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<원저>

Determination of Appropriate Exposure Angles for the Reverse Water's View using a Head Phantom

- 두부 팬텀을 이용한 Reverse Water's View에 관한 적절한 촬영 각도 분석 -

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— Abstract —

Early diagnosis for upper facial trauma is difficult by using the standard Water's view (S-Water's) in general radiograph due to overlapping of anatomical structures, the uncertainty of patient positioning, and specific patients with obese, pediatric, old, or high-risk. The purpose of this study was to analyze appropriate exposure angles through a comparison of two different protocols (S-Water's vs. reverse Water's view (R-Water's)) by using a head phantom. A head phantom and general radiograph with 75 kVp, 400 mA, 45 ms 18 mAs, and SID 100 cm. Images of R-Water's were obtained by different angles in the range of 0° to 50°, which adjusted an angle at 1 degree interval in supine position. Survey elements were developed and three observers were evaluated with four elements including the maxillary sinus, zygomatic arch, petrous ridge, and image distortion. Statistical significant analysis were used the Krippendorff's alpha and Fleiss' kappa. The intra-class correlation (ICC) coefficient for three observers were high with maxillary, 0.957 (0.903, 0.995); zygomatic arch, 0.939 (0.866, 0.987); petrous ridge, 0.972 (0.897, 1.000); and image distortion, 0.949 (0.830, 1.000). The high-quality image (HI) and perfect agreement (PA) for acquired exposure angles were high in range of the maxillary sinus (36° – 44°), zygomatic arch (33° – 40°), petrous ridge (32° – 50°), and image distortion (44° – 50°). Consequently, an appropriate exposure angles for the R-Water's view in the supine position for patients with facial trauma are in the from 36° to 40° in this phantom study. The results of this study will be helpful for the rapid diagnosis of facial fractures by simple radiography.

Key Words : Facial trauma, Water's view, Reverse Water's view, Exposure angle

Ⅰ. INTRODUCTION

The incidence of facial injuries increasing with the increase in the frequency of traffic accidents, injuries, and industrial accidents. These injuries can be divided into facial trauma and fractures. These damage usually occur simultaneously and are accompanied by damage to other areas of the face. In particular, external fractures of the orbit are caused by momentary high pressure, increased intraocular pressure, or impact on the front of the orbit. The fracture of the orbital floor is most common and the

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orbital medial wall is associated with other fractures [1–5].

Early diagnosis and appropriate treatment of the orbital fracture are necessary; otherwise, there may be adverse effects on optical function, leading to diplopia, eye movement disorders, or enophthalmos, as well as cosmetic disorders [4]. When diagnosing an orbital facture, it is difficult to accurately determine if there is a fracture line due to overlapping of anatomical structures. Most patients with facial trauma require first aid, and inaccurate positioning of the patient's head, excessive bleeding, and the presence of the catheter for tracheal tubes reduce the diagnostic value of radiation images. Therefore, a multifaceted approach is needed to increase the diagnostic value of these images in case of facial trauma.

Diagnostic methods of medical imaging for orbital fractures include general radiography and computed tomography (CT). The general radiographs available include the Skull, Town's, Caldwell, and Water's views. The Water's view is method for diagnosing and evaluating an upper facial injury. It is useful for visualizing the upper jawbone, zygoma, orbital ring, orbital floor, and nasal bone. However, visualizing the orbital area is difficult because of overlapping structures and the anatomical characteristics of thin bones. To address this issue, proper exposure conditions, accurate patient positioning, patient assistance, and professionalism and skill of the technician are required. With a CT scan, facial and orbital scan protocols that are more useful than general radiograph for visualizing various structures are available [6–8]. However, there is the disadvantage of high doses of radiation and high cost. The ideal position of the patient for a Water's view examination is prone, sitting, or standing. However, it is difficult to ideally position the patient in cases of emergency, trauma from a traffic accident, instability of head posture, or in case of obese, pediatric, old, or high-risk patients.

We wanted to increase the diagnostic value of radiography in patients with orbital fracture who cannot be positioned properly during a radiologic examination. Hence, the purpose of this study was to analyze the appropriate exposure angles through a comparison of two different protocols (standard vs. reverse Water's view) by using a head phantom.

Ⅱ. METHODS AND MATERIALS

1. Phantom and standard (and reverse) Water's view

An anthropomorphic head phantom (The phantom Laboratory, Salem, NY, USA) and general X-ray INNOVISION-SH (R-500-150, DK medical solutions, Korea) was used, as shown in Fig. 1. (source image distance [SID] = 100 cm, exposure conditions of Water's view: 75 kVp, 400 mA, 45 ms, and 18 mAs). The present study compared two exposure protocols: standard (S-Water's) vs. reverse Water's view (R-Water's). First, to acquire the reference image, a S-Water's in the prone position was performed using a head phantom (Fig. 2). Here, a fixation device used to fix a head phantom when prepared general Water's view position.

The head phantom was placed in the prone position, in close contact with the jaw and table such that the orbito-meatal line (OML) was at an angle of 37° with respect to the cassette plane. Radiation was passed through the acanthion and S-Water's images (*i. e.*, reference image) were obtained. For the R-Water's, the exposure conditions were the same. A head

Fig. 1 Digital radiography system

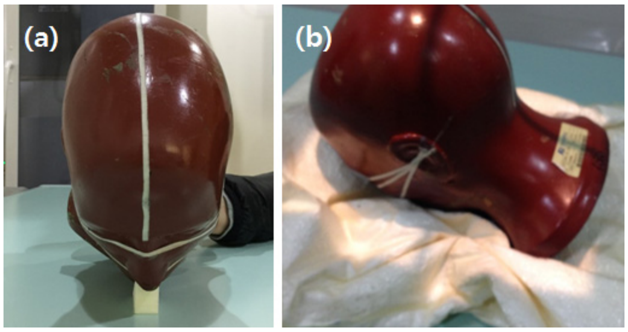

Fig. 2 Standard Water's view (S-Water's) with a head phantom in prone position in prepare (a) and in examination (b).

Fig. 3 General X-ray and head phantom that the reverse Water's view (R-Water's) performing in supine position.

phantom was placed in the supine position on the table and R–Water's images were obtained by applying different angles ranging from 0° to 50° by rotating the radiograph tube, which can typically be rotated by up to 180° (Fig. 3). R–Water's images were obtained three times by adjusting the angle at 1° intervals.

2. Evaluation

Survey elements were developed by consulting with a medical specialist (*i. e.*, radiologist) in the radiology department. Table 1 shows the four evaluation elements. For the scoring of each element, the maxillary sinus and zygomatic arch were defined as zero point, one point, and two points score according to each item. The remaining petrous ridge and image distortion were evaluated with a score of zero or one point. Overall, the evaluation process was divided into the three following categories: 1. the inter–observer agreement; 2. distribution of the exposure angles; 3. suitability of the exposure angles, which were evaluated sequentially.

1) Inter–observer agreements

Three observers (one radiologist and two radiological technologists) evaluated the general radiography images acquired using R–Water's method by using the developed survey elements in Table 1. The inter–observer agreement was evaluated by using two statistically significant analysis methods–the Krippendorff's alpha and Fleiss' kappa. Agreement for the maxillary sinus and zygomatic arch was evaluated using the Krippendorff's alpha method [9] and that for the petrous ridge and image distortion was evaluated using the Fleiss' kappa method [10]. Table 2 shows the reference score with agreement factors of the two statistical analysis methods.

2) Distribution of the exposure angle

A high–quality image (HI) and perfect agreement (PA) for the acquired exposure angles were defined and scored for each item. The high score of the HI for each exposure angle was two points for the maxillary sinus and zygomatic arch, one point for the petrous ridge, or zero points. Scoring of the PA item was same for all three observers. Here, it is means that all HI and PA (*i. e.*, both) showed all satisfied the condition.

3) Appropriate exposure angle

Evaluation elements such has HI, PA, or both were used to verify that the appropriate exposure angles were used and to analyze the distribution of the exposure angles.

Table 1 Survey elements to evaluate obtained images

Element	Contents	Score
Maxillary sinus	Almost problem that no distinguish MS or overlaps other structures Partial possible to evaluation that hidden in part of MS Enough possible to evaluation that most seen in MS	0 1 2
Zygomatic arch	Problem that no distinguish most of both ZA Partial possible to evaluation that hidden in part of both ZA Enough possible for fracture evaluation in both ZA	0 1 2
Petrous ridge	PR covered most of the MS PR located below of the MS	0 1
Image distortion	Show ID with enlargement and flexible Evaluation possible with no ID	0 1

Abbreviation: MS = maxillary sinus; ZA = zygomatic arch; PR = petrous ridge; and ID = image distortion.

Table 2 Reference values of the intra-class correlation (ICC) coefficient evaluation

Method	Score	Agreement
Kippoendorff's alpha	0.000 – 0.667 0.667 – 0.799 0.800 – 1.000 0.01 – 0.20	Discard data Consider data only to draw tentative conclusion Rely on data with reliabilities Slight agreement
Fleiss' kappa	〈 0 0.21 – 0.40 0.41 – 0.60 0.61 – 0.80 0.81 – 1.00	Poor agreement Fair agreement Moderate agreement Substantial agreement Almost perfect agreement

Table 3 ICC coefficient of three observers in four elements

Variable	k-alpha / F-kappa (95% CI)
Maxillary sinus*	0.957 (0.903, 0.995)
Zygomatic arch*	0.939 (0.866, 0.987)
Petrous ridge†	0.972 (0.897, 1.000)
Image distortion†	0.949 (0.830, 1.000)

Abbreviation: k-alpha = Krippendorff's alpah; F-kappa = Fleiss' kappa; CI, confidence interval.
* Assessed by k-alpha for the ordinal data of 3 raters; † Assessed by F-kappa for the nominal data of 3 raters; 95% CIs were obtained by bootstrapping method with 1,000 iterations.

III. Results

1. Inter-observer agreements

Table 3 shows the result of the intra-class correlation (ICC) coefficient evaluation for the three observers using the following four elements: maxillary sinus, 0.957 (0.903, 0.995); zygomatic arch, 0.939 (0.866, 0.987); petrous ridge, 0.972 (0.897, 1.000); and image distortion, 0.949 (0.830, 1.000). The ICC coefficient was very high among the three observers in this study.

2. Distribution of the exposure angles

The distribution was evaluated to the various exposure angles by determining if the image was of high-quality and in perfect agreement (Table 4). The range of angles that included (1) at least one of the four elements was from 32° to 50°, (2) at least two of

Table 4 Assessment of R-Water's view at the various exposure angles in a head phantom

Degree	Maxillary sinus			Zygomatic arch			Petrous ridge			Image distortion		
	HI*	PA†	Both‡	HI*	PA†	Both‡	HI*	PA†	Both‡	HI*	PA†	Both‡
0°	-	O	-	-	O	-	-	O	-	-	O	-
1°	-	O	-	-	O	-	-	O	-	-	O	-
2°	-	-	-	-	-	-	-	O	-	-	O	-
3°	-	O	-	-	-	-	-	O	-	-	O	-
4°	-	O	-	-	O	-	-	O	-	-	O	-
5°	-	O	-	-	O	-	-	O	-	-	O	-
6°	-	O	-	-	O	-	-	O	-	-	O	-
7°	-	O	-	-	O	-	-	O	-	-	O	-
8°	-	O	-	-	O	-	-	O	-	-	O	-
9°	-	O	-	-	O	-	-	O	-	-	O	-
10°	-	O	-	-	O	-	-	O	-	-	O	-
11°	-	O	-	-	O	-	-	O	-	-	O	-
12°	-	O	-	-	O	-	-	O	-	-	O	-
13°	-	O	-	-	O	-	-	O	-	-	O	-
14°	-	O	-	-	O	-	-	O	-	-	O	-
15°	-	O	-	-	O	-	-	O	-	-	O	-
16°	-	O	-	-	O	-	-	O	-	-	O	-
17°	-	O	-	-	O	-	-	O	-	-	O	-
18°	-	O	-	-	O	-	-	O	-	-	O	-
19°	-	O	-	-	O	-	-	O	-	-	O	-
20°	-	O	-	-	O	-	-	O	-	-	O	-
21°	-	O	-	-	O	-	-	O	-	-	O	-
22°	-	O	-	-	O	-	-	O	-	-	O	-
23°	-	O	-	-	O	-	-	O	-	-	O	-
24°	-	O	-	-	O	-	-	O	-	-	O	-
25°	-	O	-	-	O	-	-	O	-	-	O	-
26°	-	-	-	-	-	-	-	O	-	-	O	-
27°	-	O	-	-	O	-	-	O	-	-	O	-
28°	-	O	-	-	O	-	-	O	-	-	O	-
29°	-	O	-	-	O	-	-	O	-	-	O	-
30°	-	O	-	-	O	-	-	O	-	-	O	-
31°	-	O	-	-	O	-	O	-	-	-	O	-
32°	-	O	-	O	-	-	O	O	O	-	O	-
33°	-	O	-	O	O	O	O	O	O	-	O	-
34°	-	O	-	O	O	O	O	O	O	-	O	-
35°	O	-	-	O	O	O	O	O	O	-	O	-
36°	O	O	O	O	O	O	O	O	O	-	O	-
37°	O	O	O	O	O	O	O	O	O	-	O	-
38°	O	O	O	O	O	O	O	O	O	-	O	-
39°	O	O	O	O	O	O	O	O	O	-	O	-
40°	O	O	O	O	O	O	O	O	O	-	O	-
41°	O	O	O	O	-	-	O	O	O	-	O	-
42°	O	O	O	-	O	-	O	O	O	-	O	-
43°	O	O	O	-	O	-	O	O	O	O	-	-
44°	O	O	O	-	O	-	O	O	O	O	O	O
45°	O	-	-	-	O	-	O	O	O	O	O	O
46°	-	O	-	-	O	-	O	O	O	O	O	O
47°	-	O	-	-	O	-	O	O	O	O	O	O
48°	-	O	-	-	O	-	O	O	O	O	O	O
49°	-	O	-	-	O	-	O	O	O	O	O	O
50°	-	O	-	-	O	-	O	O	O	O	O	O

Abbreviation: HI, high-quality image; PA, perfect agreement

* High-quality image is defined as the degree which obtained at least one of the highest score from the three raters (2 for maxillary sinus and zygomatic arch; 1 for petrous ridge; 0 for image distortion)

† Perfect agreement is defined as the degree which obtained all of the same scores from the three raters.

‡ Both is defined as the degree which was determined as high-quality image and perfect agreement.

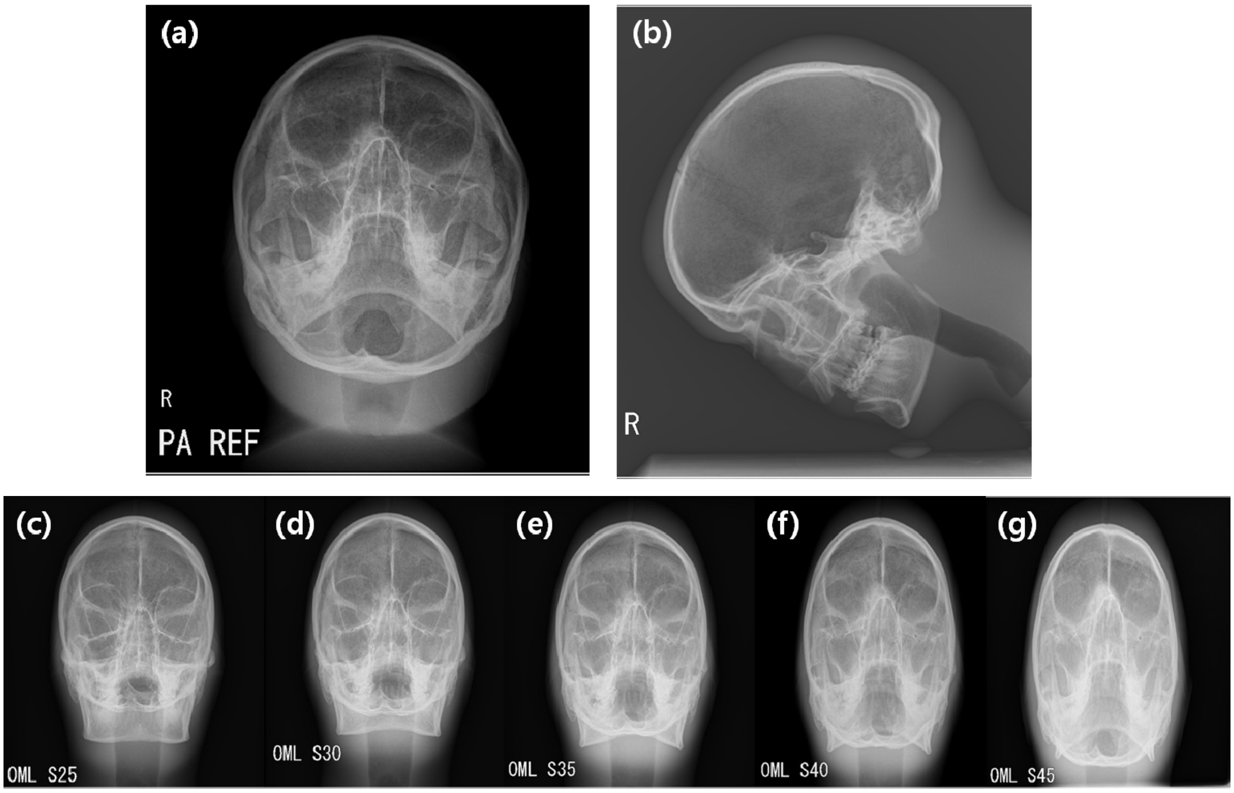

Fig. 4 Upper row are acquired images in (a) standard Water's view (S-Water's) and (b) lateral view. Bottom row are (from c to g) acquired reverse Water's view (R-Water's) images that acquired with angles at 5° interval

Table 5 Range of an appropriate exposure angles for four elements in R-Water's view

Elements of HI and PA	Range of degree
Maxillary sinus	36° - 44°
Zygomatic arch	33° - 40°
Petrous ridge	32° - 50°
Image distortion	44° - 50°
Maxillary sinus & zygomatic arch	36° - 40°
Petrous ridge & image distortion	44° - 50°
Maxillary sinus & petrous ridge	36° - 44°
Zygomatic arch & petrous ridge	33° - 40°
Maxillary sinus, zygomatic and petrous ridge	36° - 40°
At least one of the four elements	32° - 50°
At least two of the four elements	33° - 50°
At least three of the four elements	36° - 40°, 44°
All of the four elements	None

the four elements was from 33° to 50°, and (3) at least three of the four elements was from 36° to 40°, and 44°. There were no angles that included all four elements. Fig. 4 shows the reference images in S-Water's view and acquired R-Water's view images with angles at 5° interval.

3. Appropriate exposure angles

The high-quality image (HI) and perfect agreement (PA) for the acquired exposure angles had a wide range for the maxillary sinus (36° - 44°), zygomatic arch (33° - 40°), petrous ridge (32° - 50°), and image distortion (44° - 50°), as shown in Table 5.

IV. DISCUSSION

The upper facial area is very vulnerable to damage by external forces because it protrudes outward. Such damages may be difficult to diagnose and treat because of the complexity of the anatomical relationship with the adjacent bone and thus, fracture patterns vary widely. Although the structure of the facial bone can resist masticatory forces and vertical external forces, horizontal fractures, such as Le Fort fractures, can occur [5].

Diagnostic radiology for patients with upper facial trauma generally consists of general radiographic and CT examinations. Owing to the complex anatomical strucutre, it is difficult to observe the fracture pattern in case of upper facial fractures caused by trauma, while verifying the degree of bone damage and the displacement of the fragment using a general X-ray unit [11]. However, since CT has the advantage of easily distinguishing between soft and bone tissues, it can distinguish the fracture pattern. Zilkha et al. [12] evaluated 30 patients with facial trauma and reported that the CT image was better than other diagnostic images.

In general radiograph, the standard Water's view (*i. e.*, S-Water's) method is dependent on the shape of the face; however, the tip of the nose should be 0.5 cm to 1.5 cm from the film (or cassette plane) during the examination. Moreover, a concave-shaped face should be kept a little more distant from the film than a convex-shaped face [13]. Mahoney et al. [14] recommend that for the image of the vertebral body to be observed, the orbital line should be adjusted to form an angle of 37° with respect to the plan of the film. Therefore, the S-Water's image is useful many cases, such as the subcutaneous emphysema, tear drop sign of the maxillary sinus, opaque of maxillary sinus air shade, and asymmetry inferior orbital. However, it is absolutely influenced by the positioning of the patient because very complex. In addition, it is no easy to diagnosis because thin orbital bone, overlap other structures, and false negative error rate for fracture was 18% in associated report [11, 15]. Consequently, patient positioning is important for improving the diagnostic quality and treatment of upper facial trauma. Moreover, other patients without upper facial trauma, such as children and old, obese, alcoholic, and high-risk should be observed in the supine position (*i. e.*, reverse Water's view).

In this study, we analyzed the appropriate exposure angles by using a head phantom. To precisely evaluate, a total of four elements including the maxillary sinus, zygomatic arch, petrous ridge, and image distortion, were evaluated in an exposure range of 0° to 50° in R-Water's view. The ICC for the three observers was high (Table 3). Consequently, we demonstrated that the range of suitable exposure angles in R-Water's view was 36° to 40°. However, we expect that an exposure angle of 36° (incidence point: acanthion) would be excellent considering that image distortion could be occur at angles above 39°. We can verify the difference that compared images between references and acquired differential 5 degree interval images, as shown in Fig. 3.

The limitation of this study was that it was a phantom study and did not take into consideration the various examination conditions, such as phantom models (*i. e.*, Asian or westerner) and radiography type. The R-Water's view should be considered for patients who cannot be placed in the standard supine position (*i. e.*, S-Water's). It will also reduce the patient's exposure to radiation from by the CT unit, and improve the image quality in cases of emergency. In this phantom study, we determined the appropriate exposure angles for the R-Water's view. Although, it is difficult to uniformly used these exposure angles across institutions, we expect that these exposure angles may be useful for most medical institutions when no condition in S-Water's view.

V. CONCLUSION

Appropriate exposure angles for the R-Water's view in the supine position for patients with facial trauma are in the range from 36° to 40° in this phantom study. The results of this study will be helpful for the rapid diagnosis of facial fractures by simple radiography.

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•국문초록

두부 팬텀을 이용한 Reverse Water's View에 관한 적절한 촬영 각도 분석

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상안면부 외상(upper facial trauma)의 초기진단에서 standard Water's view (S-Water's)는 여러 구조물의 중첩과 얇은 뼈의 해부학적 특성 때문에 검사 시 적절한 노출조건, 정확한 환자위치잡이, 환자의 도움, 촬영자의 전문성과 숙련도가 필요하다. 본 연구는 엎드린 자세가 불가능한 경우 안와 골절에 대한 진단적 가치를 높이고 자 reverse Water's view (R-Water's)의 적절한 각도를 찾고자 하였다. 인체모형 팬텀를 사용하였고, 촬영조건은 75 kVp, 400 mA, 45 ms, 1 mAs, SID 100 cm였다. 검사방법은 팬텀을 테이블에 똑바로 누운 자세에서 orbito-meatal line (OML)의 각도를 0°에서 50° 범위에서 촬영 각도를 조절하여 영상을 얻었다. R-Water's 영상 평가는 자체 개발한 평가항목을 토대로 분석하였다. 세부항목으로는 상악동(maxillary sinus), 관골궁(zygomatic arch), 추체부(petrous ridge)와 영상왜곡(image distortion)이었다. 통계분석은 Kippendorff's alpha와 kappa를 확장한 Fleiss' kappa를 적용하였다. 각 항목별 총 세 명의 평가자에 대한 일치도는 상악동, 0.957 (0.903, 0.995); 관골궁, 0.939 (0.866, 0.987); 추체부, 0.972 (0.897, 1.000); 영상 왜곡, 0.949 (0.830, 1.000)로 모두 높았다. 측정별 각도 구간을 분석에 대한 high-quality (HI)와 perfect agreement (PA)로 정의하여 각 항목별로 점수화한 결과, 상악동 (36° – 44°), 관골궁 (33° – 40°), 추체능선 (32° – 50°), 영상왜곡 (44° – 50°)구간에서 높았다. 본 연구결과 상안면부 외상환자에 있어 똑바로 누운 자세에서의 R-Water's의 적정 각도는 36° – 40°로 판단된다. 본 연구결과는 단순촬영을 통한 안면부 골절의 신속한 진단에 도움을 줄 것으로 사료된다.

중심 단어 : 안면손상, water's 촬영, 역 water's 촬영, 촬영각도