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Determining the anatomy of the descending palatine artery and pterygoid plates with computed tomography in Class III patients

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Summary

Purpose. Understanding the anatomy of the pterygomaxillary junction region helps prevent blood loss in Le Fort I osteotomy. Here, we determined the location of the descending palatine artery and the structure of the pterygomaxillary region.

Patients and Methods. The study group consisted of 82 Japanese patients with mandibular prognathism and asymmetry, with and without maxillary retrognathism or asymmetry. A total of 164 sides were measured and divided into right versus left, men versus women, and bimaxillary osteotomy (B) versus mandibular osteotomy (S). Lateral and frontal cephalograms and computed tomography (CT) were analysed for all patients. The relationship between the cephalometric measurements and the measurements of the descending palatine artery and pterygoid plate (PP) were assessed.

Results. There were no significant correlations between measurements of cephalograms and those of the descending palatine artery and pterygoid plates. There were significant differences between right and left in lateral plate length ($p=0.0014$) and thickness of PP ($p=0.0047$). There were significant differences between men and women in right width of PP ($p=0.0034$), right thickness of PP ($p=0.0063$), left posterior length ($p=0.0196$), and left thickness of PP ($p=0.0279$). The B group had a shorter anterior length than the S group (right: $p<0.0001$, left: $p=0.0027$).

Conclusion. These results suggest that the location of the descending palatine artery and the morphology of the pterygoid plates were not significantly associated with any cephalometric measurements. CT examination is necessary to recognize the anatomy of pterygomaxillary region and the exact positions of descending palatine artery before

Le Fort I osteotomy.

Le Fort I osteotomy can surgically correct dentofacial deformities. Complication rates vary from 6.1% to 9.1% (De Mol van Otterloo et al., 1991; Tung et al., 1995). Manipulation of the bones at the base of the skull during surgery may inadvertently cause damage to the vessels and nerves in the region, resulting in life-threatening or vision-threatening complications, including intraoperative hemorrhage, infection, airway obstruction, hypomobility after intermaxillary fixation, and relapse. Dental injuries, over-impaction with unfavourable aesthetic results, oroantral and oronasal fistulas, and avascular necrosis can also occur (Bendor-Samuel et al., 1995).

Venous bleeding after Le Fort I osteotomy usually originates from the pterygoid venous plexus. Tears in the pterygoid muscles may cause venous and arterial bleeding. Major haemorrhage results from injury to the internal maxillary artery or its terminal branches (Turvey and Fonseca, 1980), with the descending palatine artery being the most common source of major bleeding (Lanigan et al., 1990). The descending palatine artery lies within the greater palatine canal, located in the perpendicular portion of the palatine bone. This artery is easily injured during osteotomy of the medial or lateral maxillary sinus walls, pterygomaxillary dysjunction, and during down-fracturing of the maxilla.

Blood supply to the mobile maxilla following a Le Fort I osteotomy is derived from the palatal vascular pedicle via the descending palatine artery, the palatine branches of the ascending pharyngeal and facial arteries, and the buccal vascular pedicle via the posterior superior alveolar artery (Siebert JW et al., 1997). Vascular flow to the mobilized Le Fort I maxilla is reduced during the mobilization process. After transient ischemia, the maxilla becomes rapidly revascularized and forms a bony union (Bell et al., 1995). However, avascular necrosis of the maxilla can occur, hence preserving the descending palatine vessels would increase the safety of the procedure (Lanigan et al., 1990).

Understanding the anatomy of the pterygomaxillary junction region helps prevent blood loss in Le Fort I osteotomy. However, there were few reports regarding the anatomy of this region in Japanese jaw deformity patients. Furthermore, no report was found regarding the relation between lateral and frontal skeletal morphology and structure of pterygomaxillary region. It is also important to assess whether the structure of the pterygomaxillary region can be related to lateral and frontal cephalogram. The purpose of this study was to evaluate the location of the descending palatine artery and the structure of the pterygomaxillary region.

Patients and Methods

Patients

The 82 Japanese adults (men: 23, women: 59) in this study presented with jaw deformities diagnosed as mandibular prognathism and asymmetry, with and without maxillary retrognathism or asymmetry. At the time of orthognathic surgery, the patients ranged in age from 15 to 42 years, with a mean age of 24.4 years (standard deviation, 6.9 years). Informed consent was obtained from patients and the study was approved by Kanazawa University Hospital. Thirty-one patients (B group) underwent Le Fort I osteotomy with a mandibular ramus osteotomy, with 25 bilateral sagittal split ramus osteotomies (BSRO) and 6 intraoral vertical ramus osteotomies (IVRO). Fifty-one patients (S group) underwent mandibular osteotomy alone, with 36 BSRO and 15 IVRO.

Cephalogram assessment

All patients underwent lateral and frontal cephalograms to assess the skeletal pattern. Cephalometric measurements were: SNA, SNB, ANB, Mx1-NA (the distance between upper incisor and Nasion-A point line), Md1-NB (the distance between lower incisor and Nasion-B point line), occlusal plane to SN, inter-incisor angle, and Mx-Md midline (the angle between the ANS-Menton line and the line perpendicular to the bilateral zygomatic frontal suture line).

One skilled observer performed all digitization to reduce methodological variability. Error analysis by digitization and re-measurement of 10 randomly selected cases generated an average error of less than 0.4 mm for the linear measurements and 0.5 degrees for the angular measurements.

CT assessment

The patients were placed in the gantry with the tragacanthal line perpendicular to the ground for CT scanning. They were instructed to breathe normally and to avoid swallowing during the scanning process. CT scans were obtained in the radiology department by skilled radiology technicians using a high-speed, advantage-type CT generator (Light Speed Plus; GE Healthcare, Milwaukee, WI, USA) with each sequence taken 1.25 mm apart for the 3D reconstruction (120 kV, average 150 mA, 0.7 sec/rotation, helical pitch 0.75). The resulting images were stored in the attached workstation computer (Advantage workstation version 4.2; GE Healthcare, Milwaukee, WI, USA), and 3D reconstruction was performed using the volume rendering method. ExaVision LITE version 1.10 medical imaging software (Ziosoft, Inc, Tokyo, Japan) was used for 3D morphological measurements (Fig. 1).

Measurements using CT

The horizontal image 2 to 3 mm above the nasal floor parallel to the FH (Frankfurt) plane at the posterior region of the maxilla was selected to measure the descending palatine canal and pterygoid plates. A total of 164 sides (82 right and 82 left sides) were measured. The RL line was determined as the line between the most anterior points of the bilateral auricles. The measurements were determined as follows (Fig. 2):

1) Anterior length: The distance between the piriform rim and the most anterior point of the descending palatine canal.
2) Posterior length: The distance between the most posterior point of the descending palatine canal and pterygomaxillary fissure line (this line passes through the most concave point of the pterygomaxillary region parallel to the RL line).
3) Width of pterygoid plates (PP): the narrowest width on the pterygomaxillary fissure line.
4) Lateral plate length: The shortest length between the most concave point on the

pterygomaxillary fissure line and the most posterior point of the lateral pterygoid plate.

5) Medial plate length: The shortest length between the most medial point on the pterygomaxillary fissure line and the most posterior point of the medial pterygoid plate.
6) Thickness of PP: The distance between the pterygomaxillary fissure line and the most posterior point of the thinnest anterior part of the pterygoid plates.

All CT images were measured by one author. Fifteen patients were selected randomly and CT images were measured again 10 days later (paired t-test; $p>.05$).

Statistical analysis

Measurements from 82 patients (164 sides) were categorized as right versus left, men versus women, and B group versus group S. Data were compared between men and women and between the B and S groups with a non-paired t-test, and between right and left with a paired t-test using the Stat View™ version 4.5 software program (Abacus Concepts, Inc., Berkeley, CA, USA). The differences were considered significant at $p<0.05$.

The relationship between the cephalometric measurements and those of the descending palatine artery and pterygoid plates were assessed with simple regression analysis.

Results

The mean anterior length was 39.1±3.8 mm on the right and 39.4±4.0 mm on the left. The posterior length was 2.7±1.6 mm on the right and 2.4±1.2 mm on the left. On one side, the descending palatine artery was posterior to the pterygomaxillary fissure. The mean width of PP was 7.7±2.3 mm on the right and 7.6±1.8 mm on the left. The mean lateral plate length was 11.3±3.2 mm on the right and 12.6±3.9 mm on the left. The mean medial plate length was 6.6±1.5 mm on the right and 6.9±1.2 mm on the left. The mean thickness of PP was 1.5±1.0 mm on the right and 1.8±1.3 mm on the left. In nine sides, the most posterior point of the anterior part of the pterygoid plate was anterior to the pterygomaxillary fissure, so sides are negative (Table 1).

There were no significant correlations between measurements of the cephalogram and those of the descending palatine artery and pterygoid plates. There were significant differences between right and left in lateral plate length (p=0.004) and PP thickness (p=0.0047) (Table 1).

In the frontal cephalogram, a positive value for the Mx-Md midline angle represents mandibular deviation to the left and a negative value represents mandibular deviation to the right. The Mx-Md midline angles of all cases were given a positive value so that all consecutive measurements could be attributed to either the deviation or the non-deviation side. However, there was no correlation between the Mx-Md midline and the pterygoid plate measurements.

There were significant differences between men and women in the right width of PP (p=0.0034), right thickness of PP (p=0.0063), left posterior length (p=0.0196), and left thickness of PP (p=0.0279), but not between other measurements (Table 2).

Group B had a shorter anterior length than group S (right: $p<0.0001$, left: $p=0.0027$), but no other differences (Table 3).

Discussion

Complications in Le Fort I osteotomy can occur from dysjunction of the pterygoid plates from the posterior maxillary wall (Arseni et al., 1970; Habal, 1986; Lanigan et al., 1987; Reiner and Willoughby, 1988; Lanigan et al., 1990b; Lanigan et al., 1993; Bendor-Sanmuel et al., 1995) . During Le Fort I osteotomy, the antral walls of the maxilla are cut before the nasal septum is detached from the nasal crest of the maxilla. At this point, the only remaining bony attachments preventing mobilization of the maxilla are the vertical projections of the palatine bone and the junction formed between the maxillary tuberosity, the pterygoid plates, and the pyramidal process of the palatine bones.

Whilst, disarticulation is simplest during the infantile period, it is complicated by the heavily interdigitated osseous union in the late juvenile and adolescent stages (Melsen and Ousterhaut, 1987). Synostosis changes the hardness of the fused fissure and malleting with a blunt osteotome usually results in fracturing the adjacent, weaker pterygoid plates. Usually, a curved Obwegeser osteotome is used through a blind approach to the pterygomaxillary fissure, but other approaches include the swan-neck and shark-fin osteotomes and ultrasonic bone curette, which improve safety (Cheng and Robinson, 1993; Laser et al., 2002; Ueki et al., 2004). Leverage alone avoids the use of osteotomes for pterygomaxillary disarticulation (Precious et al., 1991).

Separation of the posterior maxillary area may also be achieved by the osteotome transecting the tuberosity. Osteotomy through the tuberosity reduces unfavorable fractures of the pterygoid plates and also increases the safety margin by avoiding encroachment on structures of the sphenopalatine fossa (Trimble et al., 1983; O'Regan and Bharadwaj, 2007).

Although the anatomy of the pterygomaxillary region is complicated, it is unclear whether this structure is apparent from routine cephalometric measurements. However, the position of the descending palatine artery and structure of the pterygoid plates were not correlated with any cephalometric measurements, and it was impossible to define the pterygomaxillary region using the lateral and frontal cephalograms. Furthermore, the difference between the right and left sides did not correlate with asymmetric measurements, such as the Mx-Md midline, suggesting that CT data is necessary to perform the Le Fort I osteotomy, especially when bony interference in the pterygomaxillary junction region is removed.

Previously, Li *et al.*(1996) reported that the mean distance from the piriform fossa to the descending palatine canal was 38.4 mm in men and 34.6 mm in women. They stated that injury to the descending palatine artery during the Le Fort I osteotomy can be minimized by not extending the osteotomy more than 30 mm posterior to the piriform rim in females. However, race and skeletal patterns were not described. Cheung *et al*. (1998) reported that the mean distance from the piriform fossa to the descending palatine canal (anterior length) was 34.1 mm using CT of dry skull. The mean anterior length was 39.1 mm on the right and 39.4 mm on the left in this study, both longer than other studies. This may be due to the difference in the standard horizontal plane selected for measurements, as we selected a plane parallel to the FH plane and they used the plane parallel to the nasal floor. In our study, the measured plane was 2-3 mm above the nasal floor at the posterior region of the maxilla, but 5-6 mm above the nasal floor, the piriform rim is longer in the anterior region of the maxilla. We found that the B group had a shorter mean anterior length than the S group. The maxilla in the B group tended to be hypoplastic to allow Le Fort I osteotomy to be performed.

Hwang *et al.* (2001) reported that the thickness of the pterygomaxillary region was significantly greater in the disjunction group than in the fracture group in an experimental study of Le Fort I osteotomy using Korean skulls. The mean distance of distal length plus thickness of PP was 7.7 mm in the dysjunction group and 4.70 mm in the fracture group. The mean PP thickness was 3.14 mm in the dysjunction group and 1.09 mm in the fracture group. We found a mean distance of distal length plus PP thickness of 4.2 mm on the right and 4.2 mm on the left, with a mean PP thickness of 1.5 mm on the right and 1.8 mm on the left. Men were significantly larger than women in the right PP width and left posterior length, but PP thickness was significantly smaller in men than in women. Thus, the thickness of the pterygomaxillary region in our study was more akin to the fracture group in their study. The subjects in this study were patients that received orthognathic surgery. Therefore, surgeons should consider that pterygoid plate fractures in patients could occur more frequently. Osteotomy through the tuberosity may be more favourable than dysjunction at the pterygomaxillary fissure for Japanese jaw deformity patients.

When setback or impaction of the maxilla is performed, removal of the maxillary tuberosity, posterior wall, and the anterior part of the pterygoid plates are occasionally necessary. If the maxillary segment cannot be moved posteriorly, an artificial fracture of the pterygoid plates is also necessary. It is important to know the lateral and medial pterygoid plate lengths in such cases. In our previous study, an ultrasonic bone curette was used to section the pterygomaxillary region, preserving the descending palatine artery (Ueki et al.,2004). Information regarding the lateral and medial pterygoid plate lengths can be also useful for safe maxillary osteotomy with that method.

Conclusion

The location of the descending palatine artery and the morphology of the pterygoid plates are not significantly associated with any cephalometric measurements. CT examination is necessary to recognize the anatomy of pterygomaxillary region and the exact positions of descending palatine artery before Le Fort I osteotomy.

References

Tung TC, Chen YR, Bendor-Samuel RL. Surgical complications of the Le Fort I osteotomy: a retrospective review of 146 cases. Chang Keng I Hsueh 1995; 18: 102-7.

De Mol van Otterloo JJ, Tuinzing DB, Greebe RB, van der Kwast W. Intra- and early postoperative complications of the Le Fort I osteotomy: a retrospective study on 410 cases. J Craniomaxillofac Surg 1991; 19: 217-22.

Bendor-Samuel R, Chen YR, Chen PK. Unusual complications of Le Fort I osteotomy. Plasr Reconstr Surg 1995; 96: 1286-96.

Turvey T, Fonseca R. The anatomy of the internal maxillary artery in the pterygopalatine fossa: Its relationship to maxillary surgery. J Oral Surg 1980; 38: 92-5.

Lanigan DT, Hey JH, Weat RA. Major vascular complications of orthognathic surgery: Hemorrhage associated with Le Fort I osteotomies. J Oral Maxillofac Surg 1990; 48: 561-73.

Siebert JW, Angrigiani C, McCarthy JG, Longaker MT. Blood supply of Le Fort I maxilla segment: An anatomy study. Plast Reconstr Surg 1997; 100: 843-850.

Bell WH, You ZN, Finn RA, Fields RH. Wound healing after multisegmental Le Fort I osteotomy and transaction of the descending palatine vessels. J Oral Maxillofac Surg 1995; 53: 1425-33.

Lanigan D, Hey J, West R. Aseptic necrosis following maxillary osteotomies: report of 36 cases. J Oral Maxillofac Surg 1990: 48: 142-56.

Lanigan DT, Tubman E.Carotid-cavernous sinus fistula following Le Fort I osteotomy. J Oral Maxillofac Surg 1987; 45: 969-75.

Habal MB. A carotid cavernous sinus fistula after maxillary osteotomy. Plast Reconstr Surg 1986; 77: 981-7.

Arseni C, Ghitescu M, Cristescu A, Mihăilă G, Drăguțoiu E. Traumatic carotid-cavernous fistulas. Psychiatr Neurol Neurochir 1970; 73: 237-42.

Lanigan DT, Romanchuk K, Olson CK. Ophthalmic complications associated with orthognathic surgery. J Oral Maxillofac Surg 1993; 51: 480-94.

Reiner S, Willoughby JH. Transient adbucens nerve palsy following a Le Fort I maxillary osteotomy: report of a case. J Oral Maxillofac Surg 1988; 46: 699-701.

Melsen B, Ousterhaut DK. Anatomy and development of the pterygopalatomaxillary region, studied in relation to the Le Fort osteotomies. Ann Plast Surg 1987; 19: 16-26.

Cheng LH, Robinson PP. Evaluation of a swan's neck osteotome for pterygomaxillary dysjunction in the Le Fort I osteotomy. Br J Oral Maxillofac Surg 1993; 31: 52-3.

Laster Z, Ardekian L, Rachmeil A, Peled M. Use of the 'shark-fin' osteotome in separation of the pterygomaxillary junction in Le Fort I osteotomy: a clinical and computerized tomography study. Int J Oral Maxillofac Surg 2002; 31: 100-3.

Ueki K, Nakagawa K, Marukawa K, Yamomoto E. Le Fort I osteotomy using an ultrasonic bone curette to fracture the pterygoid plates. J Craniomaxillofac Surg 2004; 32: 381-6.

Precious DS, Morrison A, Richard D. Pterygomaxillary separation without the use of an osteotome. J Oral Maxillofac Surg 1991; 49: 98-9.

Trimble LD, Tideman H, Stoelinga P. A modification of the pterygoid plate separation in low level maxillary osteotomies. J Oral Maxillofac Surg 1983; 41: 544-6.

O'Regan B, Bharadwaj G. Prospective study of the incidence of serious posterior maxillary haemorrhage during a tuberosity osteotomy in low level Le Fort I operations. Br J Oral Maxillofac Surg 2007; 45: 538-42.

Li KK, Maera JG, Alexander A. Location of the descending palatine artery in relation to the Le Fort I osteotomy. J Oral Maxillofac Surg 1996; 54: 822-825.

Cheng LK, Fung SC, Li T, Samman N. Posterior maxillary anatomy: implications for Le Fort I osteotomy. Int J Oral Maxillofac Surg. 1998; 27: 346-51.

Hwang K, Lee DK, Chung IH, Lee S. Le Fort I osteotomy with sparing fracture of lateral pterygoid plate. J Cranio-fac Surg 2001; 12: 48-52.

Legends

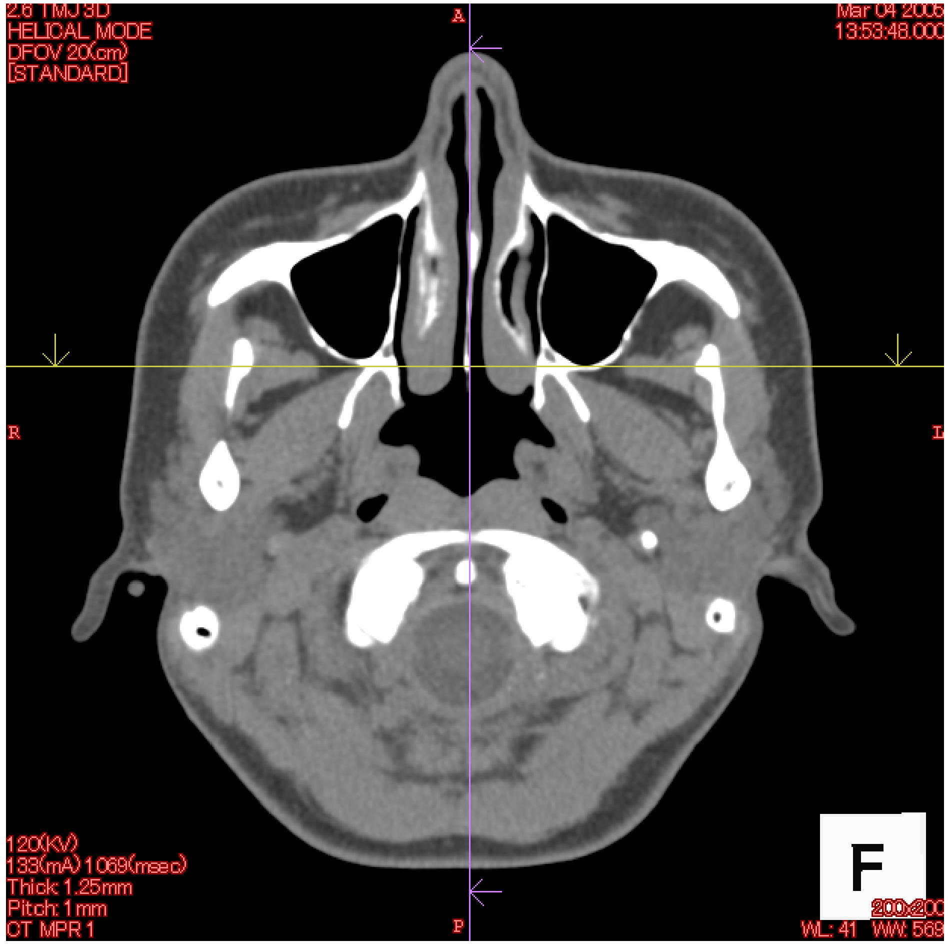
Fig.1 CT images. a: Horizontal image, b: Coronal image, c: Sagittal image. The horizontal image was parallel to the FH (Frankfurt) plane. The coronal image was perpendicular to FH plane. The sagittal image was perpendicular to the coronal image.

Fig. 2 Measurements of the Pterygomaxillary region. 1) Anterior length, 2) Posterior length, 3) Width of pterygoid plates (PP), 4) Lateral plate length, 5) Medial plate length, 6) Thickness of PP

Table 1. The patients results. SD indicates standard deviation. * indicates significant difference at $p<0.05$.

Table 2. The results of Men and Women. SD indicates standard deviation. * indicates significant difference at $p<0.05$.

Table 3. The results of the bimaxillary osteotomy (B)and mandibular osteotomy (S) groups. SD indicates standard deviation. * indicates significant difference at $p<0.05$.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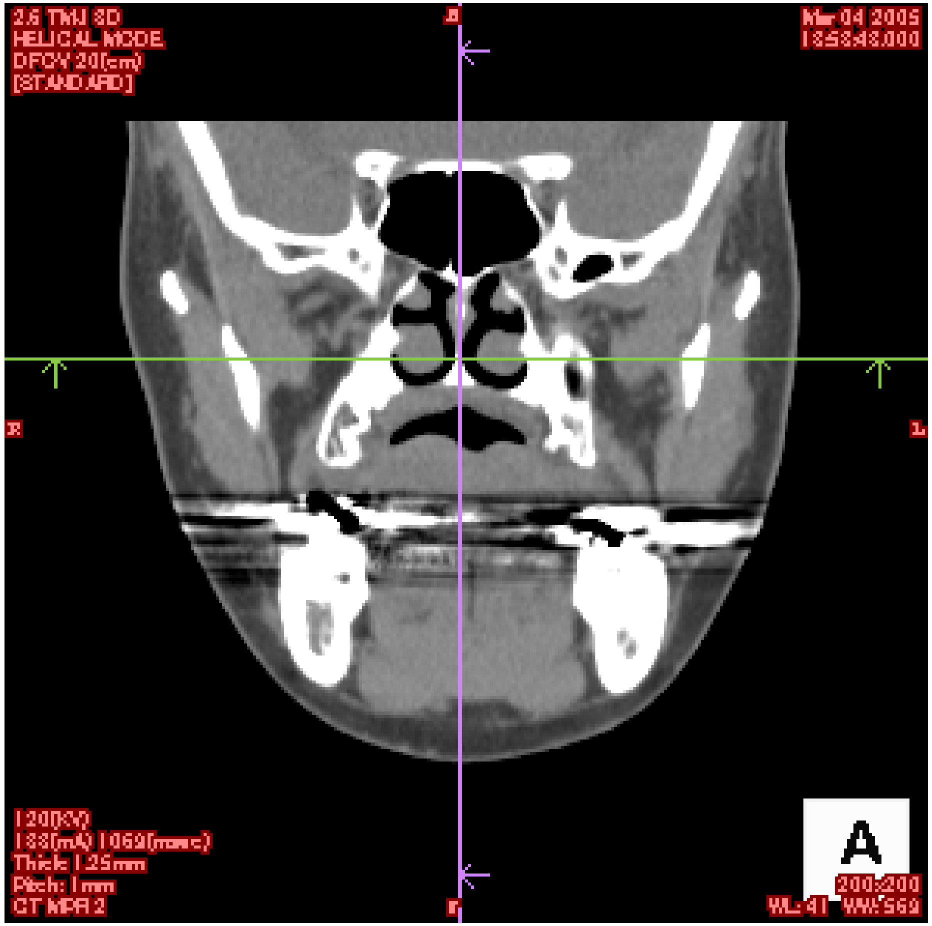
[STANDARD]
A
R
L
P
120(KV)
133(mA) 1069(msec)
Thick 1.25mm
Pitch: 1mm
CT MPR 1
F
WL: 41 WW: 569

Fig. 1a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A
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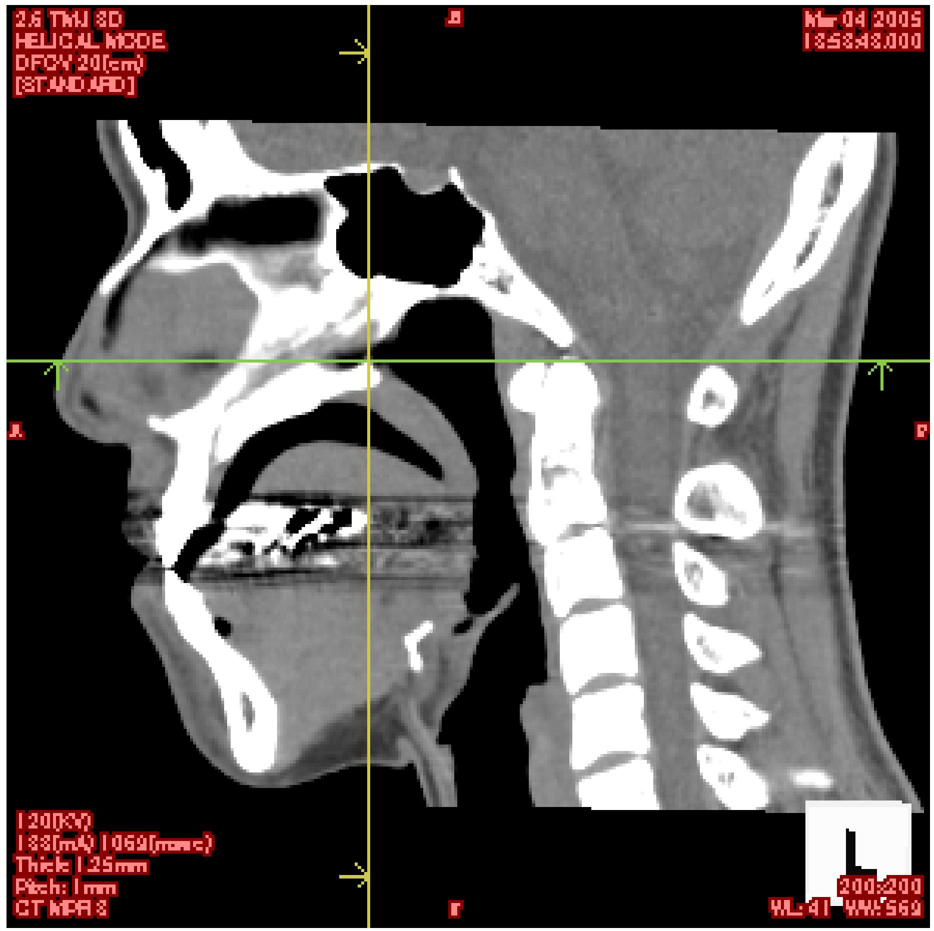
WL:41 WW:569

Fig. 1b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Mar 04 2005
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S
A
P
I
120(KV)
133(mA) 1069(msec)
Thick 1.25mm
Pitch: 1mm
CT MPR 3
200x200
WL: 41 WW: 569

Fig. 1c

Fig.2

total(n=82)	Right		Left			
	Average	SD	Average	SD	p value	
Anterior length	39.1	3.8	39.4	4.0	0.1505	
Posterior length	2.7	1.6	2.4	1.2	0.1126	
Width of PP	7.7	2.3	7.6	1.8	0.5180	
Lateral plate length	11.3	3.2	12.6	3.9	0.0014	*
Medial plate length	6.6	1.5	6.9	2.2	0.2057	
Thickness of PP	1.5	1.0	1.8	1.3	0.0047	*

Table 1.

		W(n=59) Average	SD	M(n=23) Average	SD	p value	
Right	Anterior length	38.8	3.8	39.9	4.0	0.2273	
	Posterior length	2.5	1.6	3.0	1.5	0.2029	
	Width of PP	7.3	1.5	8.9	3.3	0.0034	*
	Lateral plate length	11.2	3.5	11.7	5.6	0.5744	
	Medial plate length	6.7	1.4	6.3	1.8	0.2354	
	Thickness of PP	1.7	1.0	1.0	1.1	0.0063	*
Left	Anterior length	39.2	4.0	39.9	4.2	0.4841	
	Posterior length	2.2	1.0	2.9	1.6	0.0196	*
	Width of PP	7.4	1.7	8.0	2.0	0.1614	
	Lateral plate length	12.6	4.1	12.6	3.3	0.9868	
	Medial plate length	7.1	2.3	6.4	1.8	0.2072	
	Thickness of PP	2.0	1.3	1.4	0.9	0.0279	*

Table 2.

		B(n=31) Average	SD	S(n=51) Average	SD	p value	
Right	Anterior length	37.0	2.4	40.4	4.0	<0.0001	*
	Posterior length	2.5	1.8	2.8	1.5	0.4427	
	Width of PP	7.6	2.0	7.8	2.4	0.7528	
	Lateral plate length	10.7	3.4	11.7	3.1	0.1619	
	Medial plate length	6.4	1.3	6.8	1.6	0.2751	
	Thickness of PP	1.6	1.1	1.4	1.0	0.6146	
Left	Anterior length	37.7	3.2	40.4	4.1	0.0027	*
	Posterior length	2.2	1.1	2.5	1.3	0.2088	
	Width of PP	7.2	2.0	7.8	1.6	0.1648	
	Lateral plate length	11.3	3.3	13.3	4.0	0.0220	*
	Medial plate length	6.8	2.6	6.9	1.9	0.8495	
	Thickness of PP	2.0	1.4	1.7	1.2	0.3677	

Table 3.