al., 2003). In our study, we utilized CT data to measure the distance in a manner that is similar to that used for the performance of comparisons. The measurement level was corrected to 3 mm from the root tip, which is the root resection area during apical surgery. Measurements revealed that the average distance to the root was 10.1 mm through the buccal approach and 1.5 mm through the palatal approach. It is disadvantageous to palatal approach that the 92% of palatal canals presented apical curvature to buccal direction (Marceliano-Alves, et al., 2016). However, as the palatal approach involved a significantly shorter approach distance and the apical 3mm of palatal roots with the most severe curvature was removed, the palatal approach may have an advantage in terms of accessibility or visibility compared to the buccal approach.

Of the total 35 cases enrolled in this study, 19 (54%) showed maxillary sinus invasion between the buccal and palatal root; this incidence is higher than that observed by Kalender et al. (45.8%) (Kalender, et al., 2013) and Rigolone et al. (25%) (Rigolone, et al., 2003). If the surgeon had utilized traditional apical surgery with a buccal approach in these 19 cases, subjects may have been exposed to a high risk of iatrogenic sinusitis, as the sinuses would have been penetrated. In 16 of the 35 cases, the apical root or periapical lesion were involved in the maxillary sinus on CBCT. However, the Schneiderian membrane was not perforated during surgery, and none of the cases showed iatrogenic sinusitis after surgery.

According to an anatomy study in Korea, the greater palatine artery and nerve extend an average of 12.2 mm below the CEJ of the upper first premolar, 14.0 mm below the CEJ of the upper second premolar, and 13.2 mm below the CEJ of the maxillary first molar (D. H. Kim, et al., 2014). In addition, the greater palatine artery and nerve were located inside the palatine masticatory mucosa. Therefore, we typically utilize a vertical incision with a length of up to 10 mm and elevate a full thickness flap to avoid damage to the greater palatine artery and nerve bundle. This is the same concept as that employed in the protection of blood vessels and nerves during cleft palate surgery or oro-antral fistula recovery surgery (Anavi, et al., 2003; H. Y. Kim, et al., 2014). None of our subjects showed intraoperative bleeding, suggesting that none of them had palatal artery damage. Although delayed bleeding occurred in two cases on days five and eight, the complications were not pulsatile and immediately re-suppressed with wafer use.

In terms of the sensory nerve tests, it would be more appropriate to compare the preoperative and postoperative values on the same surgical palate than compare the surgical and contralateral palates. However, when the dentist evaluated the possibility of nerve damage after surgery, the comparison of both sides seemed acceptable. All 12 patients who were examined for great palatine nerve injury showed normosensitivity on the cotton swab tests. Although three patients reported a lower NRS on the pinprick test in the surgical palate than the contralateral palate, there were no statistically significant differences between the experimental and control sites in both the sensory nerve tests. Therefore, the damage to the sensory nerve was considered minimal.

This study is significant in that it showed a high success rate which is similar to that of the apical surgeries performed on the other roots. However, radiographic evaluation on periapical radiographs of palatal roots had a limitation because they were frequently superimposed on maxillary sinus. For more accurate radiographic evaluation, further studies are necessary to analyze the preoperative and postoperative CBCT images.

V. CONCLUSION

Based on the results of this study, the following can be concluded

1. The success rate of apical surgery on the palatal root of the maxillary first molar using a palatal approach was 91.5%, which is similar to that observed in apical surgery performed on the other roots (Song, et al., 2011; Song and Kim, 2012; Wang, et al., 2017).

2. Use of palatal approach may have an advantage in terms of accessibility or visibility.

3. A risk of bleeding from injury to the greater palatine arterial, numbness from damage to the greater palatine nerve, and iatrogenic sinusitis was low.

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Abstract (IN KOREAN)

구개측 접근법을 사용한 상악 제1대구치 구개측 치근의 치근단 수술에 대한 임상 결과

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(지도교수 정 일 영)

기존의 치근단 수술에 대한 연구에서는 상악 제1대구치 구개측 치근의 구개측 접근법에 관해서 거의 다루지 않고 있다. 이 연구는 구개측 접근법을 사용한 상악 제1대구치 구개측 치근의 치근단 수술에 대한 결과와 합병증 조사를 목표로 하였다. 2010년 3월부터 2017년 9월까지 한 명의 술자로부터 구개측 접근법을 사용한 상악 제1대구치 구개측 치근의 치근단 수술을 받은 환자들을 조사하였다. 총 46명의 환자의 46개 치아에 대하여 수술 후 6개월, 12개월 그

리고 그 후에는 매년 조사를 시행하였다. 46건의 증례 중 11 증례 follow-up 소실로 35건의 증례로 분석 시행하였다.(리콜율 76%, 평균 follow-up 기간 3.5년) 중 32건을 성공으로 평가하였다; 30건은 complete healing으로 평가하였으며 나머지 2건은 incomplete healing로 평가하였다. 실패한 세 건의 경우 모두 수술 후 1년 내에 실패 양상을 나타내었다. 수술 부위의 신경손상을 평가하기 위해 0-10 numerical rating scale (NRS)를 통한 pinprick test와 cotton swab test를 시행하였으며 그 결과는 Wilcoxon signed-rank test를 사용하여 통계적으로 비교하였다. Pinprick test 결과 모든 환자에서 7 이상의 NRS 수치를 보였으며, 수술 부위와 반대측 부위의 반응이 통계적으로 차이를 보이지 않았다(P=0.109). 모든 환자가 cotton swab test에서 normosensitivity를 보였다. 구개측 접근법을 사용한 상악 제 1대구치의 구개측 치근의 치근단 수술의 성공률은 기존의 다른 치근에 대한 치근단 수술의 성공률과 유사한 91.5%를 보였다. 구개측 접근법은 치근에 대한 접근성과 시야확보 측면에서 이점이 있었으며 동맥 혹은 신경 손상으로 인한 합병증은 적었다.

핵심되는 말: 치근단 수술, 대구개 동맥, 대구개 신경, 신경손상, 구개측 접근, 구개 치근