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Classification and characteristics of pterygoid process fracture associated with maxillary transverse fracture

Jingang An, MD,[a] Fanfan Dai, MD,[b] Zhipeng Sun, MD,[c] and Yi Zhang, MD[d]
School and Hospital of Stomatology, Peking University, Beijing, China

Objective. This study aimed to classify pterygoid process fractures associated with maxillary transverse fractures.
Study Design. Pterygoid process fractures in 100 patients with maxillary transverse fractures were observed 2- and 3-dimensionally using image processing software. Fracture line course and height and sphenoid sinus involvement were recorded.
Results. Pterygoid process fractures were classified as follows: class I, vertical (simple separation between medial and lateral plates); or class II, transverse (3 subcategories according to location of fracture line: II-1, within pterygoid fossa; II-2, above pterygoid fossa, not extending to sphenoid sinus floor; II-3, above pterygoid fossa, involving sphenoid sinus floor). Class I fracture was observed on 5 sides (2.7%); II-1, on 125 (66.5%); II-2, on 36 (19.1%); and II-3, on 22 (1.7%).
Conclusions. Pterygoid process fractures were predominantly near the upper edge of the pterygoid fossa. Pneumatization of the pterygoid process is a risk in fractures involving the sphenoid sinus floor. (Oral Surg Oral Med Oral Pathol Oral Radiol 2014;117:243-252)

The LeFort classification of maxillary transverse fracture remains in wide use after almost a century. The common feature of the 3 types of LeFort fracture is that the sphenoid pterygoid process is involved[1,2]; indeed, some authorities believe that the presence of a pterygoid process fracture almost always predicts the presence of a LeFort maxillary fracture.[3] However, because it is located deep in the posterior part of the maxilla, certain aspects of pterygoid process fracture have not been reported in detail in the literature, owing to the limitations of the imaging techniques in the past. An example is the pattern of pterygoid process fracture lines associated with maxillary transverse fracture: are they also transverse, or do they involve separation between the medial and lateral plates or between the pterygoid process and the maxilla? Do the different levels of LeFort fracture correlate with different levels of pterygoid process fracture? In the previous literature, the characteristics of the pterygoid process fracture caused by maxillary LeFort I osteotomy were discussed, and some simple classifications were made, but literature discussing the classification of pterygoid process fracture associated with maxillary LeFort fractures was rare.[4-8] In this study, medical image processing software was used to view 2- and 3-dimensional computed tomography (CT) images of maxillary transverse fractures from different perspectives. The characteristics of the pterygoid process fractures associated with the maxillary transverse fracture were observed and combined with clinical data to classify pterygoid process fracture.

MATERIALS AND METHODS

The participants were patients with maxillary transverse fracture who were admitted to the Oral and Maxillofacial Surgery Trauma Center at the School and Hospital of Stomatology, Peking University, between January 2007 and October 2011. All patients included in the study met the following criteria: (1) maxillary fracture was recorded in the medical records and confirmed by preoperative CT, and the surgical records showed that maxillary fracture reduction and fixation were performed; (2) complete clinical data were available, including detailed medical records, preoperative facial and occlusal photos, and preoperative CT of the head; (3) the time between the injury and admittance was less than 2 months, no surgical fracture reduction or fixation had been performed, and the maxillary

[a]Associate Professor, Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology.
[b]Resident, Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology.
[c]Attending Physician, Department of Oral Radiology, Peking University School and Hospital of Stomatology.
[d]Professor, Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology.
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Statement of Clinical Relevance

This article summarizes the characteristics of pterygoid process fractures associated with maxillary transverse fractures and provides a classification for pterygoid process fractures. The result can help oral and maxillofacial surgeons and radiologists understand the features of pterygoid process fractures.

Table I. LeFort classification and characteristics of bilateral maxillary fractures (89 cases)

Single-line fractures				*Multiline fractures*				
Bilateral consistent			*Bilateral inconsistent*	*Bilateral consistent*			*Bilateral inconsistent*	
I	II	III		I + II	I + III	II + III	I + II + III	
14	7	4	13	8	1	3	13	26
15.7%	7.9%	4.5%	14.6%	9.0%	1.1%	3.4%	14.6%	29.2%

transverse fracture had been classified according to the LeFort classification.

A total of 100 cases met the inclusion criteria for this study (86 male, 14 female), with a mean age of 33.7 years (range, 14-59 years). The causes of the fractures were traffic accidents (75 cases), work-related injuries (13), falls (9), blast injury (2), and violent injury (1). The mean time from injury to admittance was 19.3 days, with a range of 1 to 50 days.

Head CT images were reconstructed using image processing software (Mimics, version 10.01; Materialise, Leuven, Belgium), and maxillary LeFort fractures were identified from axial, coronal, sagittal, and 3-dimensional images. Pterygoid process fractures were observed on axial, coronal, and sagittal images. To obtain reconstructed 3-dimensional maxillofacial images, the mandible, the cervical vertebrae, and the rear of the skull, which obstruct views of the pterygoid process from the posterior and both sides, were removed; the back and sides of both pterygoid processes were then completely visible in 3 dimensions. The information obtained from the 2-dimensional and 3-dimensional images allowed us to determine the pattern of pterygoid process fracture lines, fracture level, and extension to the sphenoid sinus, and ultimately to classify pterygoid process fracture associated with maxillary transverse fracture. The default threshold (226-3071HU) for bony tissue in Mimics was used to segment these CT images.

Statistical analysis was conducted with statistical software (SPSS, version 11.0; SPSS Inc, Chicago, IL, USA) using the χ^2 test and the nonparametric Kruskal-Wallis test. Statistical significance was set at $P < .05$.

RESULTS

The 100 cases had a total of 189 sides with maxillary fractures, with unilateral fracture in 11 (11 sides) and bilateral fracture in 89 (178 sides). The characteristics of the fracture lines in the 89 bilateral maxillary fractures are shown in Table I. The 189 sides with maxillary fractures in this sample corresponded to 188 sides with pterygoid process fractures. The pterygoid process fracture was unilateral in 12 cases (12 sides), 11 of which had a unilateral maxillary fracture (with 1 case of bilateral maxillary fracture), and bilateral in 88 cases (176 sides), with 96 left sides and 92 right sides affected. The relationship between the maxillary fractures and pterygoid process fractures is shown in Table II (χ^2 test; $P < .05$). These findings indicate that there is a correlation between maxillary fracture and pterygoid process fracture, unilateral maxillary fracture being associated with unilateral pterygoid process fracture and bilateral maxillary fracture with bilateral pterygoid process fracture.

Table II. Relationship between maxillary fracture and pterygoid process fracture (cases)

Type	*Unilateral pterygoid process fracture*	*Bilateral pterygoid process fracture*	*Total*
Unilateral maxillary fracture	11	0	11
Bilateral maxillary fracture	1	88	89
Total	12	88	100

Based on the characteristics of the pterygoid process fractures observed in this sample, the following classification was established: class I, pterygoid process vertical fracture (simple separation between the medial and lateral plates); or class II, pterygoid process transverse fracture, which was further divided into 3 subcategories: II-1, fracture line located within the pterygoid fossa; II-2, fracture line located above the pterygoid fossa, not extending to the floor of the sphenoid sinus; II-3, fracture line located above the pterygoid fossa and involving the floor of the sphenoid sinus (Figures 1 to 5).

According to this classification, the 100 cases (188 sides) comprised 138 sides with simple fractures (73.4%) and 50 sides with complex fractures of 2 or 3 types (26.6%); 48 involved 2 types, and 2 involved 3 types. Thus, there were 240 fracture sites in total (Table III). Of the 50 complex fractures, 44 were single transverse fractures with separation between the medial and lateral plates (Figure 6); 4 were transverse fractures both above and below the upper edge of the pterygoid fossa (Figure 7); and 2 were transverse fractures both above and below the upper edge of the pterygoid fossa with separation between the medial and lateral plates. The distribution of pterygoid process fractures, including simple and complex fractures, is shown in Table IV.

Among the 138 sides of simple pterygoid process fracture, there were 75 sides of single-line maxillary fracture and 63 sides of multiline maxillary fracture.

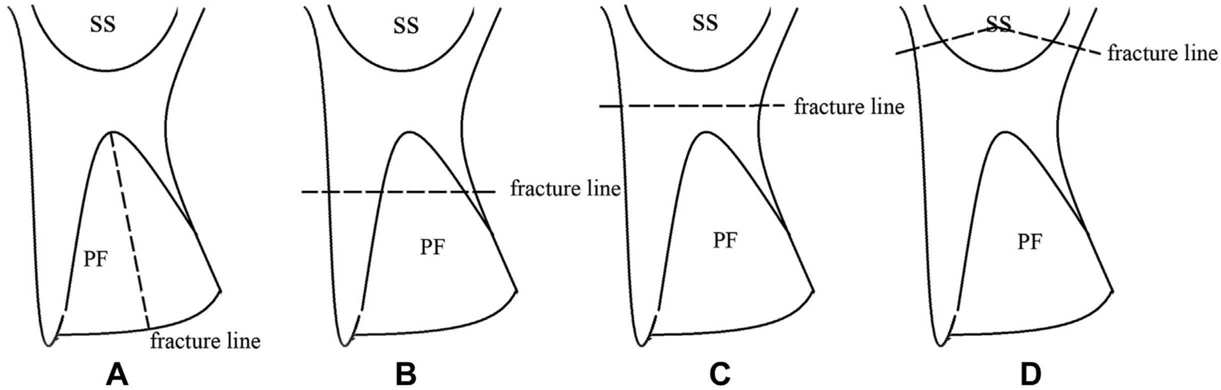

Fig. 1. Diagram of a coronal section of the right pterygoid plate, showing the classification of pterygoid plate fractures. A, Class I, vertical fracture. B, Class II-1, transverse fracture, fracture line located within the pterygoid fossa. C, Class II-2, transverse fracture, fracture line located above the pterygoid fossa and not extending to the floor of the sphenoid sinus. D, Class II-3, transverse fracture, fracture line located above the pterygoid fossa with sphenoid sinus floor involvement. (*SS*, sphenoid sinus; *PF*, pterygoid fossa.)

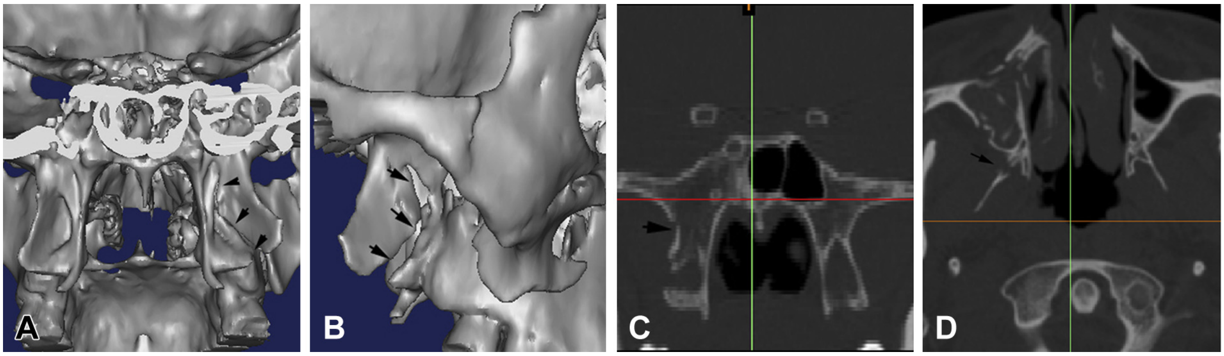

Fig. 2. Pterygoid process class I fracture. Vertical fracture of the pterygoid lateral plate; no fracture in the medial plate.

Among the 50 sides of complex pterygoid process fracture, there were 22 sides of single-line maxillary fracture and 28 sides of multiline maxillary fracture (Table V) (χ^2 test; $P > .05$). These results suggest that there is no relationship between the comminution degree of the pterygoid process fracture and that of the maxillary fracture.

Based on the highest fracture line on each side, class I fractures were identified on 5 sides (2.7%), II-1 on 125 sides (66.5%), II-2 on 36 sides (19.1%), and II-3 on 22 sides (1.7%). Most of the class II-1 fracture lines were located near the upper edge of the pterygoid fossa; the II-2 fracture lines were located above the pterygoid fossa but also close to the upper edge of the pterygoid fossa. Together, class II-1 and II-2 accounted for 161 sides in total (85.6%). The maxillary fractures were analyzed in a similar manner (Table VI). The Kruskal-Wallis test found no relationship between the height of the maxillary fracture line and that of the pterygoid process fracture line ($P > .05$), which means that when the maxillary fracture is located high, the corresponding pterygoid process fracture is not necessarily high, and vice versa.

Among the 51 cases of bilateral maxillary fracture in which both fractures were located at the same level, the 2 pterygoid process fracture lines were located at the same level in 36 cases and at different levels in 15 cases. Among the 38 cases of bilateral maxillary fracture in which the 2 fractures were located at different levels, the 2 pterygoid process fracture lines were located at the same level in 24 cases and at different levels in 14 cases (Table VII) (χ^2 test; $P < .05$). These results suggest that the level of bilateral maxillary fracture lines does not predict the level of the associated bilateral pterygoid process fracture lines.

Of the 100 cases in this sample, 36 had sphenoid sinus fractures. Of those, 23 had associated fractures in the nasal-orbital-ethmoid region, with CT showing frontal, ethmoid, and sphenoid sinus fractures (Figure 8), and 5 (7 sides) had class II-3 pterygoid process fractures; the other 13 cases had sphenoid sinus floor fractures, and all (15 sides) had class II-3 pterygoid process fractures. The sites of the sphenoid sinus fractures were the sinus floor in 18 cases (22 sides), the anterior wall in 18, the lateral wall in 8, the sinus

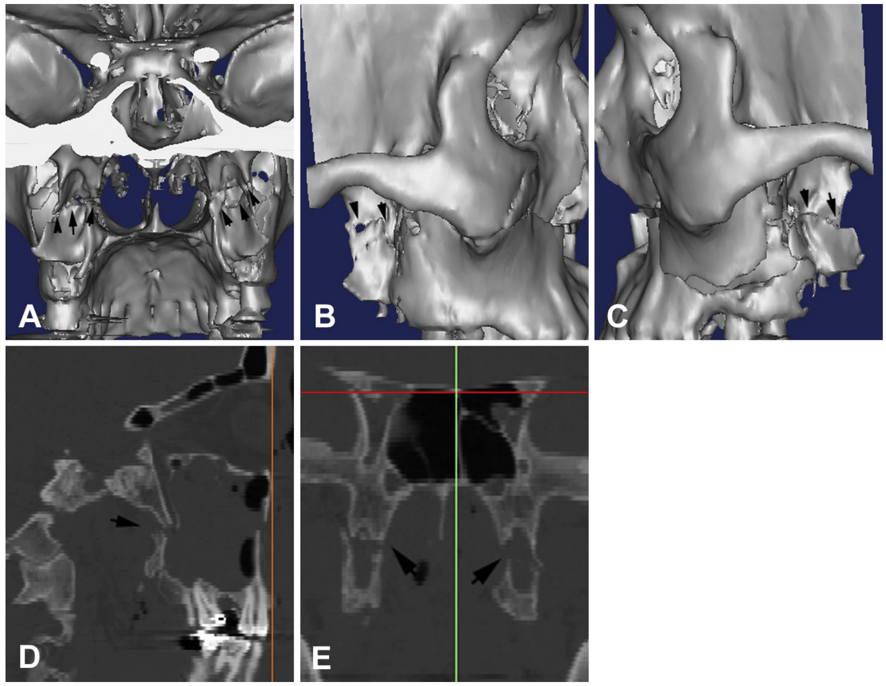

Fig. 3. Bilateral pterygoid process class II-1 fracture. Bilateral transverse fractures; the fracture lines are located within the pterygoid fossa, below the upper edge of the pterygoid fossa.

septum in 2, and the top wall in 1. The fracture extended close to the middle cranial fossa in 1 case.

Among the 100 cases, the sphenoid sinus air cell spread into the root of the pterygoid process in 29 cases (54 sides); that is, there was pneumatization of the root of the pterygoid process. Of these 29 cases, 25 were bilateral and 4 were unilateral. Eighteen cases (22 sides) had class II-3 pterygoid process fractures, of which 14 (18 sides) had a large sphenoid sinus and pneumatization of the corresponding pterygoid process; the other 4 (4 sides) showed no pneumatization. The correlation between pneumatization of the pterygoid process and class II-3 fracture for all 189 sides is shown in Table VIII (χ^2 test; $P < .05$). The results indicate that pneumatization of the pterygoid process is a risk in high-level pterygoid process fractures that extend to the sphenoid sinus floor.

DISCUSSION

The sphenoid pterygoid process extends inferiorly from the junction between the body of the sphenoid and the greater sphenoid wing. Each pterygoid process comprises 2 plates, the medial and the lateral. The lateral plate is wide and thin, with its lateral surface facing anteriorly and exteriorly. The medial plate is long and narrow; its lower end turns sharply and curves laterally at its inferior margins into a hook-like process called the pterygoid hamulus. The 2 plates fuse anteriorly and superiorly, and they diverge inferiorly to form the pterygoid fissure, containing the pyramidal process of the palatal plate. The superior and anterior parts of the pterygoid process are separated from the posterior of the maxilla by the pterygomaxillary fissure, whereas the inferior and anterior areas of the pterygoid process connect with the posterior part of the maxilla to form the pterygomaxillary ligament at the pterygomaxillary junction.[9] Thus, the superior part of the sphenoid pterygoid process connects to the base of the middle cranial fossa, whereas its anterior and inferior parts connect to the posterior of the maxilla. Anatomically, the pterygoid process is closely related to the maxilla, and together they constitute the midfacial vertical pterygomaxillary buttress. Some authors suggest that, although they are anatomically components of the basisphenoid, the pterygoid processes are functionally more closely allied with the facial skeleton, and pterygoid process fracture may be more appropriately considered a facial injury.[10]

Through anatomic and histologic studies, Melsen and Ousterhout[11] found that at the inferior part in the calcifying areas of the maxillary tuberosity, the pyramidal process of the palatine bone and the pterygoid process of the sphenoid bone were seen to approach each other through a sheet of loose fibrous tissue. But in the late juvenile and the adolescent stages, there were closed complex connections along these bones, and disarticulation invariably led to bony fractures.

Unger et al.[10] reported 111 cases of craniofacial fractures, 78 of which had fractures of the sphenoid

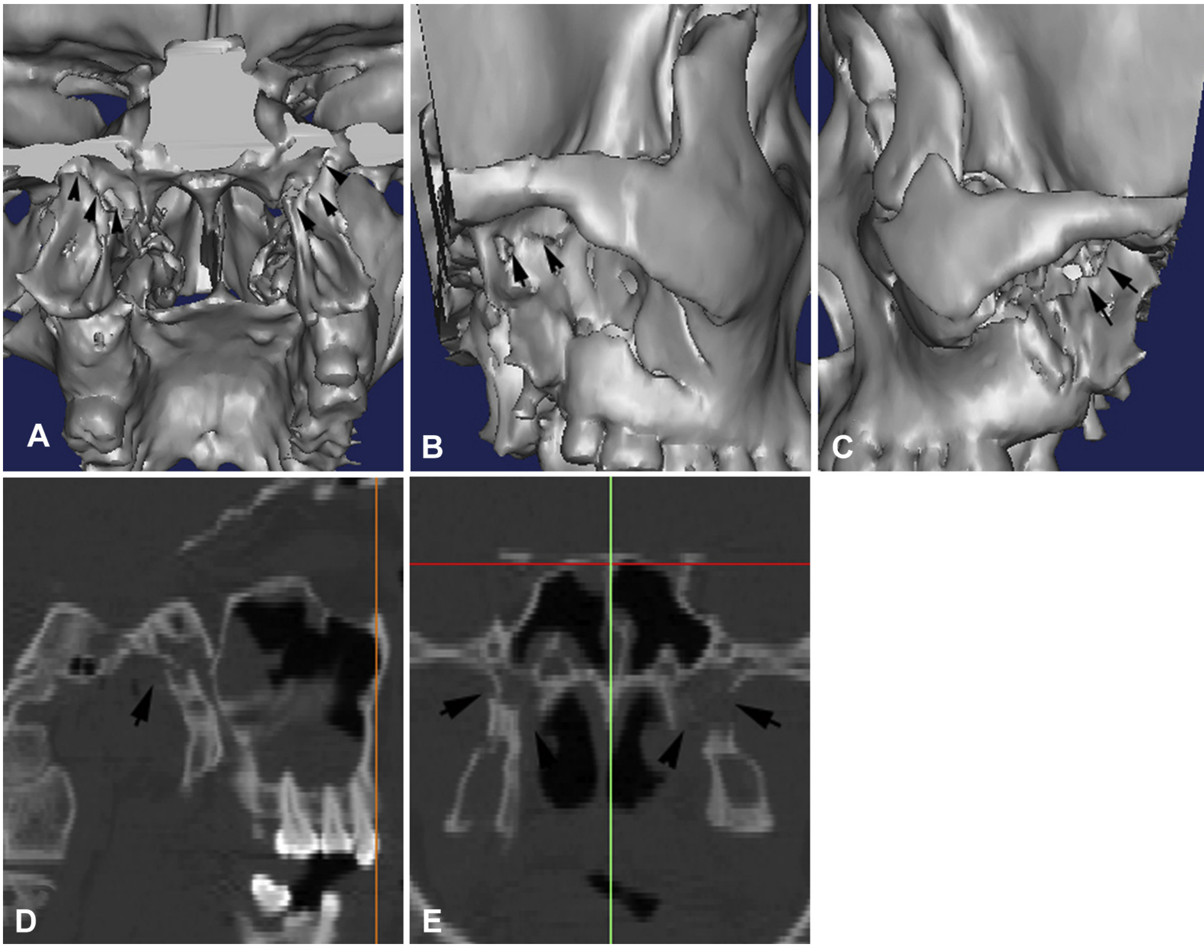

Fig. 4. Bilateral pterygoid process class II-2 fracture. The fracture lines are located above the pterygoid fossa and below the base of the skull, not extending to the floor of the sphenoid sinus.

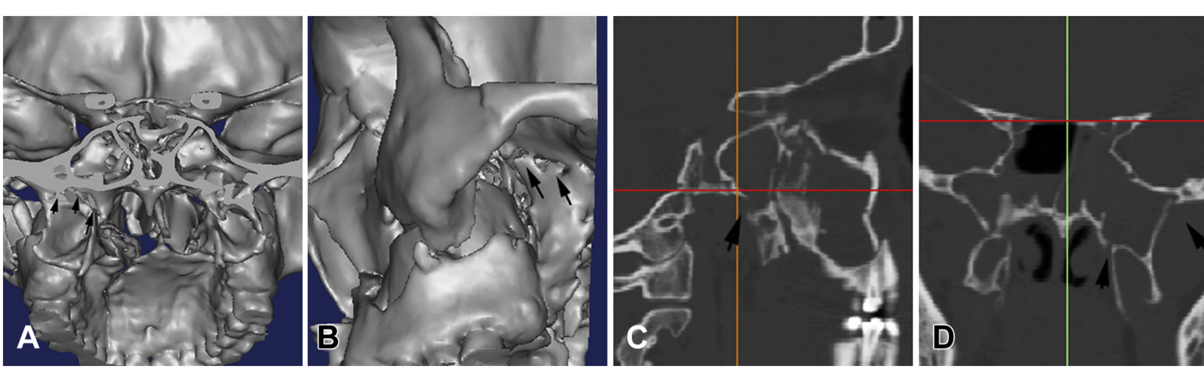

Fig. 5. Left-sided pterygoid process class II-3 fracture. The fracture line is located above the pterygoid fossa, extending to the floor of sphenoid sinus, where it led to an effusion.

bone; 31 of these (51 sides) were pterygoid process fractures, 45 sides were associated with LeFort maxillary fractures, and 2 sides were associated with fractures of the zygomatic bone. Unger and Unger[12] described 12 cases of pterygoid process fracture, 9 of which were associated with LeFort maxillary fractures and 3 with zygomaticomaxillary complex fractures. In the present study, in addition to the maxillary transverse fractures, we also found a small number of zygomatic fractures caused by a lateral striking force that were associated with pterygoid process fractures. These cases were not included in the analyzed sample, which contained only

Table III. Distribution of types of pterygoid process fracture among 188 sides

Simple fracture				*Complex fracture*						*Total*
I	II-1	II-2	II-3	I + II-1	I + II-2	I + II-3	II-1 + II-2	II-1 + II-3	I + II-1 + II-3	
5	92	25	16	33	10	1	1	3	2	188

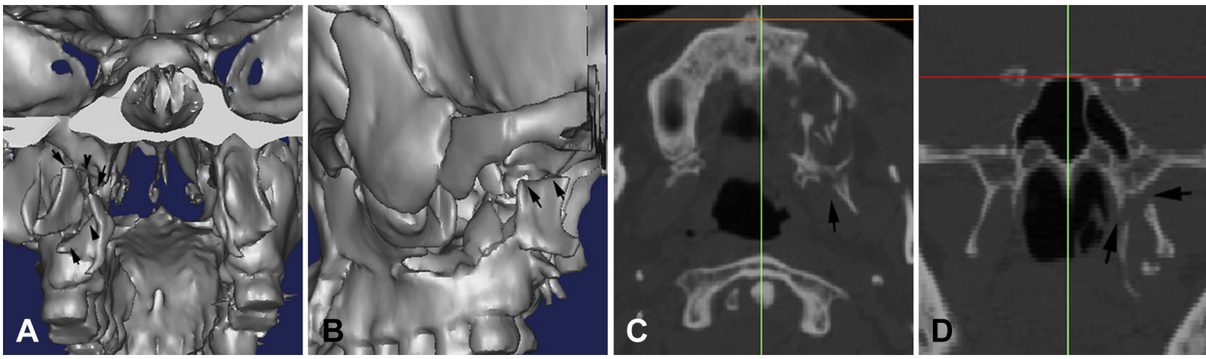

Fig. 6. Left-sided pterygoid process class II-1 fracture associated with a class I fracture.

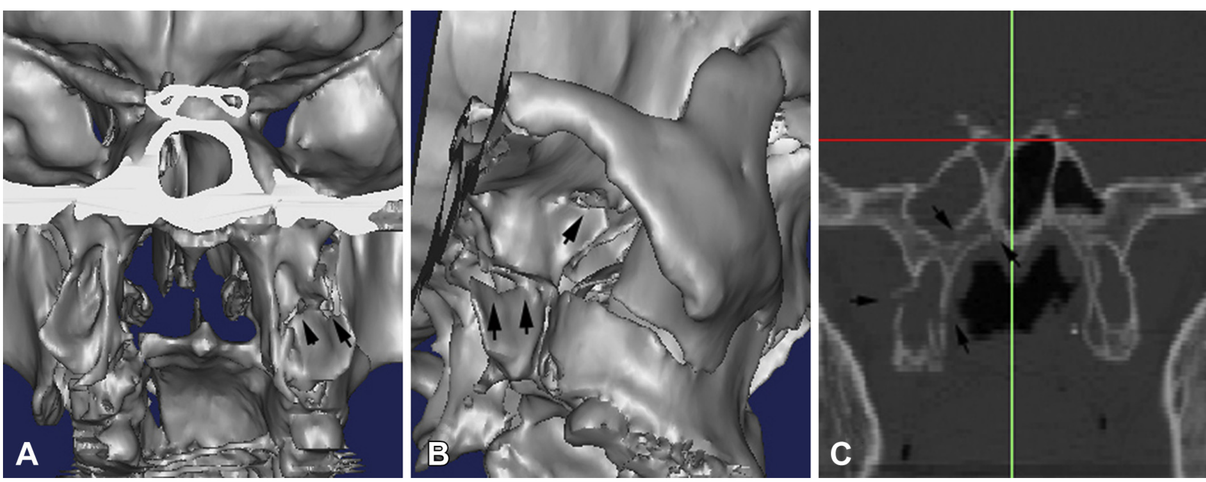

Fig. 7. Right-sided pterygoid process class II-1 fracture associated with a class II-3 fracture.

pterygoid process fractures associated with maxillary transverse fracture.

Because of the close relationship between the maxilla and the sphenoid pterygoid process in the rear, maxillary transverse fracture will inevitably extend to the pterygoid process; thus, this type of fracture can be called a maxilla−pterygoid process complex fracture. The characteristics of pterygoid process fractures associated with maxillary fractures are rarely reported because of their deep location. Deep fractures are also known as occult fractures and are generally difficult to display clearly on plain films. Before the advent of CT imaging technology, tomography was used clinically to diagnose pterygoid process fractures, but unsatisfactorily.[13] With the clinical use of CT and continuing progress in imaging technology, a good understanding of this fracture is now technically guaranteed. Orhan et al.[14] evaluated the pterygoid hamulus morphology using cone beam computed tomography, and the knowledge about the morphology of these structures provides valuable information in the differential diagnosis of untraceable pains in the oral cavity and pharynx. Coronal CT is considered optimal for observing pterygoid process fractures, including the fracture level and sphenoid sinus floor involvement; axial CT can show whether the medial and lateral pterygoid plates are separated and whether the pterygoid maxillary junction has diverged; and 3-dimensional CT can fully visualize the characteristics of these fractures. However, the pterygoid process cannot be observed directly on maxillofacial 3-dimensional CT images, because the view is blocked by the surrounding bones. To study

Table IV. Distribution of types of pterygoid process fracture

Classification	*I*	*II-1*	*II-2*	*II-3*	*Total*
Simple fracture	5	92	25	16	138
Complex fracture	46	39	11	6	102
Total	51	131	36	22	240

Table V. Relationship between pterygoid process fracture lines and maxillary fracture lines

Type (sides)	*Maxillary single-line fracture*	*Maxillary multiline fracture*	*Total*
Pterygoid process, single-line fracture	75	63	138
Pterygoid process, multiline fracture	22	28	50
Total	97	91	188

Table VI. Distribution of pterygoid process fractures according to the level of maxillary fracture (sides)

Classification	*II-1*	*II-2*	*II-3*	*Total*
LeFort I	37	7	4	48
LeFort II	39	10	7	56
LeFort III	49	19	11	79
Total	125	36	22	183

Table VII. Relationship between bilateral maxillary fracture level and bilateral pterygoid fracture level

Classification (cases)	*Pterygoid fractures at same level*	*Pterygoid fractures at different levels*	*Total*
Bilateral maxillary fractures at same level	36	15	51
Bilateral maxillary fractures at different levels	24	14	38
Total	60	29	89

pterygoid process fractures, software is used to remove the posterior and bilateral bones from images.

A relationship was found between maxillary transverse fracture and pterygoid process fracture, in that most unilateral maxillary transverse fractures were accompanied by unilateral pterygoid process fractures, whereas bilateral maxillary transverse fractures were associated with bilateral pterygoid process fractures. In general, we could therefore infer the presence of a maxillary transverse fracture from a pterygoid process fracture, especially in patients with nonobvious malposition, and pterygoid process fractures could be used as indirect diagnostic evidence of maxillary transverse fractures. If CT scans of a patient with maxillofacial injuries clearly identify a pterygoid process fracture, a maxillary transverse fracture is likely to have occurred, and maxillary dental arch malposition and malocclusion requiring surgery are probably present (Figure 9).

When maxillary LeFort I osteotomy is performed, the procedure of separation of the maxillary tuberosities from the pterygoid plates can cause pterygoid process fracture. In the literature, the incidence of pterygoid process fracture secondary to LeFort I osteotomy ranged from 20% to 87%, and the fracture sites were observed and classified. Robinson and Hendy[4] carried out LeFort I osteotomy on 8 cadavers and found that there were low-level fractures and high-level fractures. The low-level fractures occurred at the level of the osteotomy cut, and the high-level fractures occurred close to the base of the skull. Renick and Symington[5] also divided the pterygoid fractures into low-level fractures, which were inferior to the LeFort I osteotomy line, and high-level fractures, which were superior to this level. Lanigan[6] and Laster et al.[7] divided the pterygoid process fractures into 3 types: high-level fractures were defined as those that occurred at or near the base of the skull, low-level fractures were those that occurred at the level of the osteotomy cut, and intermediate fractures were those that occurred slightly above the level of the osteotomy cut. Lanigan[6] found vertical fractures of the pterygoid plates extending toward the skull base, which is similar to the findings in our class I fractures. Precious et al.[8] summarized the characteristics of pterygoid plate fractures in 58 cases of maxillary LeFort I osteotomy and found that the fractures all occurred in the lower half of the pterygoid process.

We want to determine whether the characteristics of pterygoid process fracture associated with maxillary transverse fractures and those of pterygoid process fracture in LeFort I osteotomy are the same. A definitive classification of pterygoid process fracture is needed, because there is none in the literature of facial trauma. The pterygoid process is a slender bone structure comprising medial and lateral plates that are increasingly fused from the base up. At the base of the process, the medial and lateral plates diverge, with the pterygoid fissure between them; in the middle part, the medial and lateral plates fuse anteriorly and diverge posteriorly, with the pterygoid fossa between them. At its top, the pterygoid process connects with the base of the skull, and the medial and lateral plates are completely fused. Through observation of the pterygoid process fractures in this study, we found that vertical fractures led to separation of the medial and lateral plates, and the fracture line did not reach beyond the pterygoid fossa. In most cases, pterygoid process transverse fractures occurred near the upper edge of the pterygoid fossa, especially below the upper edge. Those that occur above the pterygoid fossa should be

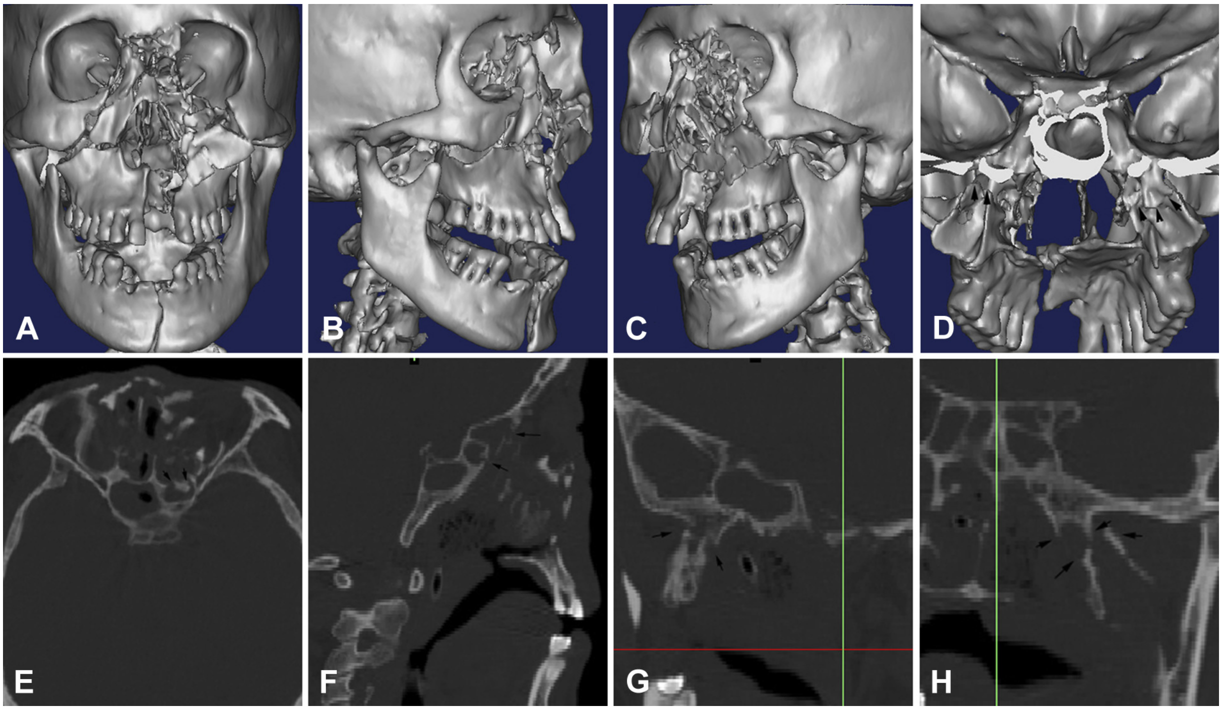

Fig. 8. A patient with LeFort I and II maxillary fractures, maxillary sagittal fracture, and nasal-orbital ethmoid fracture. On axial and sagittal computed tomography images, the fractures are seen extending to the ethmoid and sphenoid sinus, from the anterior backward. Neither pterygoid process fracture (right II-1, left II-2) extended to the floor of the sphenoid sinus. Sphenoid sinus fractures of this type are caused by a frontal striking force.

Table VIII. Relationship between pneumatization of the pterygoid process and class II-3 fracture in 188 sides with pterygoid process fracture

Category	*II-3 fracture*	*Non-II-3 fracture*	*Total*
Pterygoid process pneumatization	18	36	54
No pterygoid process pneumatization	4	130	134
Total	22	166	188

considered high-level pterygoid process fractures, regardless of whether they extend to the floor of the sphenoid sinus. Based on the characteristics of their fracture lines, we established a classification of pterygoid process fractures. Hopper et al.[15] suggested that fracture of the posterior wall of the maxillary sinus without pterygoid process fracture may coexist with maxillary transverse fracture; however, we did not observe this situation in our sample, nor any separation between the pterygoid process and the maxilla.

LeFort I, II, and III maxillary fractures differ in fracture line height. How, then, does the height of the associated pterygoid process fracture lines vary? Unger and Unger[12] found that pterygoid process fractures occurred at the junction of the middle and inferior third of the pterygoid process in LeFort I maxillary fractures, in the midportion in LeFort II fractures, and in the base in LeFort III fractures. Osborn[16] suggested that, in LeFort I and II fractures, associated pterygoid process fractures occur in the inferior or midportion of the pterygoid process, whereas in LeFort III fractures they occur at the junction between the pterygoid process and the body of the sphenoid. In both studies, low-level maxillary fractures were associated with low-level pterygoid process fractures, and high-level maxillary fractures were associated with high-level pterygoid process fractures, which is not in accord with the findings of the present study.

Through review of the cases in our sample, we found that there was no relationship between the level of the pterygoid process fracture line and that of the maxillary fracture line. Most of the pterygoid process fractures were class II-1 (66.5%) or II-2 (19.1%); this means that they occurred predominantly near the upper edge of the pterygoid fossa and indicates that this area may be the structurally weakest area of the pterygoid process. Of the 188 sides with pterygoid process fractures, 138 (73.4%) had a simple fracture and 50 (26.6%) had complex fractures of 2 or more subtypes. Simple pterygoid vertical fractures were relatively rare, occurring in only 5 sides. Pterygoid vertical fractures associated with transverse fractures were more common, occurring in 46 sides (24.5%) and indicating that a considerable

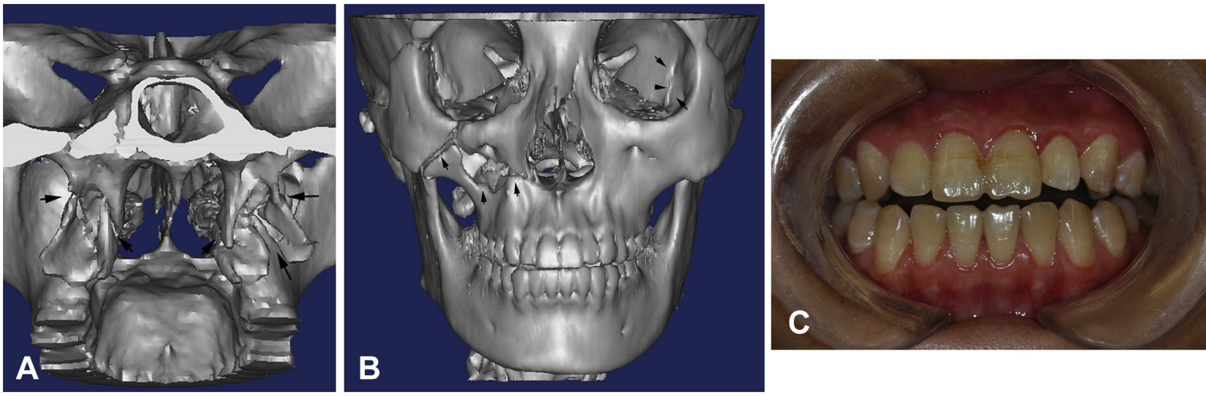

Fig. 9. A young female patient with facial trauma. A, A preoperative 3-dimensional computed tomography image showed bilateral pterygoid process class II-1I fractures associated with class I fractures. B, A 3-dimensional computed tomography image showed right-sided maxillary LeFort I and II fractures and left-sided maxillary LeFort III fractures. The left-sided maxillary fracture line was not clear, so the left-sided pterygoid process fracture can be used as indirect evidence for the left-sided maxillary fracture. C, A preoperative open bite deformity in the anterior teeth region suggested that bilateral maxillary transverse fracture existed.

proportion of transverse fractures occur simultaneously with separation of the medial and lateral plates.

Through observation and statistical analysis (see Table V), we found that there was no relationship between the comminution degree of the pterygoid process fracture and that of the maxillary fracture. Because the number of maxillary fracture lines to some extent represents the intensity of the frontal force on the maxilla, we preliminarily speculated that the comminution degree of the pterygoid process fracture not only is related to the intensity of the frontal force on the maxilla but also is related to the form, volume, and strength of the pterygoid process.

In this sample, 22 sides (11.7%) had class II-3 fractures. This is a high-level transverse fracture extending to the floor of the sphenoid sinus. Simple II-3 fractures associated with fractures of other parts of the middle cranial fossa were not observed. Pneumatization sometimes extends into the pterygoid process and plates, and there is a structural weak area at the root of the pterygoid process. CT scan examination can be used to identify this anatomic variation clearly.[17,18] Statistical analysis found that excessive gasification of the sphenoid sinus was a risk factor for II-3 fractures; that is, the risk of high-level fractures extending to the floor of the sphenoid sinus was higher in patients with excessive gasification within the base of the pterygoid process. The base of the pterygoid process and the floor of the sphenoid sinus are considered to be the structurally weakest parts of the middle cranial fossa floor, and high-level pterygoid process fractures leading to fracture of the sphenoid sinus floor could prevent an injurious force from extending upward, thereby protecting the brain. Pterygoid process fractures caused by maxillary transverse fractures therefore generally would not cause substantial damage to the middle cranial fossa. Of the 36 cases of sphenoid sinus fracture in this study, only 13 (15 sides) were caused by pterygoid process class II-3 fractures; the other 23 were complex fractures of the frontal, ethmoid, and sphenoid sinuses, 5 of which (7 sides) also had pterygoid process II-3 fractures. This indicates that, in sphenoid sinus fractures associated with midface fractures, force could be conducted directly from the anterior backward or indirectly from an inferior pterygoid process fracture. A considerable portion of sphenoid sinus fractures are caused by a frontal striking force that extends backward through the frontal and ethmoid sinuses (weak areas of the base of the skull) to the sphenoid sinus, causing its fracture and even involving the middle cranial fossa. Based on these data, it is suggested that, compared with pterygoid process fracture, a frontal striking force leads more easily to sphenoid sinus or middle cranial fossa fracture. For the middle cranial fossa, the danger posed by a frontal striking force is greater than that of an inferior pterygoid process fracture.

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Reprint requests:

Yi Zhang, MD
Department of Oral and Maxillofacial Surgery
Peking University School and Hospital of Stomatology
22 Zhongguancun Nandajie
Haidian district
Beijing 100081
China
Zhangyi2000@263.net