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ORIGINAL ARTICLE

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Roots of the maxillary first and second molars in horizontal relation to alveolar cortical plates and maxillary sinus: computed tomography assessment for infection spread

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Abstract The purposes of this study were to investigate the horizontal relationship of the roots of maxillary molars with the cortical plates and the maxillary sinus and to investigate the influence of these relationships on the spread of odontogenic infection. Computed tomography images of 120 control subjects and 49 patients with infection originating in the maxillary first or second molar were investigated. In the control group, more than 60% of the first molar roots contacted both palatal and buccal cortical plates (Type A), while such contact was not seen in more than 60% of second molars. The floor of maxillary sinus was most frequently observed at the level between the bifurcation and apices of roots in both first and second molars. In patients with infection, cortical changes were more frequently seen on the buccal side than on the palatal side, and 80% of patients with buccal cortical change showed the position in which the buccal roots were close to the buccal cortical plate. Mucosal thickening of the maxillary sinus was found in 87.8%. The buccopalatal spread of odontogenic infection originating in the maxillary first and second molars was influenced by the horizontal root position in relation to the cortices.

Keywords Infection · Maxillary sinus · Upper molar · X-ray computed tomography

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Introduction

Various pathways for odontogenic infection have been reported depending on the causal teeth [1–6]. Among these, infection originating in the maxillary first and second molars frequently spread into the maxillary sinus [1, 7–9]. In some cases, infection also spread to the buccal side and involved soft tissue structures, including the buccinator and masseter muscles [1, 10–14]. We demonstrated that odontogenic infections originating in these teeth such as apical or marginal periodontal lesions spread to the surrounding structures on CT images [1]. Through this study, we hypothesized that the anatomical relation of the root to the alveolar cortices and maxillary sinus may decide spread ways, whether buccal cellulites, maxillary sinusitis, or both.

Many studies have been performed on the vertical relationship between the root apex and the maxillary sinus floor using computed tomography (CT) [4, 15, 16]. A close vertical relation of the root to the sinus floor is reported to be a risk factor for maxillary sinusitis [4, 15]. The horizontal root location may influence degree of sinus change, when marginal periodontal lesions cause maxillary sinusitis. The horizontal relationship between the root and alveolar cortex may also influence the buccolingual spread of infection. However, there are no known reports addressing these horizontal relationships.

The purpose of the present study was to clarify the horizontal relationship of the root with the maxillary sinus and the alveolar cortex on CT images in control subjects. Moreover, we investigated influences of this relationship on infection spread.

Materials and methods

Control subjects

Control healthy subjects were retrospectively selected from the CT database at the department of Radiology and Diagnostic Imaging, Aichi-Gakuin University Dental Hospital, between 1996 and 2003. Criteria of selection were as

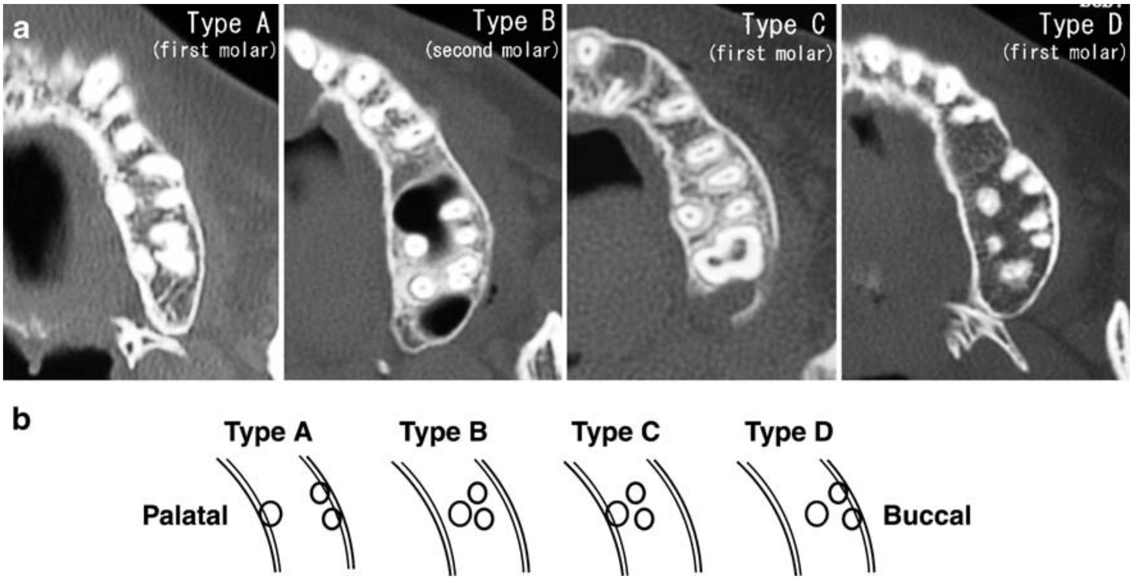

Fig. 1 Types of horizontal root position on CT image (**a**) and schematic drawing (**b**). On CT images, the first molars show the typical appearance of each type. *Type A*, all three roots are observed in contact with the buccal or palatal plates. *Type B*, there are no roots in contact with the cortical plates. *Type C*, the palatal root is observed in contact with the palatal cortical plate, but the buccal roots are not adjacent to the cortices. *Type D*, the palatal roots are not in contact with the cortices, but the buccal roots are close to the buccal plate

follows: CT scanning around the maxilla was performed on patients. Patients had normally erupted bilateral first and second molars and had neither definitive root resorption nor bony destruction around the teeth. Teeth in marked dislocation and without three clearly identified canals were also excluded. From this selected database, we picked up 20 patients (ten women and ten men) for each decade (from the second to the seventh decade) by the continuous sampling from the latest patients. They underwent CT examination under diagnosis of tumor, cyst or inflammation of the parotid gland, mandibular ramus, temporomandibular joint or coronoid process, or atypical trigeminal or facial neuralgia, and so on. Ultimately, a total of 480 molars in 120 patients were evaluated.

Computed tomography images were obtained with a Somatom ART (Simens AG, Erlangen, Germany) and HiSpeedNX/Ipro (GE Medical Systems, Tokyo, Japan). Scans were performed with a slice thickness of 2 or 3 mm, and the scan plane was parallel to the occlusal plane.

The horizontal root positions of the first and second molars were evaluated according to contact with the cortical plate on CT slices between the levels of bifurcation and the root apex. The position patterns were classified into the following four groups (Fig. 1): Type A, all three roots were observed in contact with the buccal or palatal plates; Type B, there were no roots in contact with the cortical plates; Type C, the palatal root was observed in contact with the palatal cortical plate, but the buccal roots were not adjacent to the cortices; and Type D, the palatal roots were

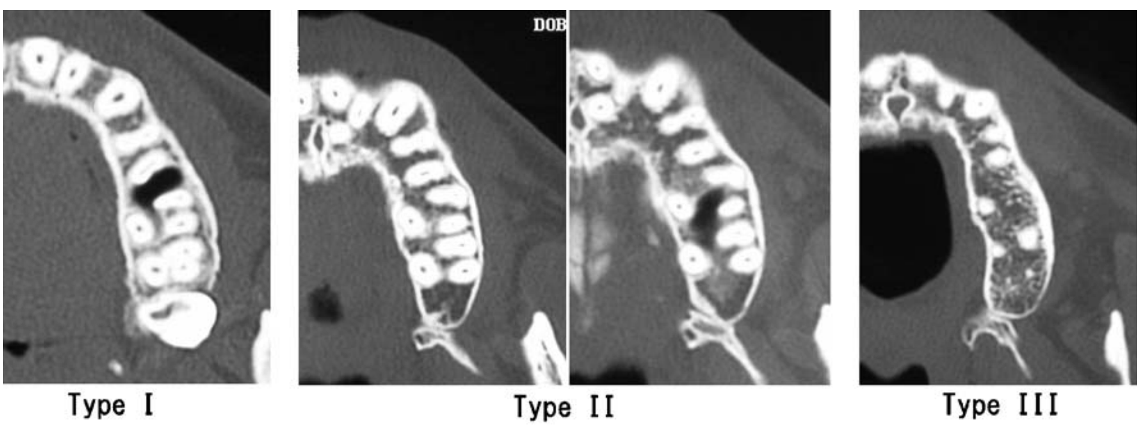

Fig. 2 Relationship between the root and the maxillary sinus. In the type I relationship, the maxillary sinus can be observed adjacent to the roots of the maxillary first molar at the level of bifurcation. In type II, the sinus can be observed adjacent to the roots at the level of the root apices (*left image*), but it cannot be seen at the bifurcation (*right image*). In the type III relationship, the sinus cannot be seen even at the level of the root apices

Table 1 Horizontal root position in normal subjects

Age	First molar				Second molar			
	A	B	C	D	A	B	C	D
10–19	22	5	11	2	2	20	18	0
20–29	22	7	4	7	3	27	10	0
30–39	29	5	2	4	1	27	10	2
40–49	26	6	7	1	0	26	11	3
50–59	25	4	4	7	2	30	8	0
60–69	27	3	1	9	2	23	10	5
Total	151 (62.9%)	30 (12.5%)	29 (12.1%)	30 (12.5%)	10 (4.2%)	153 (63.8%)	67 (27.9%)	10 (4.2%)

Root positions A–D are shown in Fig. 1

not in contact with the cortices, but the buccal roots were close to the buccal plate.

The relationship between the teeth and the maxillary sinus was also classified into the three types according to the visibility of the sinus (Fig. 2). In type I relationship, the maxillary sinus could be observed at the level of bifurcation, namely, the sinus was visible adjacent to the roots at the lowermost level where the three roots were could be seen separately. In type II, the sinus could be observed adjacent to the roots at the level of root apices, but it could not be seen at the bifurcation. Type III relationship showed that the sinus could not be seen even at the level of root apices.

Mucosal thickening of the maxillary sinus was defined as the existence of soft tissue structures over 4 mm in thickness close to the root.

These evaluations were performed by two dentists with sufficient experience in CT diagnosis. The final determination was reached by consensus after discussing if the evaluations initially differed between the two observers.

Patients with odontogenic infection originated in the maxillary molars

One hundred thirty-seven patients were examined by CT between 1996 and 2003 under a clinical diagnosis of odontogenic infection originating in the maxillary teeth because these patients complained of some symptoms such as buccal swelling and pain, fistula, and trismus and dysphagia, and the conventional radiography and physical examination could not make clear the extent of infection. Among these, 49 patients were enrolled in this study based on the criteria of patients with infection originating in the first and second molars, which had been definitively identified and not missed during the examination. The causal teeth and diseases were carefully identified with reference to CT features, conventional radiographic appearances, clinical records, and clinical courses after treatment. Patients with tumor, dental implants, and a history of surgery or radiotherapy were excluded. Thirty-seven infections originated in the first molar, and 12 infections originated in the second molar. In 34 patients, inflammatory disease originated in periapical lesions, including infection of radicular cyst. In 11 patients, the cause was supposed to be a marginal periodontitis. In the remaining four patients, the cause could not be determined. In 23 of 34 patients with periapical infection, the causal roots with the most severe changes could be identified. Ten patients showed involvement in the palatal root, ten showed involvement in the buccal root, and three showed involvement in both roots.

Computed tomography examinations were performed with the same equipment and in the same way as in control subjects. CT images were evaluated by the same dentists who assessed the CT images of control subjects regarding the types of horizontal aspects of root and infectious involvements. When the cortical plate had disappeared around the root, the root position pattern was determined with reference to the remaining cortical plate of the adjacent tooth. Bony change was evaluated with reference to interruption or thinning of the alveolar cortical plate surrounding the causal tooth in both the buccal and palatal

Table 2 Relationship between the root and sinus in normal subjects

Age	First molar			Second molar			Mucosal thickening
	I	II	III	I	II	III	
10–19	6	29	5	2	24	14	6
20–29	4	32	4	0	30	10	9
30–39	1	34	5	0	33	7	9
40–49	0	34	6	0	28	12	7
50–59	0	31	9	0	26	14	15
60–69	0	26	14	0	23	17	16
Total	11 (4.6%)	186 (77.5%)	43 (17.9%)	2 (0.8%)	164 (68.3%)	74 (30.8%)	62 (25.8%)

Relationship I–III are shown in Fig. 2

Fig. 3 Mucosal thickening was found in the left maxillary sinus of a normal subject

sides. The involvement of soft tissue was evaluated for buccinator and masticatory muscles. Maxillary sinus change was evaluated for mucosal thickening, fluid accumulation, and bony wall thickening. Mucosal thickening was considered positive when soft tissue with 4 mm or more thickness [6] was continuous to the root of the causal tooth and greater than that in the contralateral sinus. The final determination was reached by consensus after discussing if the evaluations differed between the two observers.

Differences in pattern distributions were evaluated by a chi-square test, with significance accepted at $p<0.05$.

Results

Control subjects

As for the horizontal root position, a discrepancy between the right and left patterns was found in 35 (29.2%) and 22 (18.3%) subjects for the first and second molars, respectively. Therefore, each sinus was analyzed separately. In the first molar, type A was observed most frequently in 151 teeth (62.9 %), while the other three types were demonstrated in approximately equal proportions (Table 1). For the second molar, 153 (63.8%) teeth showed type B appearance followed by type C (27.9 %). The pattern distribution significantly differed between the first and second molars ($p<0.001$, chi-square test). There was no gender and age difference in the pattern distribution.

As for the relationship between roots and sinus, discrepancies between the right and left types were seen in 21 (17.5%) and 27 (22.5%) subjects for the first and second molars, respectively. Although type II was most frequently observed in both the first and second molars, type III showed an increased incidence, and type I showed a decreased incidence in the second molar (Table 2). Type I relationship was found predominantly in the early decade.

Mucosal thickening of the maxillary sinus was found in 62 (25.8%) sinuses of 49 subjects (Table 2) (Fig. 3). In 13 subjects, it was seen in the bilateral sinuses. The incidence was higher among subjects 50 years of age or older.

Patients with odontogenic infection originated in the maxillary molars

The distribution of types of horizontal root position in the patient group was similar to that in normal subjects. Type A was predominant for the first molar, and Type B was predominant for the second molar (Table 3). There was no difference in the distribution of types between the control and infection groups (chi-square test).

Twenty patients had cortical changes in the buccal side, and 11 patients had the palatal changes (Table 3). Cortical changes were more frequently observed on the buccal side than on the palatal side (Fig. 4). In 20 patients with buccal cortical change, 16 (80%) patients showed type A or type D position, in which the buccal roots were close to the buccal cortical plate. In 8 (73%) of 11 patients with palatal cortical change, type A or C position was observed. As for the causal root and cortical involvements, there were no patients with buccal involvement whose infection originated solely in the palatal root, and there were no patients with

Table 3 Summary of CT findings in patients

		First molar (n=37)				Second molar (n=12)				
Root position		A	B	C	D	A	B	C	D	Total
		26	5	2	4	1	8	2	1	49
Changes on CT										
Cortical change	Buccal	12	1	–	2	1	3	–	1	20
	Palatal	7	–	1	2	–	–	–	1	11
Muscle change	Buccinator	3	–	–	2	–	3	–	–	8
	Masseter	1	–	–	–	–	1	–	–	2
	Medial pterygoid	–	–	–	–	–	1	–	–	1
	Temporal	–	–	–	–	–	1	–	–	1
Sinus change		22	5	2	4	1	6	2	1	43

Root position A–D are shown in Fig. 1

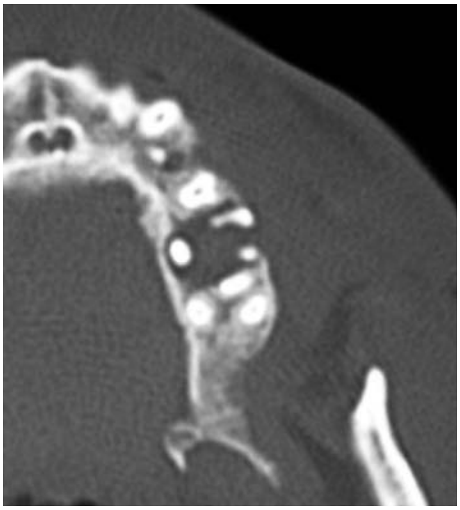

Fig. 4 Disappearance of the buccal cortical plate was clearly observed adjacent to the buccal roots of the maxillary first molar in a patient with odontogenic infection

palatal involvement whose infection originated solely in the buccal root.

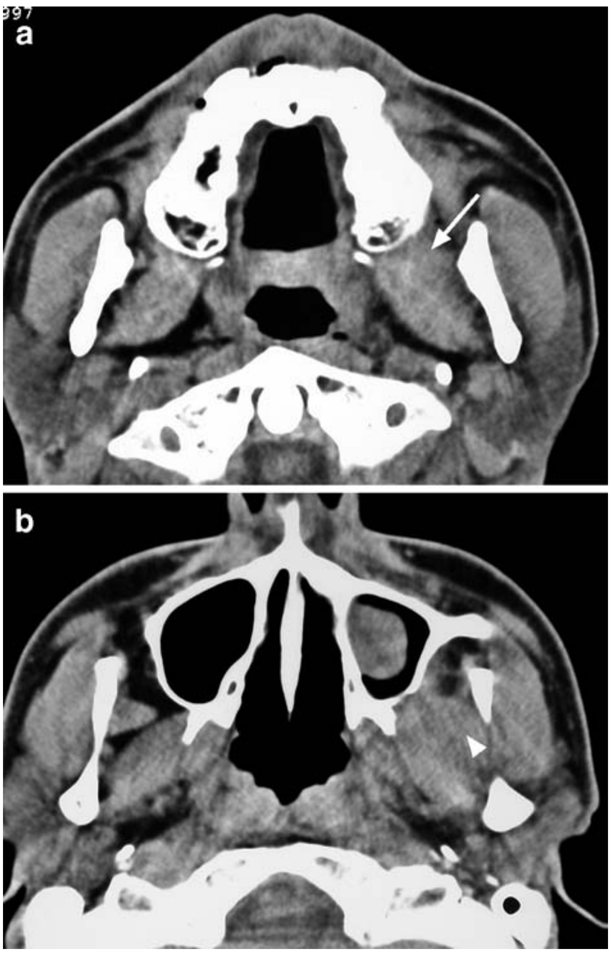

Fig. 5 Axial CT image of a patient with a second-molar infection demonstrates enlargements of the medial pterygoid (*arrow*; **a**) and temporal muscles (*arrow head*; **b**)

There were no patients with involvement in the lateral pterygoid muscle. Buccinator muscle was involved in five and three patients with infection originating in the first and second molars, respectively. Of these eight patients, two patients showed involvement in the masseter muscle, and one patient showed simultaneous involvements in the medial pterygoid and temporal muscles. In the latter patient, infection originated in the second molar (Fig. 5). There was no relationship between the types of horizontal root position and the state of muscle involvements because of the small number of patients showing muscle involvement.

Forty-three (87.8%) patients showed some changes in the maxillary sinus; that is, 33 patients (89.2%) originated in the first molar, and ten patients (83.3%) originated in the second molar. There was no difference in frequency of sinus change between the two molars. There was significant difference in frequency of sinus change between the control and infection groups ($p<0.01$). Although mucosal thickening was the most frequent appearance, most patients with this change showed few sinus symptoms. Severe symptoms such as pain and nasal obstruction were observed

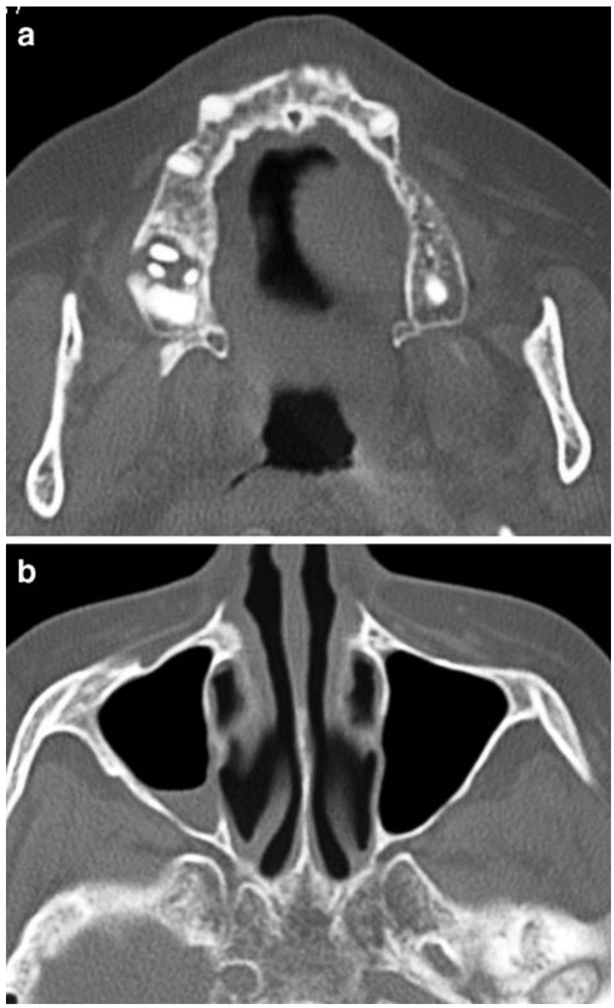

Fig. 6 Axial CT image shows formation of an air–fluid level in the right maxillary sinus (**b**) caused by infection originating in the maxillary second molar (**a**)

only in three patients with fluid accumulation (Fig. 6). Two patients showed bony wall thickening, indicating a relatively long-term inflammation. There was no difference in the sinus involvement rate between marginal and apical lesions as the origins of infection. There was no correlation between sinus change and type of horizontal root positions.

Discussion

Buccopalatal spread of odontogenic infection depends on various factors. In the present patient, there were no palatal or buccal cortical changes in patients with only buccal or palatal root infection, respectively. This result supported that the position of the causal root, whether palatal or buccal, primarily influenced the buccopalatal spread. However, this could not explain the higher incidence of buccal spread that could be verified in a clinical investigation [1] because the frequency of apical lesion was found to be almost equal between the palatal and buccal roots in the present study. Therefore, the relationship between the root and cortical plates should be considered. In normal subjects, there was a difference in the distribution of root position patterns between the first and second molars. In the first molars, the roots contacted the buccal and palatal cortical plates in more than 60% (type A), and the buccal roots contacted the buccal cortical plates in approximately 75% (type A or D position). On the other hand, more than 60% of second molars had roots without contact to the cortical plates (type B). This finding may be consistent with the anatomical observation that the roots of the posterior tooth tend toward fusion with each other [17], and that the distance from the buccal cortical surface is smaller in the buccal roots of the first molar than those in the second molar [3, 9, 15]. Originally, the first molar exists in the oral cavity much longer than the second molar; therefore, frequency of periapical infection may be higher. Furthermore, infection originating in roots contacting the buccal plates may be more likely to spread extensively into buccal structures than that of roots not contacting the buccal plates. CT examination is probably applied to infection spreading widely in bony and surrounding structures, and therefore, this may be why a larger number of patients showed infection originating in the first molar than in the second molar. Based on these findings, we concluded that anatomical relations between the root position and the cortical plates might influence the spread of odontogenic infection originating in the maxillary molars.

The relationship between the root and maxillary sinus location may influence the infection spread to the maxillary sinus. In this regard, many studies have been carried out using CT to investigate the maxillary sinus morphology [7, 9, 18]. Based on CT analyses, the distance of root apices to the floor of the maxillary sinus is reported to be smallest in the mesiobuccal root of the second molar among the maxillary posterior teeth [15, 19]. According to this anatomical observation, maxillary sinus change is supposed to be more frequently seen at the root apices of the second molar than that of the first molar. In the present study, however, there was no difference in frequency of sinus change between the two molars. When the sinus change caused by periapical lesion is taken into account, these observations would be useful to discuss infection spread in the odontogenic origin. However, sinus change is not always caused by periapical lesions. Marginal periodontitis could be a cause of sinus change as confirmed in the present study. Eleven of 49 patients were considered to have marginal periodontitis as a cause of odontogenic infection. The classification presented here would be effective to analyze sinus change and the relationship between the root and sinus locations. In normal subjects, the most frequently observed relationship was type II for both the first and second molars. Namely, the sinus was adjacent to the roots between the level of bifurcation and the apices. This finding indicates that severe marginal periodontitis such as lesion expanding into the bifurcation can easily induce a change in the sinus close to the lesion. In patients of the present study, the relationship between the root and sinus could not be evaluated because the sinus could not be differentiated from the bony resorption caused by odontogenic infection. However, patients actually showed the sinus changes with high frequency, and this clinical findings may be supported by such anatomical relationship as seen in the control group.

Based on the report of Yoshiura et al. [7], mucosal thickening was defined as positive in the present study when the mucosa was more than 4 mm in thickness. Patients who only demonstrated mucosal thickening were not associated with severe symptoms in the affected sinus. Severe symptoms such as nasal obstruction and pain were seen in the patients with a finding of fluid level formation. However, mucosal thickening may be a characteristic feature due to infection spread from a causal tooth because it could be observed in only 25.8% sinuses of normal subjects.

As for the spread to surrounding muscles, the buccinator muscle was most frequently involved in both the first and second molars. Anatomical location of the buccinator muscle can explain the result. Masseter muscle involvement was seen in both teeth, but involvements of the medial pterygoid and temporal muscles were observed only in second-molar infection. Although a study with a sufficient number of patients is needed, infections originating in these two teeth may show different spread patterns.

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