Periodontal outcome of buccally impacted maxillary canines after orthodontic traction following closed eruption technique

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Periodontal outcome of buccally impacted maxillary canines after orthodontic traction following closed eruption technique

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2014년 12 월

이 지 연

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ABSTRACT

Periodontal outcome of buccally impacted maxillary canines after orthodontic traction following closed eruption technique

The aim of this investigation was to evaluate the periodontal status of the buccally impacted maxillary canines after orthodontic traction following closed eruption technique by clinical and radiographic methods and to investigate pre-treatment orthodontic variables affecting the periodontal changes. 54 patients (21 males and 33 females) having one maxillary canine in a buccally impacted position was choosed (impaction group) and a contralateral canine in a normal position served as a control group. Probing depth, bone probing depth, keratinized gingiva width, attached gingiva width, clinical crown length, distance from cemento-enamel junction (CEJ) to alveolar crest (AC) and bone support were measured at 1.4 months after the end of treatment. The following results were observed.

1. Probing depth on midbuccal and mesiolingual sides was significant increased in the impaction group (mean difference 0.20 mm, 0.25 mm, respectively, P <0.05). Bone probing depth on mesiolingual and distolingual sides was increased in the impaction group than the control group (mean difference 0.24 mm, 0.48 mm, respectively, P < 0.05).
2. The attached gingiva width was significant shorter in the impaction group compared to the control group (mean difference 0.62 mm,

$P < 0.01$). The buccal clinical crown length was longer on the impaction group than the control group (mean difference 1.12 mm, $P < 0.001$).

3. The distance from CEJ to AC was significant longer in the impaction group on mesial and distal sides compared to the control group (mean difference 0.89 mm, 0.82 mm, $P < 0.001$). There were significant smaller bone supports at mesial and distal sides in impaction group compared to control group (mean difference 7.30%, 8.80%, $P < 0.001$).
4. If the impacted canine was localized at the more mesial angulation (to the horizontal) and the deeper from occlusal plane at the beginning of treatment, the distance from CEJ to AC on distal side was increased significantly at the end of treatment ($P < 0.01$).

These results revealed that forced eruption of the maxillary impacted canine after orthodontic traction following closed eruption technique, resulted in significant gingival recession on the buccal side and alveolar bone loss on the interproximal sides. Initial intraosseous position and the inclination of impacted canine were related with the periodontal changes.

Key Words: closed eruption technique, buccally impacted canine, alveolar bone loss, gingival recession

Periodontal outcome of buccally impacted maxillary canines after orthodontic traction following closed eruption technique

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(Directed by Professor Kyung-Ho Kim, D.D.S., M.S., Ph. D)

I. Introduction

Maxillary canine is essential for the continuity of the dental arch and plays an important role in establishing an esthetic view and maintaining the arch form and function of the dentition (Abrams et al., 1987). Also, position of the permanent maxillary canine is significant in maintaining the harmony and symmetry of the occlusal relationship. However, it is well known that maxillary canine is the most frequently impacted tooth after third molars (Moss, 1968). Prevalence of the impacted canines was reported from 1% to 3% in the general population (Grover and Lorton, 1985), the percentage of palatal and buccal impaction varies widely, according to studies in the literature. In general, it has been reported that palatal impaction of the maxillary canines occurs 3 to 6 times more often than buccal impaction (Fournier et al., 1982; Jacoby, 1983). However, most of these studies were performed for Caucasian patients. Oliver et al (Oliver et al., 1989) suggested that the trend of maxillary canine impaction in Asians would differ from that of Caucasian patients, and recent studies have reported that buccal impaction of the maxillary canines occurs 2 to 3 times more often than palatal impaction in Asians of Korean and Chinese descent (Kim et al., 2012).

Buccally impacted canine has been indicated as the most difficult to manage because ordinarily there is lack of room in the alveolar bone for one tooth to pass the other (Johnston, 1969; von der Heydt, 1975). Also buccally impacted canines are covered by thin oral mucosa, while palatally impacted canines are covered by thick and keratinized palatal tissue. This results in a very thin alveolar osseous plate which is then more susceptible to dehiscence and gingival recession and the resistance to mechanical irritation such as tooth brushing may be reduced (Hirschfeld, 1923; Sperry et al., 1977). Accordingly, when considering the periodontal implications of surgical exposure and alignment of ectopic maxillary canines, it is important to differentiate between palatally and buccally impacted teeth.

Many studies have shown that long-term periodontal health is better when the more resilient keratinized gingival tissue is maintained on the buccal aspect of the canine (Boyd, 1984; Kohavi et al., 1984; Tegsjö et al., 1983; Vanarsdall and Corn, 1977). To achieve this goal, the two techniques, apically positioned flap and closed eruption technique, can be used for surgical uncovering and bringing the buccally impacted canine into occlusion. In particular, if the tooth is located high above the mucogingival junction or deep in the alveolus, the apically positioned flap cannot always be used safely because it would result in instability of the crown and possible reintrusion of tooth after orthodontic treatment (Kokich, 2004). Therefore, in that case, although the closed eruption technique does not allow the orthodontist to clinically determine the location of an impacted tooth and thus select a favorable force vector (Becker et al., 1996; Wisth et al., 1976), it is believed by some to be the best method of uncovering buccally impacted teeth (Crescini et al., 1994; Kokich and Mathews, 1993). Some clinicians stressed that the closed eruption technique replicates natural tooth eruption and therefore produces the best esthetic and periodontal results

(Crescini et al., 1994; Aldo Crescini et al., 2007) and advocated the closed eruption technique in terms of patient comfort and long-term periodontal health (Johnston, 1969; Lappin, 1951; von der Heydt, 1975).

However, previous reports on periodontal structures response following surgically uncovering procedures are conflicting (Årtun et al., 1986; Bishara et al., 1976; Boyd, 1982; Shapira and Kuftinec, 1981; Theofanatos et al., 1993). In addition, it is uncertain whether the periodontal variables changed during orthodontic treatment or throughout retention period (Becker et al., 1983; Crescini et al., 1994; Hansson and Rindler, 1998). Meanwhile, few are available in the literatures concerning the possible significances of pre-treatment radiographic measurements with respect to the periodontal status of impacted canines (Crescini et al., 2007a, 2007b). Crescini et al found that pre-treatment radiographic variables were not prognostic indicators of final periodontal status of orthodontically repositioned canines. However, they evaluated only two periodontal variables (pocket depth and keratinized tissue width) as dependant variables and did not investigated the loss of attachment surrounding the impacted canine. In terms of periodontal outcome after the orthodontic treatment of impacted canines, the initial intraosseous position and inclination of maxillary impacted canines might affect on the periodontal health at the end of treatment.

Therefore, the aim of this study was 1) to evaluate periodontal status of the buccally impacted maxillary canines after orthodontic traction following closed eruption technique by clinical and radiographic methods and 2) to investigate pre-treatment orthodontic variables affecting the periodontal prognosis.

II. MATERIALS AND METHODS

The study was approved by Institution of Research review Board of the Gangnam Severance Hospital (No. 3-2014-0087).

A. Subjects

This retrospective study included subjects (n=54, 21 males and 33 females) having one maxillary canine in a buccally impacted position (impaction group) and a contralateral canine in a normal position (control group). From the total of 138 patients who had visited the Department of Orthodontics, Gangnam Severance Hospital from January 2002 to June 2009 and had been diagnosed with buccal impaction of the maxillary canine and scheduled for orthodontic traction following closed eruption technique, 84 patients were excluded, based on the exclusion criteria: missing teeth adjacent of the canine, open contacts against adjacent lateral incisor or first premolar at the end of treatment, poor oral hygiene (index of 2 or 3 in plaque index (PI) and gingival index (GI)) and if the initial panoramic radiographs present a great deal of distortion between right and left sides. Two roentgenographic techniques (Tube-shift technique and Buccal-object rule (Richards, 1980)) have been used to determine the buccal position of impacted canines with the two periapical films which were taken with the different horizontal and vertical angulation of the cone changed when the second film is taken. If the object moves in the opposite direction, it is situated closer to the source of radiation and therefore is considered buccally located.

Thirty-four maxillary canines were impacted on the left side and twenty on the right side (Table 1). A total of 54 patients had a combined surgical-orthodontic approach to bring the impacted teeth into occlusion. Mean age of samples was 12.85 ± 3.50 years and the mean duration of active traction was 12.74 ± 7.74

months (Table 2). All closed eruption technique were performed by a single surgeon and one orthodontist with over 15 years of clinical experience participated in the orthodontic aspect of treatment. And all radiographs were taken by a single trained radiologist. In all the cases, fiberectomy was not carried out in any of the patients at the end of treatment. All canines examined were in good alignment and occlusion, and neither rotation nor intrusion was observed after the treatment.

Table 1. The number of samples according to the location of impacted canine

Impacted site / Gender	Right	Left	Total (n)
Male (n)	6	15	21
Female (n)	14	19	33
Total (n)	20	34	54

Table 2. Demographic description of subjects

	Mean	SD
Age (year)	12.85	3.50
Duration of active traction (month)	12.74	7.74
Follow up period (month)	1.39	2.13

B. Surgical procedure and orthodontic treatment

After reflection of gingival flap, the crown of the impacted canine was exposed by removing the surrounding bone minimally. A button with a twisted wire was bonded to the crown, and the gingival flap was sutured back, leaving only a twisted wire passing through the alveolar ridge to apply orthodontic force. The impacted canine was then extruded either by light and interrupted force with rubber elastics combined with removable appliance or by light and continuous forces combined with fixed appliance. During the orthodontic treatment, patients were recalled monthly to adjust their appliances and manage oral hygiene.

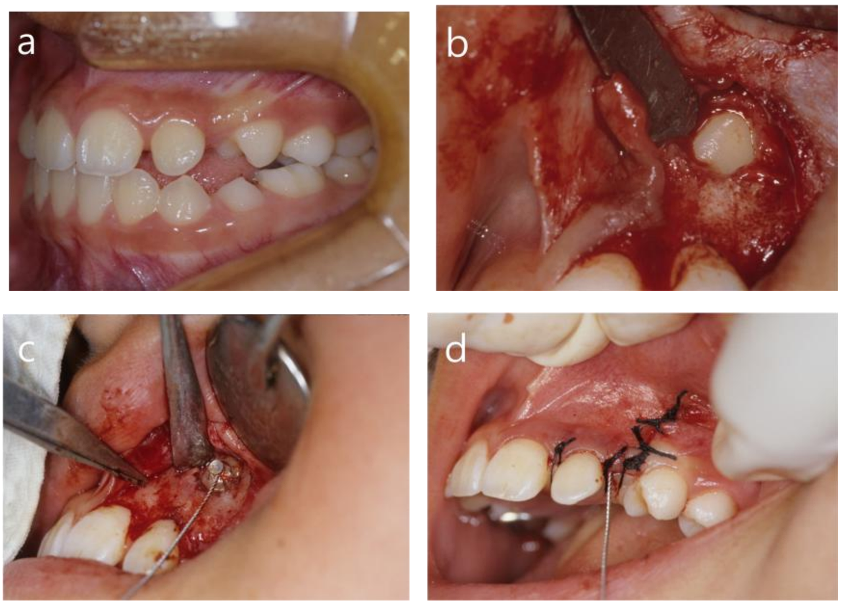

Fig. 1 The closed eruption technique procedures

(a) buccally impacted canine; (b) flap access; (c) button with twisted ligature wire bonded; (d) flap sutured in its original position.

C. Evaluation method

Pre-treatment orthodontic variables (s-sector, α-angle, d-depth, and Nolla's developmental stage) were measured before treatment using panoramic radiographs. Approximately one month after removal of orthodontic appliance (1.39 ± 2.13 months on average), periodontal status were examined by periapical radiographs and clinical examinations.

1. Pre-treatment orthodontic variables

From the panoramic radiographs, mesiodistal displacement and angulation of impacted and contralateral canines, and the distance from the canine cusp tip to occlusal plane were measured. To minimize errors in panoramic radiographs, the patients were positioned in the focal through precisely according to the manufacturer's specification. Magnification was standardized to an 108% enlargement for panoramic radiographs. The mesiodistal displacement (s−sector) was recorded by modification of Ericson and Kurol's definition (Ericson and Kurol, 1988) (Figure 2). Angular measurement (α−angle) was measured to determine the intra−osseous inclination of the maxillary canine. The most superior point of the condyle was selected as a landmark and a bicondylar line was drawn and used as a constructed horizontal reference line (HRL) (Warford Jr et al., 2003). The α−angle was formed between the HRL and the long axis of the canine. The long axis of the canine tooth was drawn through the midpoint of the maximum width of the crown and the apex of the tooth. The d−depth was defined as a perpendicular distance from the canine cusp tip to the occlusal plane (Figure 3). The occlusal plane was determined by drawing a line passing through the maxillary incisal edge of the central incisor and the mesiobuccal cusp of the maxillary 1^{st} molar on both sides. Canine developmental stages were evaluated according to Nolla's developmental stage (Nolla, 1960).

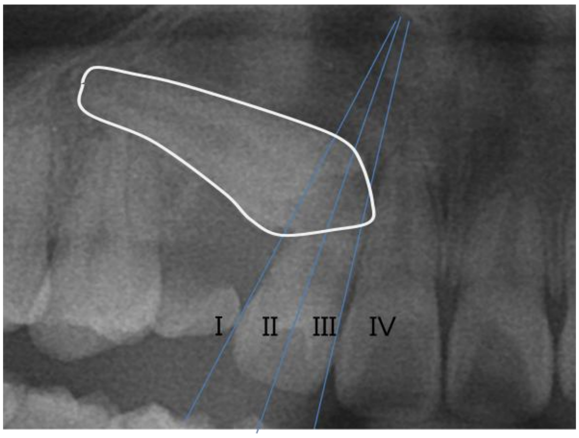

Fig. 2 Modification of Ericson and Kurol's definition (Ericson and Kurol, 1988)

S−sector is determined according to location of the canine cusp tip. Sector I represents area distal to the line tangent to distal height of contour of the lateral incisors. Sector II is mesial to sector I, but distal to bisector of the lateral incisor's long axis. Sector III is mesial to sector II, but distal to mesial height of contour of the lateral incisor. Sector IV includes all areas mesial to sector III.

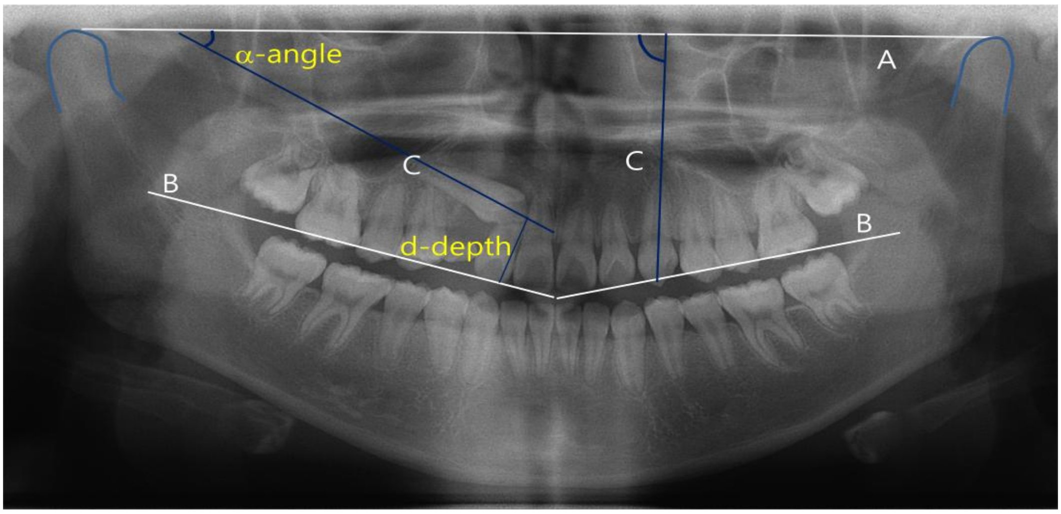

Fig. 3 Schematic drawing showing the measurements used to localize the position of canine

The tracings are made on initial panoramic radiograph. A, horizontal reference line (bicondylar line); B, occlusal plane; C, the long axis of the canine; α−angle, the angle between A and C; d−depth, the perpendicular distance from the canine cusp tip to the occlusal plane.

2. Measurements of alveolar bone and tooth on periapical radiographs

When taking periapical radiographs at the end of orthodontic treatment, 0.016 x 0.022−inch stainless−steel guide wire of 10 mm in length was fixed with wax on the buccal surface of the maxillary canines to compensate the distortion resulting from axis change of the x−ray beam. The periapical radiographs were taken twice for each canine, one with the central ray to the distal surface of the canine, and the other with the central ray to the mesial surface by paralleling radiographic technique. The periapical radiographs were then converted into digital images by scanning, and the magnification error was corrected by using the guide wire of 10 mm. The cemento−enamel junction (CEJ), the alveolar crest (AC) on the mesial and distal surfaces of the impacted canine and contralateral canines and root apex were digitated. The mesial and distal distances between CEJ and AC (CEJ−AC distance) were measured parallel to the long axis of the tooth on the mesial and distal centered roentgenograms, respectively. Root length (RL) was measured as a perpendicular distance of the root apex to a line connecting the mesial and distal CEJs (Figure 4). The ratios of apex−AC and apex−CEJ (apex−AC / apex−CEJ) were used to represent the percentage of bone support (BS) at the mesial and distal sides (Becker et al., 1983; Kohavi et al., 1984). Image measuring program (Image J, National institutes of Health, Bethesda, MD, USA) was used for measurements.

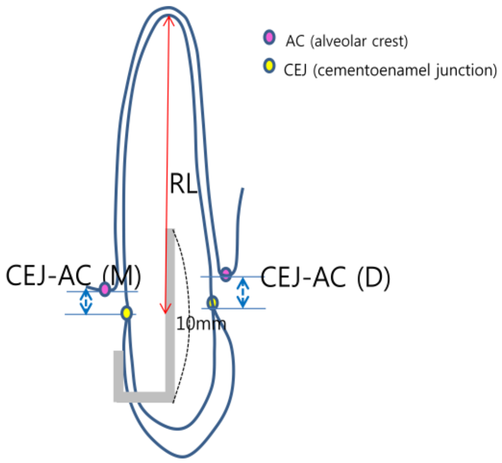

Fig. 4 Measurements on periapical radiographs

A 0.016 x 0.022−inch stainless−steel guide wire of 10 mm in length was fixed with wax on the buccal surface of the tooth. Blue arrows indicate the distance from the CEJ (cemento−enamel junction) to the AC (alveolar crest) on mesial and distal sides. Red arrow indicates the root length (RL), which was measured as a perpendicular distance of the root apex to a line connecting the mesial and distal CEJs.

3. Periodontal evaluation

Periodontal evaluation included gingival index (GI), plaque index (PI), probing depth (PD), bone probing depth (BPD), keratinized gingiva width (KGW), attached gingiva width (AGW), and clinical crown length (CCL). The examinations were performed both on the impacted and contralateral canines using a periodontal probe (N22T, devemed GmbH, Tuttlingen, Germany). Plaque control was performed with scaling during orthodontic treatment. Oral hygiene and gingival condition were scored according to PI (Silness and Löe, 1964) and GI (Löe and Silness, 1963) and patients who exhibited an index of 2 or 3 were excluded to prevent bias of gingival inflammation to the periodontal tissue. PD and BPD were measured from free gingival margin to the bottom of the sulcus and to the alveolar crest, respectively. For the BPD measurements, the tip of the probe was forced through the connective tissue under local anesthesia until definite resistance was met with a light force (2N) (Greenberg et al., 1976). PD and BPD were measured at six sites per tooth (Figure 6): the mesiobuccal (MB), mesiolingual (ML), distobuccal (DB), distolingual (DL), midbuccal (Mid.B), and midlingual (Mid.L) areas. KGW was measured at the midbuccal point and determined as a distance from free gingival margin to the mucogingival junction. Idodine solution was used to visualize the mucogingival junction. AGW was calculated by subtracting the PD measured at the midbuccal point from the KGW. CCL was measured on the midbuccal and midpalatal surface of the tooth from the incisal edge to the deepest point on the curvature of the vestibulo-gingival margin, parallel to the long axis of the tooth. All measurements were measured to the nearest 0.5 mm with the periodontal probe.

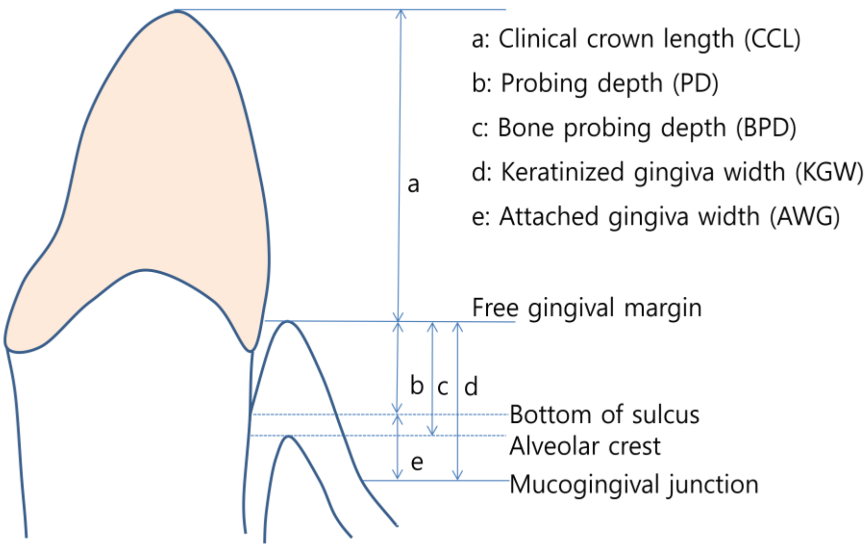

Fig. 5 Periodontal tissue measurements

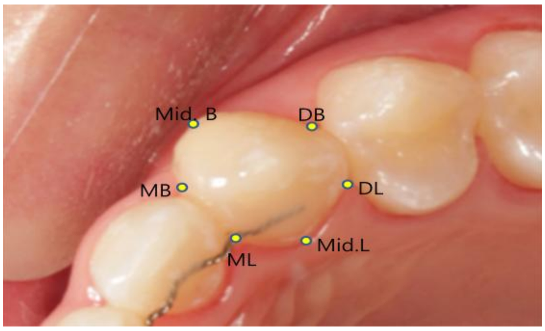

Fig. 6 Six areas measured for the periodontal evaluation

D. Statistical analysis

All analyses were performed using IBM SPSS Statistics 20.0 for Windows (IBM Co., Armonk, NY, USA). The differences between the impaction group and the control group were compared by paired *t*-test. The McNemar tests were used to determine the significance of differences in s-sector and Nolla's developmental stage in two groups. Simple and multiple linear regression analyses were conducted to determine if pre-treatment orthodontic variables (α-angle, d-depth, s-sector, and Nolla's developmental stage) influenced to the periodontal changes (PD, BPD, KGW, AGW, CEJ-AC, RL, and BS). The variance inflation factor revealed that there was no multi-collinearity with covariates. One examiner performed all the measurements. To evaluate intraclass reliability, the examiner re-analyzed all measurements for 20 randomly selected subjects within a two-week interval. The intraclass correlation coefficient (ICC) showed high reliability (ICC ≈ 1.00). A two-sided *P* -value of less than 0.05 was considered statistically significant.

III. RESULTS

A. Pre-treatment orthodontic variables

Before treatment, the impaction group had smaller α-angle and longer d-depth (P < 0.05) (Table 3). In the impaction group, 24%, 26%, 15%, and 35% of the canine cusp tips were located in sector I, II, III, and IV, respectively, while in the control group 80%, 19% 1%, and 0% were located in sector I, II, III, and IV, respectively. When a comparison was performed by the McNemar test, mesiodistal displacement of impaction group (s-sector) compared to the control group was a significant difference (P < 0.05) (Table 4). And 15%, 28%, 41%, and 16% of the impacted canines were distributed in Nolla's developmental stage 7, 8, 9, and 10, respectively, while in the control group 4%, 20% 50%, and 26% were distributed in Nolla's developmental stage 7, 8, 9, and 10, respectively. There was no statistically significant differences in Nolla's developmental stage between two groups (P > 0.05) (Table 5).

Table 3. Comparison of pre-treatment orthodontic variables in the impaction group and the control group

	Impaction		Control		Diff.		Sig
	Mean	SD	Mean	SD	Mean	SD	
α-angle(°)	62.1	22.30	87.0	8.74	−24.9	23.36	<0.0001
d-depth(mm)	15.0	4.49	3.6	5.48	11.4	6.45	<0.0001

Diff., difference; SD, standard deviation; Sig, significant; α-angle, the angle between bicondylar line and the long axis of the canine; d-depth, the perpendicular distance from the canine cusp tip to the occlusal plane.

Table 4. Number and percentage of samples according to s−sector of maxillary canines

	s−sector				Total
	I	II	III	IV	
Impaction	13(24%)	14(26%)	8(15%)	19(35%)	54
Control	43(80%)	10(19%)	1(1%)	0(0%)	54

s−sector, be determined according to location of the canine cusp tip; Sector I, area distal to the line tangent to distal height of contour of the lateral incisors; Sector II, mesial to sector I, but distal to bisector of the lateral incisor's long axis; Sector III , mesial to sector II, but distal to mesial height of contour of the lateral incisor; Sector IV, all areas mesial to sector III. ($P < 0.0001$)

Table 5. Numbers and percentage of samples according to Nolla's developmental stage of maxillary canines

	Nolla's developmental stage				Total
	7	8	9	10	
Impaction	8(15%)	15(28%)	22(41%)	9(16%)	54
Control	2(4%)	11(20%)	27(50%)	14(26%)	54

stage 7, one third of root completed; stage 8, two third of root completed; stage 9, root almost completed; stage 10, root completed. (P=0.254)

B. Comparison of post−treatment variables

As seen in Table 6, there were significant differences in PD on midbuccal and mesiolingual sides and in BPD on mesiolingual and distolingual sides between two groups ($P < 0.05$). KGW and AGW were significant shorter in impaction group compared to the control group ($P < 0.05$). CCL of the impaction group was longer than that of the control group on buccal side ($P < 0.05$)(Figure 7). However, there were no root exposures on all the samples. CEJ−AC distance was significant longer in impaction group on mesial and distal sides ($P < 0.05$)(Figure 8). There was a significant shorter RL and smaller BS observed in the impaction group compared to the control group ($P < 0.05$).

Table 6. Comparison of post−treatment variables

		Impaction		Control		Diff.		Sig
		Mean	SD	Mean	SD	Mean	SD	
PD	MB	2.46	0.75	2.32	0.43	0.13	0.63	0.166
	Mid.B	1.73	0.50	1.53	0.63	0.20	0.56	0.020*
	DB	2.54	0.58	2.50	0.62	0.04	0.52	0.570
	ML	2.66	0.67	2.41	0.54	0.25	0.53	0.003**
	Mid.L	2.05	0.50	1.95	0.59	0.09	0.50	0.232
	DL	2.68	0.72	2.63	0.58	0.06	0.69	0.580
BPD	MB	4.42	0.98	4.16	0.66	0.26	0.91	0.062
	Mid.B	3.27	0.84	3.19	0.73	0.08	0.75	0.484
	DB	4.30	0.55	4.31	0.68	−0.01	0.64	0.907
	ML	4.45	0.80	4.21	0.63	0.24	0.69	0.026*
	Mid.L	3.82	0.71	3.60	0.61	0.23	0.73	0.050
	DL	4.72	0.95	4.24	0.56	0.48	0.96	0.002**
KGW		3.51	1.22	3.94	0.97	−0.43	1.39	0.002**
AGW		1.78	1.22	2.41	1.00	−0.62	1.22	0.004**
CCL	B	9.97	1.19	8.85	1.05	1.12	0.96	0.0001***
	P	8.82	1.20	8.83	0.84	−0.01	0.86	0.949
CEJ−AC	M	2.58	0.88	1.69	0.62	0.89	0.94	0.0001***
	D	2.29	0.89	1.46	0.46	0.82	0.80	0.0001***
RL		15.10	2.93	16.88	3.00	−1.78	2.88	0.001**
BS	M	82.02	8.81	89.33	4.81	−7.30	8.23	0.0001***
	D	84.33	4.81	93.12	4.54	−8.80	6.26	0.0001***

These values except BS are expressed in millimeters and BS is expressed in percentage rounded to the second decimal digit. Diff., difference between impaction group and control group; PD, probing depth; BPD, bone probing depth; KGW, keratinized gingiva width; AGW, attached gingiva width; CCL, clinical crown length; CEJ, cemento−enamel junction; AC, alveolar crest; RL, root length; BS, bone support; MB, mesiobuccal; Mid.B, midbuccal; DB, distobuccal; ML, mesiolingual; Mid.L, midlingual; DL, distolingual; B, buccal; P, palatal; M, mesial; D, distal; Diff., difference; SD, standard deviation; Sig, significant.

* $P<0.05$ ** $P<0.01$ *** $P<0.001$

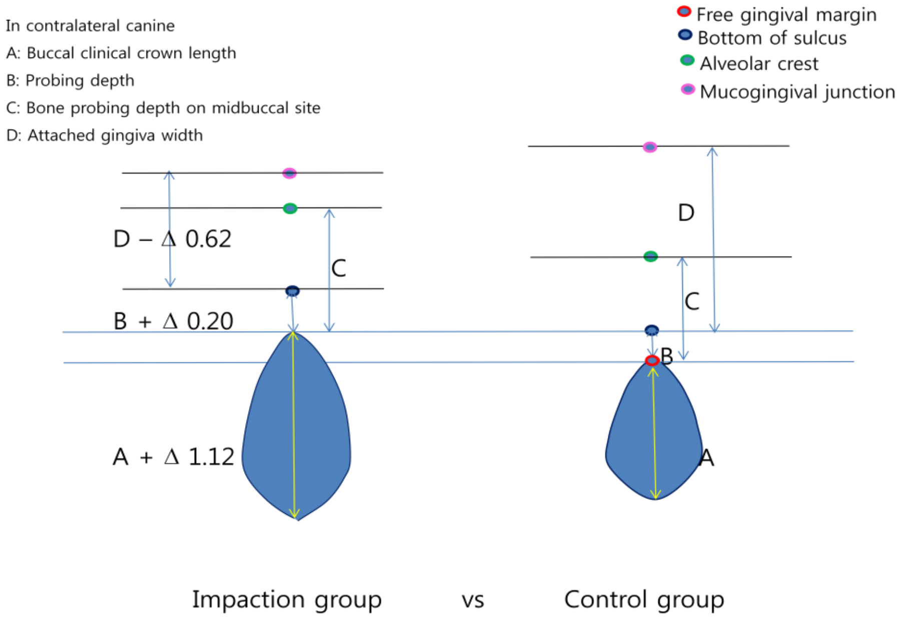

Fig. 7 Schematic description of the periodontal outcome after closed eruption technique of buccally impacted canines

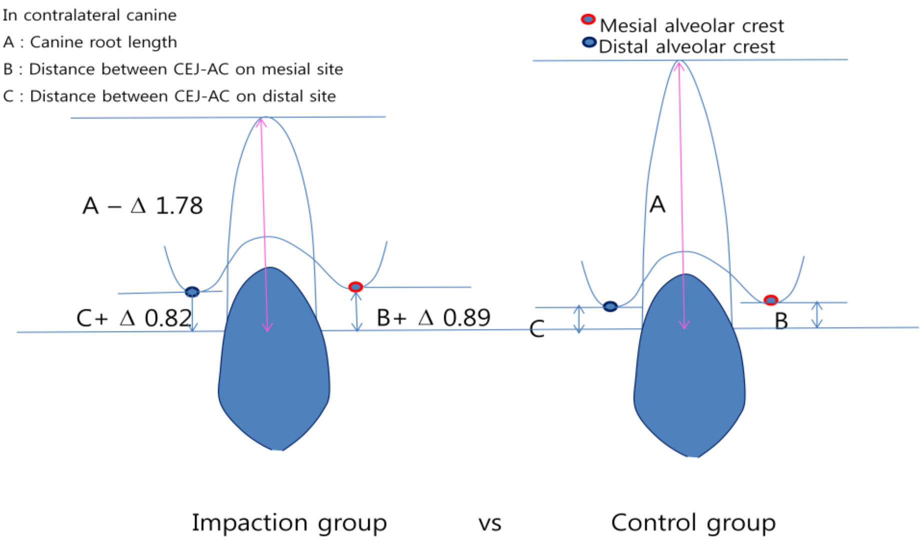

Fig. 8 Schematic description of the periodontal outcome after closed eruption technique of buccally impacted canines on mesial and distal sides

C. Predisposing factors affecting changes to the periodontal tissues

Simple regression analysis revealed that significant relationship between d-depth and distobuccal BPD. The α-angle and d-depth were correlated with the distal CEJ-AC distance, which, in turn, influenced distal BS ($P < 0.05$) (Table 7).

Table 7. Standardized coefficients by simple linear regression analysis for factors affecting changes to the periodontal tissues

		α-angle	d-depth	s-sector	Nolla stage
PD	MB	0.011	−0.009	−0.043	0.046
	Mid.B	−0.001	0.014	0.016	0.075
	DB	−0.001	0.017	−0.051	0.042
	ML	−0.002	0.026	0.085	0.042
	Mid.L	0.003	−0.003	0.089	0.102
	DL	−0.005	0.042	0.016	−0.046
BPD	MB	0.012	0.024	0.022	0.016
	Mid.B	−0.001	0.052	0.065	0.021
	DB	−0.005	0.046*	0.088	0.129
	ML	−0.002	0.035	0.058	0.172
	Mid.L	0.007	0.013	−0.085	0.117
	DL	0.001	0.026	−0.102	0.079
KGW		−0.015	0.028	0.273	0.038
AGW		−0.010	0.047	0.215	−0.133
CCL	B	−0.009	−0.007	−0.235	−0.024
	P	−0.007	0.024	−0.073	0.088
CEJ-AC	M	−0.012	0.043	0.097	−0.007
	D	−0.017**	0.085**	0.025	−0.164
RL		−0.002	−0.033	−0.088	0.379
BS	M	0.001	−0.004	−0.009	0.002
	D	0.001*	−0.006**	−0.005	−0.002

PD, probing depth; BPD, bone probing depth; KGW, keratinized gingiva width; AGW, attached gingiva width; CCL; clinical crown length; CEJ, cemento-enamel junction; AC, alveolar crest; RL, root length; BS, bone support; MB, mesiobuccal; Mid.B, midbuccal; DB, distobuccal; ML, mesiolingual; Mid.L, midlingual; DL, distolingual; B, buccal; P, palatal; M, mesial; D, distal.
* P<0.05 ** P<0.01 *** P<0.001

Multiple regression analysis showed that the α−angle and d−depth were correlated with the distal CEJ−AC distance, which, in turn, influenced distal BS ($P < 0.01$). D−depth influenced mesiobuccal, distobuccal and midlingual BPDs. RL was affected by the Nolla's developmental stage ($P < 0.05$) (Table 8).

Table 8. Standardized coefficients by multiple linear regression analysis for factors affecting changes to the periodontal tissues

		α−angle	d−depth	s−sector	Nolla stage
PD	MB	0.017	0.035	−0.012	0.140
	Mid.B	0.002	0.019	0.002	0.059
	DB	0.006	0.046	−0.025	0.194
	ML	0.001	0.022	0.025	0.024
	Mid.L	0.007	0.013	0.117	0.131
	DL	0.003	0.056	−0.029	0.065
BPD	MB	0.026	0.094*	0.022	0.175
	Mid.B	0.011	0.092	0.012	0.067
	DB	0.006	0.072*	0.038	0.209
	ML	0.003	0.038	−0.050	0.171
	Mid.L	0.016	0.076*	−0.180	0.118
	DL	0.010	0.076	−0.175	0.207
KGW		−0.007	0.010	0.296	0.154
AGW		0.005	0.065	0.205	0.101
CCL	B	0.008	0.028	−0.225	−0.219
	P	−0.007	0.021	−0.141	0.092
CEJ−AC	M	0.116	0.027	0.026	−0.109
	D	−0.065**	0.089***	−0.084	−0.019
RL		−0.279	−0.084	0.142	−1.380**
BS	M	−0.012	−0.003	0.001	0.032
	D	0.031**	−0.054**	0.009	0.001

See Table 7 for the abbreviations * $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$

IV. Discussion

Before surgically uncovering procedure and orthodontic treatment, it is important to localize the accurate position of impacted canine in determining the feasibility of the surgical approach, the proper direction for orthodontic force, the type of tooth movement, and prognosis of periodontal structures (Bishara, 1992; Ericson and Kurol, 2000). In this study, there was a significant difference in α-angle between two groups, which means that the more mesial angulation (to the horizontal) in impaction group compared to the control group. Warford et al (Warford Jr et al., 2003) found that α-angle was higher for non impacted canines, which are similar to our results. Also as regard with d-depth and s-sector, the impacted canine have a long distance in order to take its proper position in the arch ($P < 0.05$)(Table 3 and 4). Lindauer et al (Lindauer et al., 1992) identified up to 78% of the canines that are destined to become impacted, all of which have cusp tips located in sector II, III, and IV. Our study correspond with the previous results in 76% of impacted canines (31 of 54) were found in sectors II, III, and IV, which suggests that the correction of impacted canines necessitates large tooth movement in the vertical and buccal/palatal direction which is rare in orthodontic correction of sagittal malocclusions as well as rotational types of movement. However, various stages of root formation between impaction and the control group did not show any differences ($P > 0.05$)(Table 5). It seems that root formation is not be related to the eruption process. Therefore, it might be concluded that patients with buccally ectopic maxillary canines had a normal rate of dental development. This give rise to the hypothesis that intrinsic mechanisms of development do not completely control the position and eventual impaction of the canine because root formation seems to be unrelated to the eruption process. However, this is contrary to the findings of Rozylo-Kalinowska et al (Rozylo-Kalinowska et al., 2011). They elucidated that dental age estimated using Demirjian's method of Caucasian patients was significantly lower in patients with impacted maxillary canines than in healthy controls. This difference result may be due to the different evaluation methods as to dental age and the ethnic group. In particular, because Dermirjian's system is estimated based on evaluation of the seven left mandibular teeth, it is possible that the effects on the maxillary arch may be different when an anomaly exists in the maxillary arch.

The mean PD was statistically greater only in midbuccal and mesiolingual sites on impaction group, but the difference was not exceeded 0.5 mm. This finding differs from that of Vermette et al (Vermette et al., 1995), who found no difference between pocket depths measured at the labial aspect of impacted maxillary incisor treated by a closed eruption technique and its antimere. And there were no detectable and visible root exposures at all the sites measured in our subjects. The impacted canines had just come into their final position, whereas the control teeth had already been in the arch. Considering that, the greater PD in impaction group compared with the control group may be associated with pocket formation rather than recession of the gingival margin. Pseudo-pockets are considered physiologic on freshly erupted teeth and tend to decrease later, until the sulcus reaches a stable depth at the end of the orthodontic treatment (Magnusson et al., 1981).

The attached and keratinized gingivas measured to investigate the surgical approach (closed eruption technique) from the buccal surface had resulted in a significant reduction of attached gingiva compared to the control group. Some literatures stated that no significant differences were detected between the experimental and control teeth in the width of keratinized tissue (Crescini et al., 1994; Quirynen et al., 2000). However, Kohavi et al (Kohavi et al., 1984) reported that attached gingival width was significantly reduced following the alignment of buccal ectopic maxillary canines as compared with the contralateral canine, which is in parallel with our results. In our study, the control group had approximately 0.62 mm more attached gingiva than the impaction group. However, the width of attached gingiva in impaction group was less than 2 mm, which is considered physiologically inadequate (Lang and Löe, 1972). This may be due to the delayed remodeling of the periodontal structures, because simply reflecting a flap to expose an impacted tooth might have compromised the epithelial attachment (Frank and Long, 2002). Also, during the closed eruption technique, there was a need for alveolar bone removal for bonding the button type attaching device, which can result in the loss of supporting tissues. Insufficient buccal alveolar bone is then more susceptible to gingival recession (Hirschfeld, 1923; Sperry et al., 1977) and, during orthodontic treatment, this might be the another possible cause of loss in AGW. In addition, the movement of twisted ligature wire was accompanied consistantly during the orthodontic traction and the tension from the gingival fibers generated by tooth movement may accelerate gingival recession of the buccal surface. Although we speculated that the severity of the initial intraosseous position and inclination of maxillary impacted canines may affect on the periodontal health at the end of treatment, the simple and multiple regression analyses showed that the KGW and AGW were not correlated with pre−treatment orthodontic variables (α−angle, d−depth, s−sector, and Nolla's developmental stage). This indicates that KGW and AGW were not affected by the severity of the impaction.

The absence of an attached gingiva around the erupting canine may cause inflammation of the periodontium (Bishara, 1992; Lang and Löe, 1972) because of a weakened seal of the marginal tissue. In that case, tissue resistance to the stresses of mastication and function is less than the optimal, so more loss of periodontal support is possible if precautions are not taken to alleviate such potential problems (Vanarsdall and Corn, 1977). Therefore the preservation of a functional band of attached gingiva should be an important objective in the management of buccally impacted teeth with the orthodontic traction following closed eruption technique.

The buccal CCL in impaction group was 1.12 mm longer than control group ($P < 0.05$) (Table 6) and these observation indicated 1.12 mm apical movement of the free gingival margin compared to the control groups. And alveolar crest on the midbuccal side moved 1.20 mm more apically considering the 0.08 mm apical movement of the BPD. In other words, the apical movement of gingiva tissue, including the free gingiva margin and the gingival attachment to the tooth is less than the apical migration of alveolar bone. This means that a marginal gingiva without proper alveolar bone support can migrate apically, leading to root exposure during the retention period (Wennström, 1996). This result is in contrast to that of previous literatures (Becker et al., 2002; Vermette et al., 1995), which reported that the crown length of the central incisor uncovering with the closed eruption technique was similar to contralateral nonimpacted teeth in the same mouth. This different result might be due to differences in the teeth investigated or to the larger samples in our study. The difficulty in immediately placing the bracket in the correct position and the precise traction force through the twisted ligature wire which had been placed on buccal aspect of the canine during the surgery might erupt the canine in a rotated position. This procedure of derotating the canine could result in reduced attached gingiva on the buccal side and increased length of the crown (Parkin et al., 2013). Another reason might be the twisted wire acted as a foreign body on the buccal surface to induce plaque accumulation and inflammation, which cause a loss of the connective tissue attachment during the treatment (Boyd, 1984). Also impacted canines are in a state of partial eruption for a long period, during which time the surrounding gingival tissue is often constantly irritated by the sharp profile of twisted ligature wire and it may accelerate gingival recession of the buccal surface.

The mean CEJ−AC distances on mesial and distal sides were 0.89 mm, 0.82 mm longer, respectively, in the impaction group than in the control group ($P < 0.05$). RL was 1.78 mm shorter in the impaction group than in the control group ($P < 0.05$). Although pre−treatment orthodontic variables did not appear to influence RL in our sample, RL was affected by the Nolla's developmental stage at the beginning of treatment ($\beta = -1.380$, $P < 0.05$)(Table 8). This means that impacted canine is more developed at the beginning of treatment, impacted canine has a shorter RL at the end of treatment. However, possibly impacted teeth had inherently shorter root length. This hypothesis could not be tested in this study. There were significant differences in BS between two groups, which was in parallel with Kennedy et al (Kennedy et al., 1983), who suggested that buccal eruption permanent teeth appears to contribute to loss of interproximal bone support. Possible explanation of this result is the magnitude and type of orthodontic force. During the orthodontic treatment procedures of impacted canine, the use of light force (20–30g) was applicated to erupt the tooth (Mantzikos and Shamus, 1997; Oesterle and Wood, 1991; Starr, 1991). However, impacted teeth can rarely be repositioned in the alveolar process with eruptive force alone. Many movements including root torque movement, tipping, rotational movement are required so the force level can be as great as 150g (Profitt et al., 2000). Especially tipping forces have a greater potential to create hyalinized areas in the PDL at the level of the alveolar crest because a point of force application was applicated apart from the center of resistance of a tooth, which was created a lever effect and increases moment. For this reason, the side of an orthodontically erupted tooth receiving pressure was apt to show periodontal destruction and hyalinized areas, which were eliminated by PDL regeneration in conjunction with bone resorption from within the trabeculae. In addition, bone regeneration on the mesial surface of mesioangulated impacted maxillary canines occurs over a long distance and can be especially sensitive to the effect of periodontal inflammation (Hansson and Linder–Aronson, 1972; Hansson and Rindler, 1998). When soft tissue fibers on the tension side of a tooth are severed or torn, new bone is not formed and the integrity of the soft tissue barrier can be weakened (Kozlovsky et al., 1988; Pontoriero et al., 1987). In particular, the regression analysis showed that α–angle and d–depth influenced the distal CEJ–AC distance, which means that if the impacted canine is angled more mesially (to the horizontal) and localized with the deep depth to occlusal plane at the beginning of treatment, there is a high possibility that distal alveolar crest level is resorbed at the end of treatment ($P < 0.01$) The mean BPD difference between two groups at mesiolingual and distolingual sides was statistically significant ($P < 0.05$), but clinically negligible. However, a significant differences of BPD were not observed at the buccal sites (mesiobuccal, midbuccal and distobuccal sides), which is unexpected results. This implied that although a buccally impacted tooth might have a thinner buccal plate of bone and have a greater risk of attachment loss, some repair of alveolar bone dehiscences on teeth positioned significantly out of arch form might be possible if they are moved palatally into alignment (Engelking and Zachrisson, 1982; Karring et al., 1982). Nonetheless, it should be noted that the standard deviation of the measurements was greater in impaction group. This indicates a greater risk of pocket formation and alveolar bone loss on the impaction group.

This study used the split-mouth design which allows each subjects to serve as his or her own control. This eliminates the need for matching criteria and minimizes such variables as oral hygiene, gingival biotype, appliance design, force levels, retention duration, and difference in periodontal reaction. Also at the proximal surfaces, the clinical recordings of loss of attachment were supplemented by periapical x-ray measurements because of difficulties in obtaining satisfactory BPD. Meanwhile, this study should be interpreted with caution due to the following limitation: since our study was a retrospective study, it has high risks of selection, allocation, and treatment because this study includes only cases of unilateral deep infraosseous impactions, which were selected after treatment according to the reported entry criteria. Also buccally impacted canines might have a thinner alveolar bone and gingiva, and a greater risk of attachment loss (Hirschfeld, 1923; Sperry et al., 1977), however, both the periapical x-ray measurements and periodontal examination had a limitation to give information about the thickness of buccal alveolar bone and gingiva. In this study, a careful analysis of the periodontal tissue following the closed eruption technique of maxillary canines has been made, we remarked that the impacted canine has a small but clinically significant increase in the some parts of PD and BPD, reduction in mesial and distal BS, AGW and increased buccal CCL compared with the contralateral canine. Due to the progressive nature of periodontitis, even little damage to the supporting tissue associated with orthodontic treatment may be of great clinical importance (Jacobson, 1952; Morse, 1971; Schluger, 1968). Therefore, for fewer esthetic deformities and a more favorable prognosis for impacted canines in the orthodontic management of impacted canines, the clinician has to take account for protecting keratinized gingiva and preventing alveolar bone resorption on interproximal side during the treatment and retention period. Also periodontal complications associated with orthodontic eruption of impacted canines arise from inadequate oral hygiene (Moriarty, 1995), the orthodontists should take active measures to avoid inflammation and the patient demonstrated marginal oral hygiene, especially at the surgical sites. And incorporating additional supragingival and subgingival plaque control measures into the patient's daily routine, and more frequent professional appoints might have limited damage to the periodontium. In future research, additional study should be performed to investigate the changes on the periodontal tissues of impacted canine during long-term follow period with the results of this study by using recently developed technology, such as cone beam CT and 3-D imaging. These techniques could help visualizing aspects related to impacted canines (3-D location, neighboring teeth resorption, ankylosis) that may assist in treatment planning. In addition, the individual anatomical variation as well as gingival biotype which might have been affected periodontal structures and a keener appreciation of biologic interactions in the interpretation of many recurring clinical problems should be taken into account to future research.

V. Conclusion

The treatment of impacted canine can be considered successfully only if the forced eruption and the alignment lead the tooth to a stable position in the arch along with the presence of a healthy periodontium. In this study, buccally impacted maxillary canines may be successfully and safely relocated by orthodontic traction following closed eruption technique toward the center of the alveolar ridge. However, the impacted canine indicates a small but statistically significant gingival recession and proximal alveolar bone resorption compared with the contralateral canine after orthodontic traction following closed eruption technique. Also if the impacted canine was localized at the more mesial angulation (to the horizontal) and the deeper from occlusal plane at the beginning of treatment, the distance from CEJ to AC on distal side was increased significantly at the end of treatment.

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국 문 요 약

Closed eruption technique을 이용한 상악 협측 매복 견치의 수술적 노출 및 교정 치료 후 치주조직 변화

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연세대학교 강남세브란스병원 치과 교정과에 내원하여 Closed eruption technique 을 이용한 협측 매복 견치의 수술적 노출 및 교정 치료를 시행한 환자 54 명(남자 21 명, 여자 33 명)을 대상으로 하였다. 치료 후 평균 1.4 개월 뒤에 치근단 방사선사진 및 임상치주검사를 통하여 반대측 정상 맹출 견치와의 치아주위조직을 비교하였다. 또한 초진 파노라마 방사선 사진을 통하여 치료 전 매복 견치의 기울기, 측절치와의 위치관계, 교합평면에 대한 매복 깊이 및 치아 발육 정도에 따른 치료 후 치아 주위조직과의 관련성을 평가하였으며 다음과 같은 결론을 얻었다.

1. 매복 견치 측의 probing depth 는 협측 중앙면 및 근심 설측면에서 반대측 정상 맹출 견치에 비해 각각 0.20 mm, 0.25mm 깊었으며, bone probing depth 는 근, 원심 설측면 에서 각각 평균 0.24 mm, 0.48 mm 깊었다 ($P < 0.05$).
2. 매복 견치 측의 부착치은이 반대측에 비해 평균 0.62 mm 짧았으며 ($P < 0.01$), 협측 임상치관 길이가 평균 1.12 mm 길었다 ($P < 0.001$).
3. 매복 견치 측의 근, 원심 cemento-enamel junction 으로부터 alveolar crest 까지의 거리가 반대측에 비해 각각 평균 0.89 mm, 0.82 mm 길었으며 ($P < 0.001$), 근, 원심 bone support 가 각각 평균 7.30%, 8.80% 작았다 ($P < 0.001$).

4. 치료 전 매복 견치 위치가 수평 기준선에 대해 근심 경사가 크고 교합평면에 대해 깊이 매복되어 있을수록 치료 후 원심 cemento-enamel junction 으로부터 alveolar crest 까지의 거리가 유의성 있게 양의 상관관계를 나타내었다 ($P < 0.01$).

이상의 연구를 통하여 협측 매복 견치를 Closed eruption technique 을 이용하여 교정적으로 견인 시켰을 때 반대측 정상 맹출 견치에 비해 협측 치은 퇴축 및 인접면 치조골 소실이 일어남을 확인하였으며 치료 전 매복 견치의 매복 위치에 따라 치료 후 치아 주위조직과의 상관성이 있음을 알 수 있었다.

핵심되는 말: closed eruption technique, 협측 매복 견치, 치조골 소실, 치은 퇴축