Risk assessment for jawbone fracture

using classification of the mandibular inferior cortical shape by pantomography

パノラマエックス線検査による下顎骨下縁皮質骨形態の分類を用いた

顎骨骨折のリスク評価

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本論文は、

1) Assessment of Maxillary Fracture Risk Using Classification of the Mandibular Inferior Cortical Shape by Pantomography
Journal of Hard Tissue Biology（第 27 巻 2 号　平成 30 年 4 月発行予定）
2) Risk Assessment for Condylar Fracture Using Classification of the Mandibular Inferior Cortical Shape by Pantomography
International Journal of Oral-Medical Sciences (in press)

をまとめたものである。

Abstract

Purposes:

The purposes of this study were to assess the risk of 1) maxillary fracture, and 2) condylar fracture by classification of the mandibular inferior cortical shape using pantomography.

Materials and Methods:

This retrospective study was approved by the Institutional Review Board (EC15-12-009-1).

1. 364 patients (190 males, 174 females; age 20-91 years, mean age 48.0 years) with suspected maxillary fractures who underwent both pantomography and multidetector row computed tomography (MDCT) from April 2011 to December 2016 were included in this study.
2. 254 patients (131 men, 123 women; age 20-91 years, mean age 56.2 years) with suspected condylar fractures who underwent both pantomography and MDCT from April 2006 to December 2016 were included in this study.

The mandibular inferior cortical shape was evaluated by pantomography on both sides of the mandible, distal to the mental foramen by specialist of two oral and maxillofacial radiologists, and classified into three types as follows; Type l: normal

cortex, Type 2: mildly to moderately eroded cortex and Type 3: severely eroded cortex. Moreover, the patients were divided into two groups; Group I: normal bone mineral density (Type 1) and Group II: low bone mineral density (Types 2 and 3).

Results:

1. Of the 364 patients, fractures were seen in 219 patients (60.2%). Of the 219 patients with maxillary fractures, 51 patients were in Group I (23.3%) and 168 patients were in Group II (76.7%). Of the 145 patients without maxillary fractures, 120 patients were in Group I (82.8%) and 25 patients were in Group II (17.2%). There was a statistically significant difference between Groups I and II in the prevalence of maxillary fractures ($p < 0.05$).
2. Of the 254 patients, condylar fractures were seen in 158 patients (62.2%). Of the 158 patients with condylar fractures, 27 patients were in Group I (17.1%) and 131 patients were in Group II (82.9%). Of the 96 patients without mandibular fracture, 57 patients were in Group I (59.4%) and 39 patients were in Group II (40.6%). There was a statistically significant difference between Group I and Group II in the prevalence of condylar fractures ($p < 0.05$).

Conclusion:

Our results suggest that classification of the mandibular inferior cortical shape on pantomography may provide a risk assessment of the maxillary fracture and condylar fracture.

Key Words

Maxillary fracture risk, Condylar fracture risk, Pantomography,

Multidetector row computed tomography (MDCT), Mandibular inferior cortical shape

Introduction

The facial bones serve the essential role of housing and protecting the airway as well as the organs of the special senses[1]. The maxilla represents the bridge between the cranial base superiorly and the dental occlusal plane inferiorly. Its intimate association with the oral cavity, nasal cavity and orbits, and the multitude of structures contained within and adjacent to it, make the maxilla a functionally and cosmetically important structure[2]. Maxillofacial injuries remain a serious clinical problem because of the maxilla's anatomical significance, with important organs, including the beginning of the digestive and respiratory systems, located in this area[3].

Fractures of mandibular condyle process are the most common fractures of the mandible area[4, 5]. Of all mandibular fractures, 25-35% are fractures of the mandibular condyle[6]. This area has a great clinical value due to important components such as the facial nerve and temporomandibular joint[7]. Deranged occlusion, inability to masticate food, difficulty in opening mouth, haemotympanum and pain in preauricular region are some of the complaints of patients[8].

Despite having a higher radiation dosage than that associated with radiography, computed tomography (CT) is the imaging technique of choice for evaluating craniomaxillofacial injuries as it can display the multiplicity of fragments, degrees of rotation and dislocation, and any skull base involvement[9]. Conversely, pantomography is widely used to assess orofacial trauma and other disorders[10]. Some investigators have suggested that classification of the mandibular inferior cortical shape detected on pantomography[11, 12].

However, there have been few studies evaluating the risk of maxillary fracture and condylar fracture by classification of the mandibular inferior cortical shape using pantomography.

The purposes of this study were to assess 1) maxillary fracture, and 2) condylar fracture risk according to the classification of the mandibular inferior cortical shape using pantomography.

Materials and Methods

This retrospective study was approved by the Institutional Review Board (EC15-12-009-1).

Study subjects

1. Assessment of Maxillary Fracture Risk Using Classification of the Mandibular Inferior Cortical Shape by Pantomography

364 patients (190 males, 174 females; age 20-91 years, mean age 48.0 years) with suspected maxillary fractures who underwent both pantomography and MDCT from April 2011 to December 2016 were included in this study. All patients read and signed an informed consent form prior to inclusion in this study.

2. Risk Assessment for Condylar Fracture Using Classification of the Mandibular Inferior Cortical Shape by Pantomography

254 patients (131 men, 123 women; age 20-91 years, mean age 56.2 years) with suspected condylar fractures who underwent both pantomography and MDCT from April 2006 to December 2016 were included in this study. All patients read and signed an informed consent form.

CT and pantomography protocol

CT imaging was performed with a 64MDCT (Aquilion 64, Toshiba Medical Systems, Tokyo, Japan) using the maxillofacial trauma protocol at our hospital: tube voltage,120kV; tube current, 100 mA; field of view, 240 mm×240 mm; rotation time, 1.0 s; mean effective dose, 1.6 mSv; mean CTDIvol value, 37.3 mGy; mean DLP value, 520.3 mGy cm. In this study, the k-factor used is the head neck factor 0.0031 mSv/(mGy cm). The protocol consisted of axial acquisition (0.50 mm) with axial (3.0 mm), coronal (3.0 mm) and sagittal (1.0mm) MPR and 3D images.

The mandibular inferior cortical shape was assessed on digital pantomography (Veraviewepocs; J. Morita, Kyoto, Japan) at 1 to 10 mA and peak kV between 60 and 80, depending on the subject's jaw size.

The MDCT images and pantomography images were interpreted using a medical liquid crystal display monitor (RadiForce G31; Eizo Nanami, Ishikawa, Japan).

Image analysis

The mandibular inferior cortical shape was evaluated on both sides of the mandible, distal to the mental foramen on pantomography by specialist two oral and maxillofacial radiologists, and classified into three types (Fig. 1)[12];

Type l. Normal cortex: the endosteal margin of the cortex was even and sharp on both sides; Type 2. Mildly to moderately eroded cortex: the endosteal margin showed semilunar defects or seemed to form endosteal cortical residues on one or both sides; and Type 3. Severely eroded cortex: the cortical layer formed heavy endosteal cortical residues and was clearly porous. Moreover, the patients were divided into two groups; Group I: normal bone mineral density (Type 1), and Group II: low bone mineral density (Type 2 and 3)[12]. We examined comparing with presence of the fractures and classification of the mandibular inferior cortical shape using pantomography.

Statistical analysis

Statistical analysis was performed using $\chi 2$ test with Fisher's exact test. These analyses were performed with the statistical package SPSS version 21.0 (SPSS Japan, Tokyo, Japan). *P*-values < 0.05 considered statistically significant.

Results

1. Assessment of Maxillary Fracture Risk Using Classification of the Mandibular Inferior Cortical Shape by Pantomography

Of the 364 patients, fractures were seen in 219 patients (60.2%). Of the 219 patients with maxillary fractures, 51 patients were in Group I (23.3%) and 168 patients were in Group II (76.7%). Of the 145 patients without maxillary fractures, 120 patients were in Group I (82.8%) and 25 patients were in Group II (17.2%). There was a statistically significant difference between Groups I and II in the prevalence of maxillary fractures ($p < 0.05$) (Fig. 2).

Unifocal fractures occurred in 53 of 219 (24.2%) patients and multifocal fractures were seen in 166 of 219 (75.8 %) patients. Of the Group I patients with maxillary fractures, 33.3% (17/51) demonstrated unifocal fracture patterns and 66.7% (34/51) demonstrated multifocal fracture patterns. Of the Group II patients, 21.4% (36/168) demonstrated unifocal fracture patterns and 78.6% (132/168) demonstrated multifocal fracture patterns.

The most common site of multifocal fracture type in Group I was at the zygomaticomaxillary fractures (seen in 12/34 (35.3%) patients) followed by the alveolar ridge (which occurred in 7/34 (20.6%) of patients). The most common site of multifocal fracture in Group II was at the tripod fractures seen in 40/132 (30.3%) fractures followed by the zygomaticomaxillary fractures which occurred in 29/132 (21.2%) fractures (Table 1) (Fig. 3). The prevalence of tripod fractures in Group II was higher than in Group I. There was a statistically significant difference between Groups I and II in the prevalence of tripod fractures ($p < 0.05$).

2. Risk Assessment for Condylar Fracture Using Classification of the Mandibular Inferior Cortical Shape by Pantomography

Of the 254 patients, condylar fractures were seen in 158 patients (62.2%). Of the 158 patients with condylar fractures, 27 patients were in Group I (17.1%) and 131 patients were in Group II (82.9%). Of the 96 patients without condylar fracture, 57 patients were in Group I (59.4%) and 39 patients were in Group II (40.6%). There was a statistically significant difference between Group I and Group II in the prevalence of condylar fractures ($p < 0.05$) (Fig. 4).

Unilateral fractures occurred in 93 of 158 (58.8%) patients and bilateral fractures were seen in 65 of 158 (41.1%) patients. Of the Group I patients with condylar fractures, 88.9% (24 of 27 patients) demonstrated unilateral fracture patterns and 11.1% (3 of 27 patients) demonstrated bilateral fracture patterns. 52.7% (69 of 131 patients) of the Group II patients demonstrated unilateral fracture patterns and 47.3% (62 of 131 patients) demonstrated bilateral fracture patterns. There was a statistically significant difference between Group I and Group II in the prevalence of unilateral or bilateral fractures ($p < 0.05$) (Fig. 5).

Of the 93 patients with unilateral fractures, 49 patients were right condylar fractures (52.7%) and 44 patients were left condylar fractures (47.3%). Of the Group I patients with unilateral fractures, 41.7% (10 of 24 patients) demonstrated right condylar fractures and 58.3% (14 of 24 patients) demonstrated left condylar fractures. Of the Group II patients with unilateral fractures, 56.5% (39 of 69 patients) demonstrated right condylar fractures and 43.5% (30 of 69 patients) demonstrated left condylar fractures (Table 2).

Discussion

The present study showed that patients with Group II mandibular inferior cortical shape more frequently sustained 1) maxillary fracture, and 2) condylar fracture compared to patients with Group I morphology. Patients with Group II mandibular inferior cortical shape have a higher risk of the 1) maxillary fracture, and 2) condylar fracture compared to patients with Group I morphology.

1. Assessment of Maxillary Fracture Risk Using Classification of the Mandibular Inferior Cortical Shape by Pantomography

In the present study, the most common site of unifocal fracture was at the anterior alveolar ridge location. The anterior maxilla is the most common site for alveolar fractures because of the location and vulnerability of this anterior region[13]. The maxillary anterior teeth are the most commonly affected and the central incisors present the highest risk of dentoalveolar trauma[14]. In the present study, the second most common site of unifocal fracture was at the anterior maxillary wall (7.5%). Isolated fractures of the maxillary sinus are uncommon and generally consist of depressed fractures of the anterior wall of the maxillary sinus[15].

Zygomaticomaxillary fractures are almost always associated with fractures of the internal orbit[16]. Inferior and posterior displacement of the zygoma produces varying degrees of disorganization of the soft tissues of the orbital cavity with bony expansion causing enopthalmos[17]. In our study, the zygomaticomaxillary site was the most common site for multifocal fractures in Group I and the second most common site in Group II.

In the present study, the prevalence of tripod fractures of Group II are higher than Group I. The principal lines of tripod fractures involve the three processes of the malar bone (orbital, zygomatic and maxillary)[18]. As the zygoma becomes separated from its three attachment points, there is a widening of the zygomaticofrontal suture, and fracture of the inferior orbital rim involving the posterolateral wall of the maxillary sinus and the zygomatic arch[19]. Patients with tripod fractures often present with tenderness, ecchymosis and edema over the malar prominence, lateral orbit and upper and lower eyelids, and loss of malar projection and blunting of the lateral canthus relative to the unaffected side[20].

2. Risk Assessment for Condylar Fracture Using Classification of the Mandibular Inferior Cortical Shape by Pantomography

The mandibular condyle is frequently fractured owing to the small cross-sectional area of the condylar neck that extends spiral upwards. The anatomic configuration of the mandible transmits the kinetic energy from a blow along the mandible to the condylar neck, where the compressive strength of the bone is exceeded and fracturing occurs[21].

Unilateral mandibular condylar fractures occur approximately two times more frequently than bilateral fractures[22]. Iida et al[23] reported that 201 patients were unilateral condylar fractures and 86 patients were bilateral condylar fractures. In our study, the case of Group I unilateral condylar fractures were 88.9% and bilateral condylar fractures were 11.1%. The case of Group II, unilateral condylar fractures were 52.7% and bilateral condylar fractures were 47.3%. Patients with Group II have a higher risk of the bilateral condylar fracture compared to patients with Group I in the present study. The mandibular condyle is frequently fractured owing to the small cross-sectional area of the condylar neck that extends spiral upwards. The anatomic configuration of the mandible transmits the kinetic energy from a blow along the mandible to the condylar neck including unilateral or bilateral, where the compressive strength of the bone is exceeded and fracturing occurs[21].

Given the unique geometry of the mandible and temporomandibular joints, these fractures can result in marked pain, dysfunction, and deformity if not recognized and treated appropriately[24]. Complications related to the condylar fracture are ranged from tympanic bone fracture, fracture of mandibular fossa of temporal bone with or without dislocation of the condylar segment into the middle cranial fossa, injury to the cranial nerves, vascular damage and bleeding, growth inhibition and arteriovenous fistula[25, 26]. Therefore, the understanding of condylar fracture risk according to classification of the mandibular inferior cortical shape is essential in diagnosis and treating fractures of the condylar region.

Conclusion

Patients with Group II mandibular inferior cortical shape have a higher prevalence of maxillary fracture and condylar fracture compared to patients with Group I mandibular cortical shape. The present results suggest that classification of the mandibular inferior cortical shape on pantomography may provide a risk assessment of jawbone fractures.

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Figures and legends

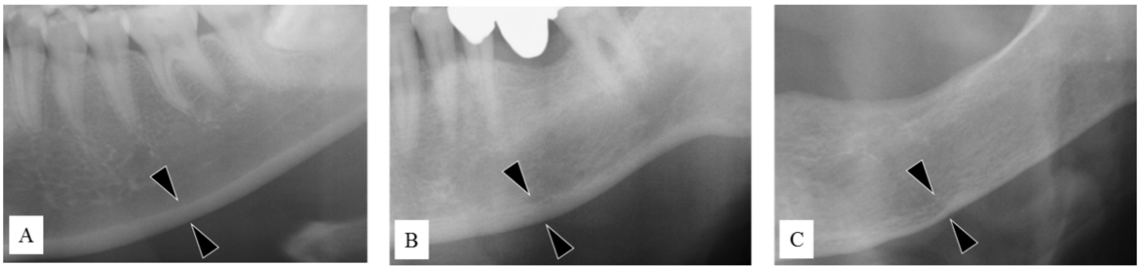

Fig. 1 Classification of the mandibular inferior cortical shape on pantomography

(A) Normal cortex: the endosteal margin of the cortex is even and sharp on both sides (*arrow heads*).

(B) Mildly to moderately eroded cortex: the endosteal margin shows semi-lunar defects (lacunar resorption) or appears to form endosteal cortical residues (*arrow heads*).

(C) Severely eroded cortex: the cortical layer forms heavy endosteal cortical residues and is clearly porous (*arrow heads*).

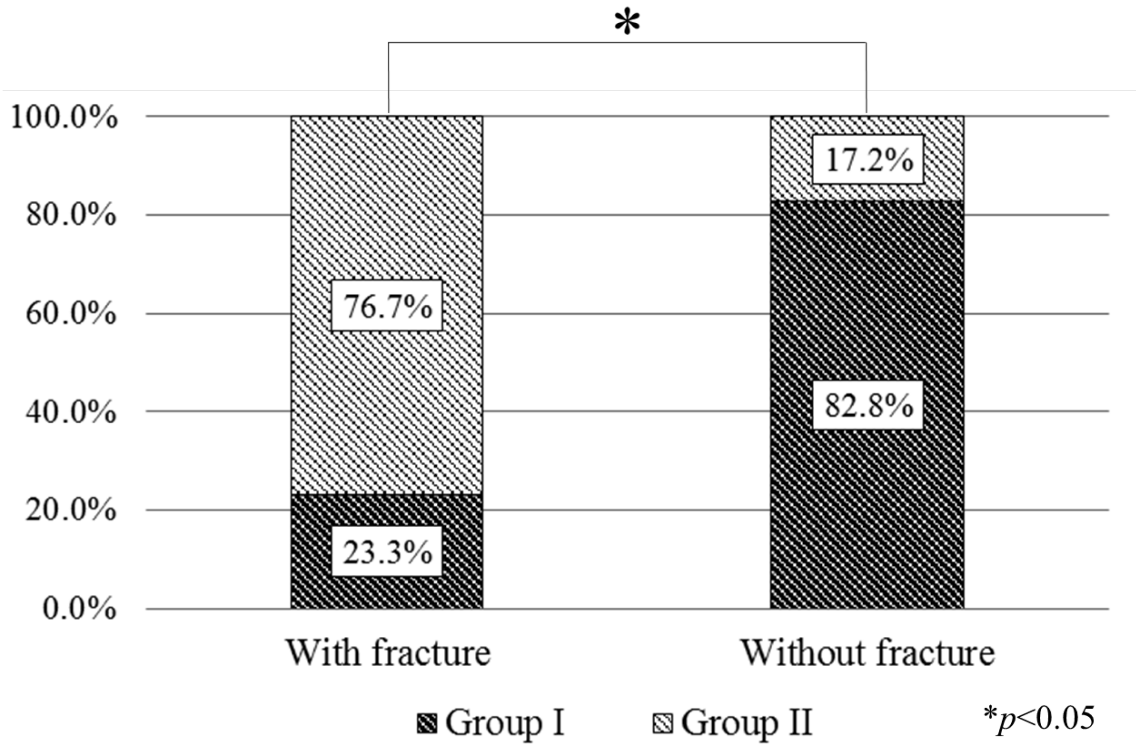

Fig. 2 Patients with or without maxillary fractures according to the classification of the mandibular inferior cortical shape using pantomography

There was a statistically significant difference between Groups I and II in the prevalence of maxillary fractures ($p < 0.05$).

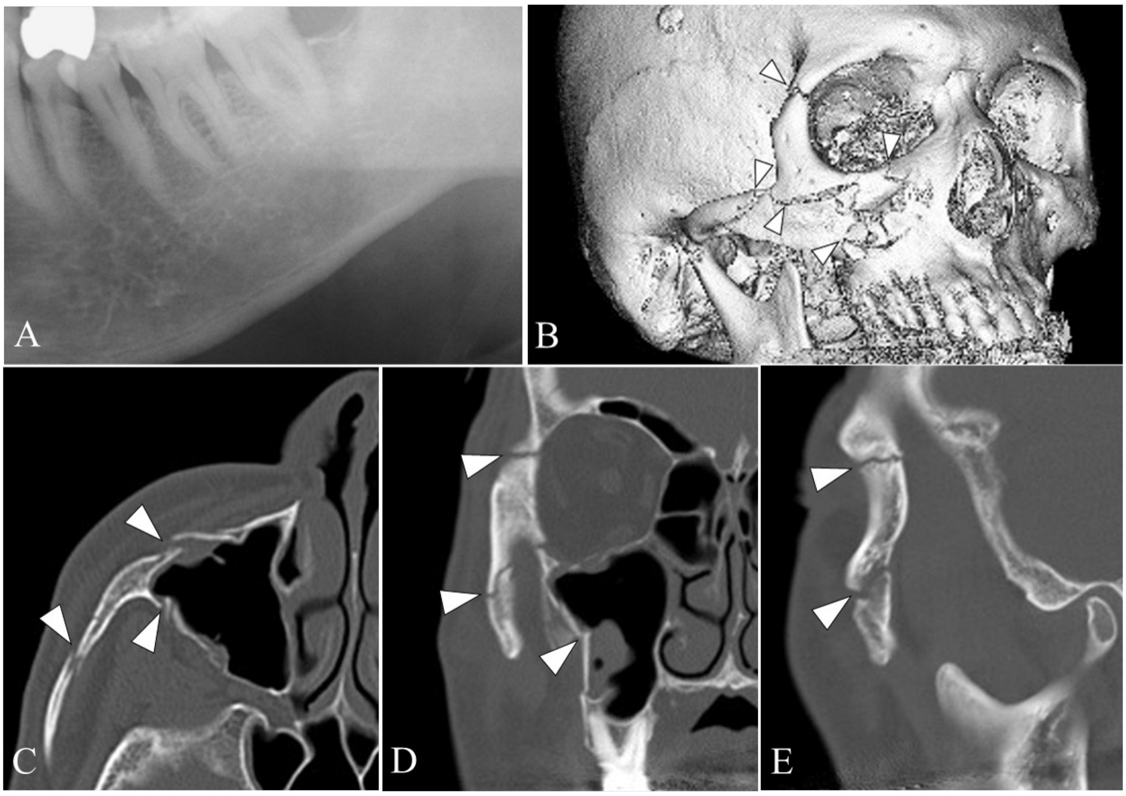

Fig. 3 Typical type of Group II: Tripod fractures in a 78-year-old women

(A) Pantomography shows that the cortical layer forms heavy endosteal cortical residues and is clearly porous.

(B) 3D image shows the orbital, zygomatic and anterior maxillary wall fractures (*arrows*).

(C) Axial image shows the maxillary wall (anterior and posterolateral) and zygomatic fractures (*arrows*).

(D) Sagittal image shows the orbital, zygomatic and posterolateral maxillary wall fractures (*arrows*).

(E) Coronal image shows the orbital and zygomatic fractures (*arrows*).

Tripod fractures were the most common type of fractures in Group II.

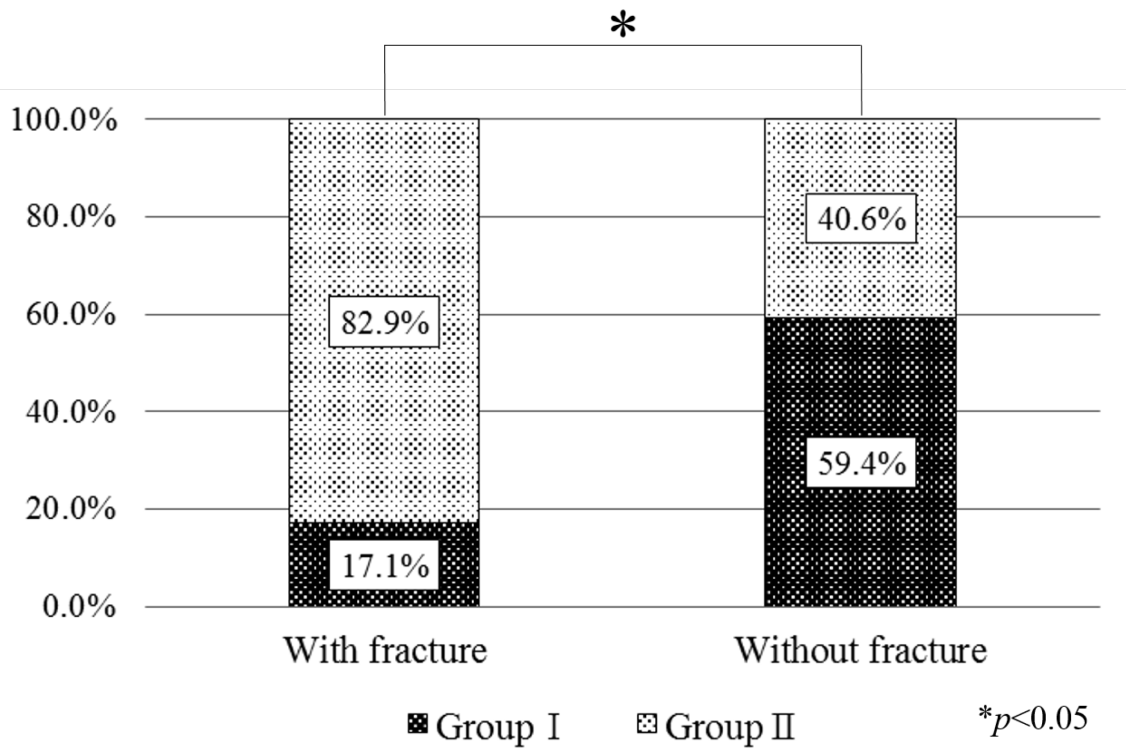

Fig. 4 Patients with or without condylar fractures according to the classification of the mandibular inferior cortical shape

There was a statistically significant difference between Group I and Group II in prevalence of condylar fractures ($p < 0.05$).

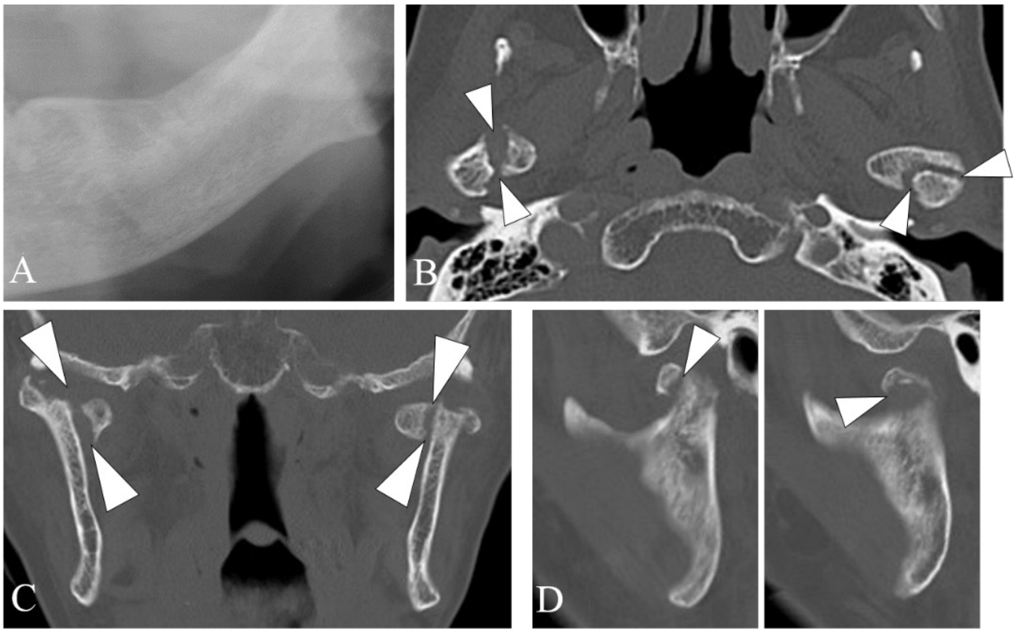

Fig. 5 Typical type of Group II: Bilateral condylar fractures in a 75-year-old woman

(A) Pantomography shows that the cortical layer forms heavy endosteal cortical residues and is clearly porous.

(B-D) Axial (B), sagittal (C) and coronal (D) images show bilateral condylar fractures (arrows).

The most common site of fracture in Group II was at the condylar location.

Table 1. The frequency and sites of multifocal fractures (166 patients) according to the mandibular inferior cortical shape using pantomography

	Group Ⅰ	Group Ⅱ
LeFort Ⅰ	1 (2.9%)	9 (6.8%)
LeFort Ⅱ	0 (0.0%)	1 (0.8%)
Zygomaticomaxillary fractures	12 (35.3%)	29 (22.0%)
Tripod fractures	3 (8.8%)	40 (30.3%)*
Alveolar rigde fractures	7 (20.6%)	21 (15.9%)
Other	11 (32.4%)	32 (24.2%)
Alveolar rigde + Nasal fractures	0 (0%)	8 (6.1%)
Alveolar rigde + Orbital floor fractures	0 (0%)	1 (0.8%)
Alveolar rigde + Palatal fractures	0 (0%)	1 (0.8%)
Unifocal anterior maxillary wall + Posterolateral maxillary wall fractures	2 (5.9%)	8 (6.1%)
Multifocal anterior maxillary wall + Posterolateral maxillary wall fractures	1 (2.9%)	0 (0%)
Unifocal anterior maxillary wall + Posterolateral maxillary wall + Alveolar rigde fractures	2 (5.9%)	8 (6.1%)
Multifocal anterior maxillary wall + Posterolateral maxillary wall + Alveolar rigde fractures	0 (0%)	1 (0.8%)
Unifocal anterior maxillary wall + Posterolateral maxillary wall + Nasal fractures	2 (5.9%)	0 (0%)
Multifocal anterior maxillary wall + Posterolateral maxillary wall + Nasal fractures	0 (0%)	1 (0.8%)
Unifocal anterior maxillary wall + Posterolateral maxillary wall + Orbital floor fractures	3 (8.8%)	2 (1.5%)
Unifocal anterior maxillary wall + Posterolateral maxillary wall + Medial maxillary wall fracture	0 (0%)	1 (0.8%)
Unifocal anterior maxillary wall + Posterolateral maxillary wall + Alveolar rigde + Nasal fractures	0 (0%)	1 (0.8%)
Unifocal anterior maxillary wall + Posterolateral maxillary wall fractures+ Orbital floor + Frontal sinus fracture	1 (2.9%)	0 (0%)
Total	34	132

*p<0.05

Table 2. The frequency and sites of condylar fractures (158 patients) according to the mandibular inferior cortical shape using pantomography

	Group Ⅰ	Group Ⅱ
Bilateral condylar fractures	3 (11.1%)	62 (47.3%)*
Unilateral condylar fractures	24 (88.9%)	69 (52.7%)
Right condylar fractures	10 (41.7%)	39 (56.5%)
Left condylar fractures	14 (58.3%)	30 (43.5%)
Total	27	131

*$p<0.05$