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Original

Evaluation of the Correlation between the Volume of Orbital Tissue Incarcerated into the Maxillary and Sinus Ocular Deviation, after Orbital Floor Fracture

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Abstract: In the case of orbital floor fractures, enophthalmos occurs if the volume of orbital tissue incarcerated into the maxillary sinus increases. However, during severe eyelid swelling, enophthalmos measurement is inaccurate. We aimed to investigate the correlation between the incarcerated tissue volume and ocular deviation. Patients with isolated orbital floor fracture were included. Orbital and incarcerated tissue volumes were measured using coronal computed tomography images. The ratio of incarcerated tissue volume to orbital volume (V) was calculated. Ocular deviation was measured using the Showa exophthalmometer. Ocular deviations in anterior-posterior and superior-inferior planes were defined as E1 and E2, respectively. Correlations between V and E1, V and E2, and E1 and E2 were statistically analyzed. Correlation coefficients between V and E1, V and E2, and E1 and E2 were 0.765, 0.279, and 0.237, respectively, and regression lines were $E1 = 0.13 \times V + 0.18$, $E2 = 0.05 \times V - 0.16$, $E2 = 0.24 \times E1 + 0.07$, respectively. Only the correlation between V and E1 was statistically significant. When enophthalmos cannot be measured after an isolated orbital floor fracture, if the tissue incarcerated volume can be measured using CT images, enophthalmos can be diagnosed.

Key words: orbital floor fracture, enophthalmos, exophthalmometer, ocular deviation, hypoglobus

Introduction

Enophthalmos is one of the major symptoms after orbital floor fracture. When the orbital tissue incarcerated into the maxillary sinus (following the incarcerated tissue volume) increases, ocular deviation occurs posteriorly. Consequently, inferior ocular deviation as well as enophthalmos may occur. However when enophthalmos is measured using the Hertel exophthalmometer (Hertel), the datum point is outside the orbital edge. In the case of severe eyelid swelling, the datum point cannot be defined. Therefore, measurement using Hertel is inaccurate. If enophthalmos is inferred from the incarcerated tissue volume, it could be diagnosed in cases where the measurement is difficult because of severe eyelid swelling. We investigated the correlation between the incarcerated tissue volume and ocular deviation

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(enophthalmos and hypoglobus) in patients with an isolated orbital floor fracture.

Methods

Appropriate cases were selected from 284 patients with orbital floor fracture who visited our hospital from April 2008 to June 2011. The inclusion criteria were as follows: isolated orbital floor fracture, >20 years of age, male, and a period of >7 days since the injury. The exclusion criteria were the presence of orbital rim and orbital medial wall fractures, orbital emphysema, anamnesis of past orbital floor fracture, orbital floor fracture on both sides, not Japanese, and insufficient inspection and measurement. These criteria were chosen because differences in sex, age, and race[2] affect the facial skeleton. In the early stage (especially within 7 days after injury), orbital emphysema affects ocular deviation[3], and the orbital volume increases with malar bone and orbital medial wall fractures[4] and anamnesis of orbital floor fracture.

The incarcerated tissue and orbital volumes were measured using computed tomography (CT) (Light Speed VCT VISIO, GE Healthcare Company). The coronal section of the orbital CT was used for measurement. The measurement range was decided in accordance with the method of measurement of Furuta[5]; the initial image was that immediately in front of the posterior lacrimal sac edge and the final image was that of the optic canal opening. The following points were considered while tracing the measurement range in each CT image: A straight line was drawn linking the fractured bone fragments. If an anatomical boundary line was not drawn, a straight line was drawn linking both ends of the bone fracture (in other words, the lacrimal fossa, front of the outside orbital edge, superior orbital fissure, and inferior orbital fissure). The tissue of the maxillary sinus side was measured from the line that bounded both ends of the bone fracture (Fig. 1, 2). To achieve the most accurate calculation possible, the shadow that appeared to be clearly different from the contrast of extraocular muscles was judged to be hematoma, and was not traced.

The orbit and range incarcerated into the maxillary sinus were measured in each slice. The orbital and incarcerated tissue volumes were determined by a method in which the slice width (2 mm) was multiplied by an area, and the areas were summed. To reduce the influence of individual differences, the ratio of incarcerated tissue volume to orbital volume (V) was calculated.

Calculated ocular deviation was measured using the Showa exophthalmometer (SEM)[1]. When ocular deviation is measured using Hertel, the sagittal deviation can be measured; however the vertical deviation cannot be measured. Therefore, SEM was used to measure anterior-posterior and superior-inferior deviations simultaneously. SEM is a system in which the front and the right and left sides are simultaneously photographed with three charge coupled device (CCD) cameras, and sagittal and vertical deviations can be measured from the image (Fig. 3, 4). One CCD camera was placed in front of the face eye height to photograph the first eye position. The other CCD cameras were placed on right and left sides to photograph both sides simultaneously. The right and left side CCD cameras were placed perpendicular to the front CCD camera (Fig. 5). The photographs of both sides were used to measure,

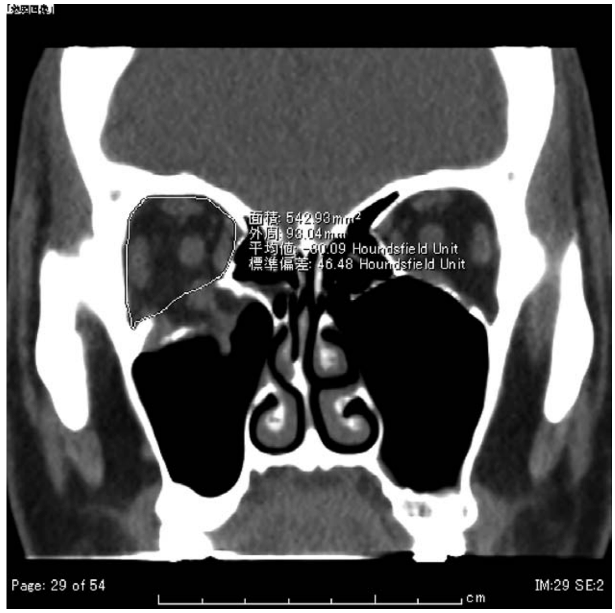

Fig. 1. Computed tomography (CT) image used for measuring the orbital volume. The measurement range is traced along the orbit. A straight line is linked from the tip to the end of the fracture fragment. The orbital volume is calculated from the traced measurement range.

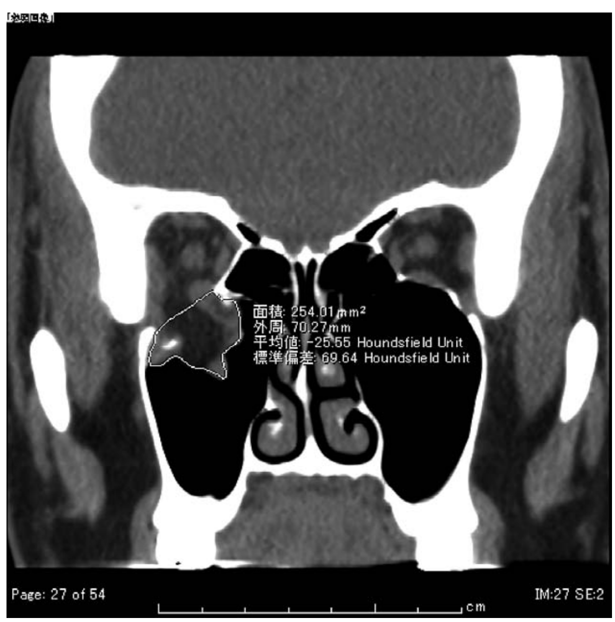

Fig. 2. Computed tomography (CT) image used for measuring the volume of orbital tissue incarcerated into the maxillary sinus. The shadow is traced in the maxillary sinus side from the line linked to both ends of the fractured bone fragment. The orbital volume is calculated from the traced measurement range.

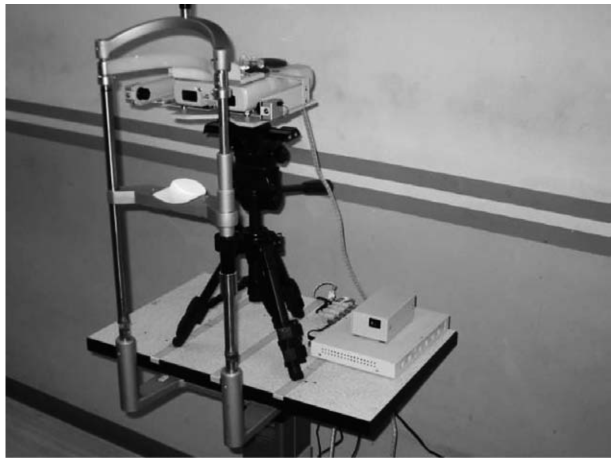

Fig. 3. A general view of the Showa exophthalmometer (SEM). The subject's face is positioned on the chin stand and photographed.

Fig. 4. An enlarged picture of the Showa exophthalmometer (SEM). Cameras are positioned on the front and the right and left sides.

the shortest distance from the point of the nose to the top of the cornea on both sides. The difference between the injury and non-injury sides was determined. This difference was defined as enophthalmos (E1)[1]. The posterior deviation of the injury side was defined as a positive value. The photograph of the front was used to determine the difference between the top of the cornea of the non-injury and injury sides. This difference was defined as hypoglobus (E2)[1]. The inferior deviation of the injury side was defined as a positive value (Fig. 6).

The Excel statistics software Statcel 3 was used for statistical analysis. The Pearson coefficient of correlation and single regression analysis were used to statistically analyze each correlation (V, E1, and E2). A P-value of <0.05 was considered statistically significant. The results were presented as means ± standard deviations.

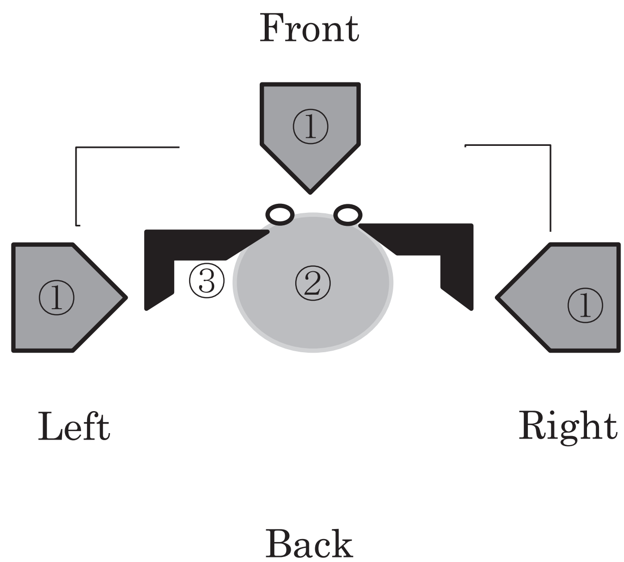

Fig. 5. This is the schematic view of the camera placement in the Showa exophthalmometer (SEM). This is the view from above. The upper part is the front.
①: the charge coupled device (CCD) cameras. ②: the head of the subject. ③: the sum fixation board of the slit.
The right and left sides and the front of CCD cameras are in a vertical relationship. The anterior-posterior and superior-inferior directions can be measured from CCD camera photographs taken simultaneously.

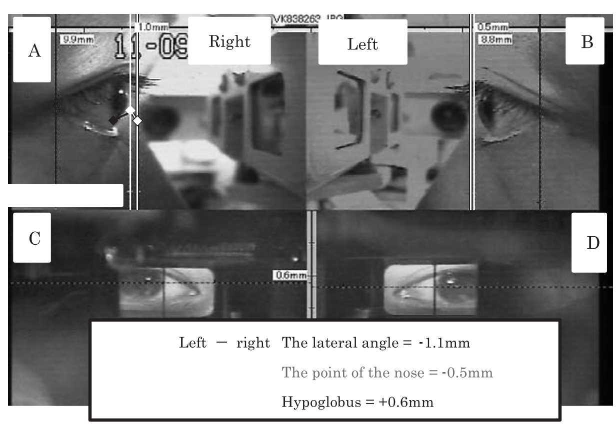

Fig. 6. A photograph of the face of a patient from the front and side taken using the Showa exophthalmometer (SEM). A (illustration at the upper left) : the side view of the right eye. B (at the upper right) : the side view of the left eye. The lateral angle (black line), top of the cornea (white line), and point of the nose (double line) were determined from this photograph, the line perpendicular to the green and red lines was measured, and the difference between the injury and non-injury sides was found. This difference is E1. C (illustration at the lower left) : the front view of the right eye. D (at the lower right) : the front view of the left eye. The top of the cornea (broken line) was determined from this photograph and the difference between the injury and non- injury sides was found. This difference is E2.

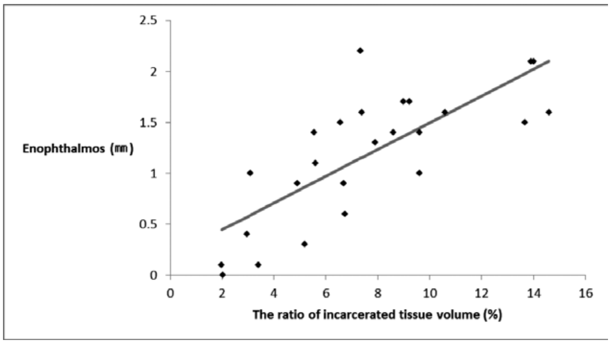

Fig. 7. The figure shows the correlation coefficient and regression line between the ratio of incarcerated tissue volume to orbital volume (V) and enophthalmos (E1). The vertical axis is E1, and the horizontal axis is V. Posterior deviation of the injury side was defined as a positive value. The regression axis is E1 = 0.13 × V + 0.18 (r = 0.765), and the correlation between V and E1 was statistically significant.

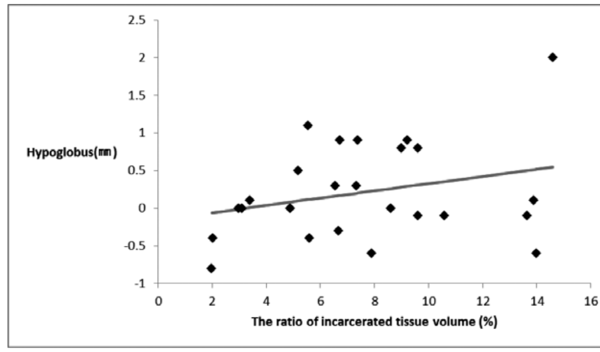

Fig. 8. The figure shows the correlation coefficient and regression line between the ratio of incarcerated tissue volume to orbital volume (V) and hypoglobus (E2) . The vertical axis is E2 and the horizontal axis is V. Inferior deviation of the injury side was defined as a positive value. The regression axis is E2 = 0.05 × V−0.16 (r = 0.279), and the correlation between V and E2 was not statistically significant.

Results

The target age was 35.6 ± 10.5 years (range ; 22～64 years). The right eye injuries occurred in 11 patients and left eye injuries in 14 patients. The time from injury to inspection was 18.2 ± 12.6 days (range ; 7～48 days). E1 was 1.18 ± 0.64 mm (range ; 0～2.2 mm). There was no exophthalmos in E1. However, superior deviation was found in E2. The maximum superior deviation was 0.8 mm and the maximum inferior deviation was 2.0 mm. E2 was 0.21 ± 0.64 mm. The absolute value of E2 was 0.48 ± 0.47 mm. The orbital volume of the injury side was 20.1 ± 1.59 cm^3 (range ; 17.0～23.0 cm^3). The incarcerated tissue volume was 1.55 ± 0.84 cm^3 (range ; 0.39～3.36 cm^3). The contralateral orbital volume was 20.1 ± 1.72 cm^3 (range ; 16.4～22.7 cm^3).

The correlation coefficient between V and E1 was 0.765, and the regression line was E1 = 0.13 × V + 0.18 ($P = 8.14 \times 10^{-6}$) (Fig. 7). The correlation coefficient between V and E2 was 0.279 and the regression line was E2 = 0.05 × V−0.16 ($P = 0.176$) (Fig. 8). The correlation coefficient between E1 and E2 was 0.237 and the regression line was E2 = 0.24 × E1 + 0.07 ($P = 0.254$) (Fig. 9). Only the correlation between V and E1 was statistically significant.

Discussion

Enophthalmos occurs when the orbital tissue is incarcerated into the maxillary sinus in orbital floor fracture. In this study, the correlation coefficient between V and E1 was 0.765, and the regression line was E1 = 0.13 × V + 0.18. It is expected that if the incarcerated tissue volume is applied to the regression line of V and E1 using 20.1 cm^3 (the mean orbital volume), enophthalmos of 0.8 mm, 1.5 mm, and 2.1 mm occur for an incarcerated tissue volume of 1 cm^3, 2 cm^3, and 3 cm^3 respectively. Furuta reported that enophthalmos of 0.5 mm occurred when the orbital volume increased by 1 cm^3 [5]. Xianqun *et al* reported that enophthalmos of 0.89 mm

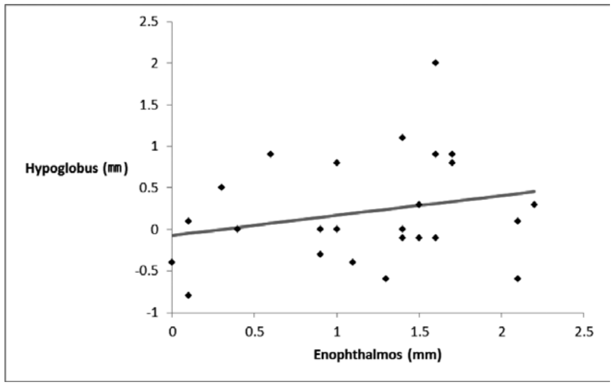

Fig. 9. The figure shows the correlation coefficient and regression line between enophthalmos (E1) and hypoglobus (E2). The vertical axis is E2 and the horizontal axis is E1. Posterior and inferior deviations of the injury side were defined as positive values. The regression axis is $E2 = 0.24 \times E1 + 0.07$ ($r = 0.237$), and the correlation between E1 and E2 was not statistically significant.

occurred when the orbital volume increased by 1 cm^3 [6] : V and E1 were correlated in our study as well as in theirs. However, correlations between V and E2 and between E1 and E2 were not statistically significant. This could be because the orbital pulley affects ocular deviation. Kono *et al*[7,8] reported that typically the normal position of the pulley of the four straight muscles is stable in the horizontal and vertical directions : however, it moves up to around 14 mm in the sagittal direction. Thus it is thought that the function of the pulley prevents the occurrence of hypoglobus.

In this study, V was used instead of the incarcerated tissue volume itself. The correlation coefficient between enophthalmos and the incarcerated tissue volume was 0.734, but that between E1 and V was 0.765 : therefore, in this study, the latter was used.

However, there are some limitations of this study. At first hematoma and edema may be included in the orbit and the incarcerated tissue volume in the acute phase of orbital floor fractures. But hematoma and edema cannot be completely distinguished from the orbit and the incarcerated tissue volume. Only the range in which the contrast was clear was excluded. However, we were unable to determine how hematoma and edema influenced ocular deviation.

In this study, the patients with an isolated orbital floor fracture, who were Japanese, male, aged ＞20 years, with a period of ＞7 days after injury and without orbital emphysema were investigated. Orbital emphysema affects ocular deviation ; however, the volume of tissue incarcerated into the maxillary sinus does not change after disappearance of orbital emphysema. If orbital emphysema occurs just after injury and disappears afterwards, ocular deviation could be determined from the incarcerated tissue volume.

If enophthalmos cannot be measured accurately using Hertel because of eyelid swelling immediately after injury and if the incarcerated tissue volume cannot be determined using CT, enophthalmos could be inferred from the incarcerated tissue volume as determined in this study, and this could be used in making surgical decisions.

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