■Title page■

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Scarring caused by the percutaneous approach to fractures of the orbit and orbital rim

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The patients and their family were informed and provided consent for clinical information and the accompanying images to be included in this report. This study was conducted after obtaining approval of the ethics committee of Nagasaki University Hospital (No 21021521), and in accordance with the Declaration of Helsinki Principles.

(h) Conflict of Interest Statement

The authors declare that they have no competing interests.

(i) Authors' contributions

Kazuya Kashiyama conceived and wrote the article. Kazuya Kashiyama and the others were involved in

treating the patient. Kazuya Kashiyama participated in editing the manuscript critically. All authors declare that they contributed to this article, and that they have read and approved the final manuscript.

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Abstract （Limit the abstract to 250words.）194words.

Percutaneous and transconjunctival approaches are commonly used for fractures of the orbit and orbital rim. However, it leaves visible scarring on the face. Although previous studies reported scarring from the percutaneous approach, few reported the degree of such scarring. We examined the degree of scarring associated with percutaneous approaches to fractures of the orbit and orbital rim in the Japanese population. We reviewed photographs of patients who were treated surgically for fractures of the orbital floor, medial orbital wall, or zygomatic bone via percutaneous approaches to examine the presence of scarring and deformation. In 36% of all cases, the observers were unable to determine the side on which the surgery was performed. Furthermore, the site of scarring was identified accurately in only 20.6% of the cases in which observers were able to identify the surgical side. Our study demonstrated that the subciliary approach left minimal scarring under the eyelashes. On the other hand, the medial canthal approach left depressed and wide scarring, whereas pigmentation was apparent in patients who underwent surgery via the lateral eyebrow approach. Similarly, pigmentation under the eyelashes and at the site of secondary incision was common after the subciliary approach.

Keywords

percutaneous approach, subciliary, medial canthal, lateral eyebrow, facial fracture

Text

Introduction

There are several surgical approaches to the orbit and orbital rim for surgical reduction of facial fractures such as through the orbital floor and zygomatic bone. Although different institutions use different approaches, most can be categorized as being either percutaneous or transconjunctival approaches. There are both advantages and disadvantages to these approaches [1-6]. Studies that compared the two approaches highlighted scarring of visible parts of the face as one of the major disadvantages of percutaneous approaches. However, little has been reported regarding the degree of scarring classified as a postoperative complication. In the present study, we investigated challenges associated with percutaneous approaches to the orbit and orbital rim. Specifically, independent observers evaluated photographs of patients who underwent surgery at our institution via percutaneous approaches to rate the degree of scarring and deformation.

Materials and Methods

A retrospective review of our institutional data was performed to identify patients who underwent surgery for fractures of the orbit or orbital rim via a percutaneous approach at the Department of Plastic and Reconstructive Surgery at Nagasaki University Hospital between 2003 and 2018. A total of 97 patients were identified. Of them, 11 were excluded for having multiple fractures of the face or visible scarring of the facial soft tissue prior to surgery, or for requiring multiple surgeries. Thus, 86 patients were included in the study. Fractures were of the orbital floor (n=54), medial orbital wall (n=9), orbital floor and medial orbital wall (n=4), and zygomatic bone requiring surgical reduction of the orbital floor or orbital rim (n=19). The study was approved by the institutional research ethics board and conformed to the ethical principles of the Declaration of Helsinki. Consent was received from patients or their legal representatives for the use of clinical photographs in this study.

Assessment of clinical photographs

A slide deck was created to show postoperative photographs at random. Photographs that were taken at least 12 months (mean: 14.6 months) after the surgery were selected. The slide deck was presented to independent observers and the following questions were asked: 1) On which side was the surgery performed (left, right, unknown), 2) where was the incision made (lower eyelid, epicanthic fold, around eyebrow, others, unknown), 3) were there any deformations of the eyelid or around the eye (if yes, describe in detail), and 4) 5-scale scoring of the scar (not visible, barely visible, noticeable, very noticeable, extremely noticeable). A total of 21 observers assessed the images. These individuals included the general public (n=2), medical students (n=5), surgical residents with no experience with facial fractures (n=2), plastic surgeons with no experience with facial fractures (n=3), plastic surgeons with experience assisting during surgery for facial fractures (n=3), plastic surgeons with experience performing surgery for facial fractures under guidance of another surgeon (n=3), and plastic surgeons with experience in both teaching and performing surgery for facial fractures alone (n=3). Informational slides about facial fractures and surgical approaches were presented to the observers from the general public because they had no knowledge of facial fractures.

Percutaneous approaches to the bones

The following approaches were examined for the purpose of the study. 1) Subciliary approach: the subciliary approach was used to access the orbital floor and infraorbital margin. A skin incision was made approximately 2 mm away from the eyelashes and a secondary incision was made outwards at the lateral corner of the eye for better access. This procedure was performed on 77 patients. 2) Lateral eyebrow approach: the lateral eyebrow approach was used for reduction and fixation of the zygomaticofrontal suture in patients who had fractures of the zygomatic bone. Among 19 patients who had fractures of the zygomatic bone, 14 required reduction with incision via the lateral eyebrow approach. 3) Medial canthal approach: a W-shaped or crescent-shaped skin incision in the epicanthic fold was made to reach the medial

orbital wall. A total of 13 patients required incisions via the medial canthal approach (Supplemental table 1, Figure 1).

Statistical Analysis

Statistical analyses were carried out with Kruskal-Wallis analysis of variance, followed by the post hoc test. Values of $p < 0.05$ were defined as significant. All statistical analyses were carried out with EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan)[7].

Results

In 36% of all cases, the observers were unable to determine the side on which the surgery was performed. Specifically, the sides were undetermined in 39.9% of orbital floor fracture cases, 24.8% of medial orbital wall fracture cases, 36.9% of orbital floor and medial orbital wall fracture cases, and 29.8% of zygomatic fracture bone fracture cases. Among cases in which the side of the surgery was determined, 45.5% were answered correctly. These cases were composed of 41.8% orbital floor fracture cases, 60.3% medial orbital wall fracture cases, 41.7% orbital floor and medial orbital wall fracture cases, and 38.3% zygomatic fracture bone fracture cases (Supplemental table 2). Of all cases, the side and exact site of scarring were assigned correctly in 20.6% of cases. These cases were composed of 23.5% orbital floor fracture cases, 36.0% medial orbital wall fracture cases, 0% orbital floor and medial orbital wall fracture cases, and 22.8% zygomatic fracture bone fracture cases. In cases with two incisions, it was recorded as being correctly assigned only if both of the incisions were identified (Supplemental table 2).

Deformation was not identified in 63.9% of cases. These cases were composed of 65.3% orbital floor fracture cases, 71.4% medial orbital wall fracture cases, 63.1% orbital floor and medial

orbital wall fracture cases, and 55.6% zygomatic fracture bone fracture cases (Supplemental table 2).

Scarring was evaluated on a 5-point rating scale: not visible (1), barely visible (2), noticeable (3), very noticeable (4), and extremely visible (5). Cases that were not scored were excluded. The total scores were 1.3 points for orbital floor fracture cases, 1.5 points for medial orbital wall fracture cases, 1.5 points for orbital floor and medial orbital wall fracture cases, and 1.5 points for zygomatic fracture bone fracture cases. The mean score for all cases was 1.4 points.

Discussion

Cosmetic considerations are important for facial surgeries. Compared with transconjunctival approaches to the orbit and orbital rim, percutaneous approaches are relatively easier to perform as they provide a wide surgical field of view. However, they are also associated with the risk of scarring. There are many studies to date that examined the differences between the two approaches[1-6]. However, little is known about the degree of scarring considered a postoperative complication. In the present study, we examined the degree of scarring associated with percutaneous approaches to fractures of the orbit and orbital rim by having independent observers review clinical photographs taken postoperatively.

The observers were unable to assign the side of fracture and surgery in 36.0% of all cases. Furthermore, among the cases in which the side of the surgery was determined, only 45.5% were answered correctly. This suggests that scarring is not apparent in photographs for most percutaneous approaches. The site of surgery was accurately identified in 20.6% of cases in which the observers were able to identify the surgical side. The accuracy rate was the highest for fractures of the medial orbital wall in which an incision was made in the epicanthic fold. This suggests that scarring is more notable after the percutaneous approach in the epicanthic fold than after other procedures. Accuracy rates in the assessment of the surgical side were not

significantly different when compared based on the surgical experience of the observers (Figure 2). On the other hand, experience in surgery affected the accuracy of identifying the site of surgical incision. Specifically, the average accuracy rates were 19.5% for those with no experience in surgery, 35.7% for those who had experience in operating with an attending physician, and 45.5% for those who had experience operating independently (Figure 3). This difference may be caused by physicians with operative experience knowing where to look for scarring as they can predict where scarring typically occurs after specific surgical approaches.

Deformation, such as that of the eyelids, was not identified in 63.9% of all cases. The average score for scarring was 1.5 points, which is in the range of "not visible" and "barely visible".

Among 13 cases of the medial canthal approach, scarring was barely visible in 6 (Figure S1a). However, unevenness of the skin was apparent in 3 cases (Figure S1b), and white and wide scarring was visible in 4 (Figure S1c). In percutaneous approaches to the medial orbital wall[8-11], skin incisions can be categorized as arc-shaped[8, 9], Z-plasty[12, 13], or W-shaped incisions[14]. Previous studies discussed the arc-shaped design, which takes considers wrinkling of the skin, and methods to adjust the top of W- and Z-shaped incisions to minimize scarring. In our study, an arc-shaped incision was used in 2 cases and W-shaped incision was used in 11. The epicanthic fold is a slightly slanted structure that runs from the root and dorsum of the nose towards the orbit. As such, depending on the site of incision, scarring in the epicanthic fold can be highly visible when light hits the face. When making an incision, it is common to consider the ways that relaxed skin tension lines are formed. However, for any type of incision, it is challenging to align the incision at the epicanthic fold with the relaxed skin tension lines[12, 13, 15]. As the epicanthic fold must be either separated or resected during percutaneous approaches, internal forces can pull away from the incision postoperatively and cause wide scarring. In addition, complex facial movements frequently involve the epicanthic fold as it is linked to facial muscles such as the orbicularis oculi muscle, procerus muscle, and corrugator supercilia. These movements can pull the wound surface and scar tissue in different directions. Collectively, these factors make the

epicanthic fold prone to developing thickening, widening, and webbing. When access to the wound is required from the site of incision, the epicanthic fold is typically separated or resected during percutaneous approaches. This requires reconstruction of the epicanthic fold. Inadequate fixation and suturing of the epicanthic fold can lead to postoperative loss of physiological indent between the separated site and the residual fold. Thus, in our practice, we do not resect the epicanthic fold in percutaneous approaches. We instead separate the entire periosteum and fix it onto the bone on one side (Figure S2a,b). Although transnasal wiring fixation is the common procedure for fixing the epicanthic fold, we fix to the contralateral side to minimize the risk of the wire becoming loose. Thus, there were no cases of separated epicanthic fold in our study. However, there were many cases in which depressed and wide scarring was apparent. Precious studies reported the advantages of using incisions that take into consideration the alignment with relaxed skin tension lines[16], in addition to combining percutaneous approaches with other approaches[17]. Thus, additional studies are needed to define the most appropriate percutaneous approach for the epicanthic fold to minimize scarring.

We also demonstrated that the subciliary approach causes minimal scarring under the eyelashes (Figure S3a). However, pigmentation and deformation, observed as a shadow forming at the site of secondary incision, were apparent in the frontal view in 7 cases (Figure S3b). Pigmentation was particularly apparent away from the eyelashes and at the outer area (Figure S3c). In addition, scarring was more significant in cases where the incision was made away from the eyelashes (Figure S3d). Depending on the type of incision made, the inferior palpable arch of the lower eyelid may be damaged when a subciliary approach is performed immediately under the eyelashes. Furthermore, as the orbicularis oculi muscle has to be separated from the skin, there is a risk of postoperative marginal ectropion due to the loss of innervation of nervous zygomatic branches of the facial nerve in the pretarsal portion[18]. In most cases, we made the incision approximately 2 mm away from the ends of eyelashes. Postoperative deformation was identified in two of these cases and was characterized as ptosis of the lower eyelid (Figure S3e). Although

some consider the risk of ectropion and recommend making the incision further away from the eyelashes, this can make scarring more notable[19]. Deformation of the lower eyelid due to the incision made under the eyelashes is mostly transient, and should improve as innervation to the orbicularis oculi muscle is restored and swelling decreases[20-23]. Ridgway et al. performed a meta-analysis of 17 publications and determined the incidence of postoperative ectropion for incisions made under the eyelashes to be 14%[18]. Although no cases of ectropion were identified, deformation was noted in 2 of 77 cases. Both of these cases were characterized by ptosis of the lower eyelid. Based on these findings of postoperative and residual deformation, incision within 1-2 mm of the eyelashes should be recommended to minimize scarring.

We found no notable scarring associated with lateral eyebrow approaches. However, pigmentation was significant in cases where an incision was made away from the eyebrow (Figure S4).

Collectively, our study demonstrated that in the East Asian population, a subciliary approach to the lower eyelid was optimal for minimizing scarring within 1 year after surgery on facial bones performed via percutaneous approaches. However, depressed and wide scarring was notable after the medial canthal approach. Furthermore, pigmentation was noted close to the outer edges and at the site of secondary incision in some cases of the subciliary approach and lateral eyebrow approach when the incision was made away from the eyebrows. To prevent pigmentation, it may be necessary to ensure that these areas are not exposed to direct light postoperatively.

There are several limitations to our study. First, analysis of the results was complex as our cases represented 3 different approaches. Second, qualitative evaluation was difficult due to the use of clinical photographs. Additional studies are needed to determine the degree of scarring caused by percutaneous approaches to the orbit and orbital rim.

In addition to scarring, other factors that should be considered for fracture of the orbit include addressing the symptoms of diplopia vision and enophthalmos, required technical skills for the

surgical procedure, and risk of postoperative complications. However, a major issue associated with percutaneous incision is visible scarring. Thus, it is an important factor to consider for fractures of the orbit and orbital rim.

Conclusion

In the present study, we examined the degree of scarring caused by the percutaneous approach to fractures of the orbit and orbital rim. The subciliary approach caused minimal scarring under the eyelashes; however, the medial canthal approach caused deformation and wide scarring. Pigmentation was notable after the lateral eyebrow approach and subciliary approach, particularly under the eyelashes and at the site of secondary incision.

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Figure legends

Figure 1: Site of incision

1) Subciliary approach
2) Secondary incision to facilitate opening of the incision
3) Lateral eyebrow approach
4) Medial canthal approach

Figure 2: Accuracy in determining the side on which surgery was performed

P=0.52. The P-values were obtained by Kruskal-Wallis analysis.

y-axis: accurate response (%)

a: non-medical general public

b: medical students

c: surgical residents with no experience with facial fractures

d: plastic surgeons with no experience with facial fractures

e: plastic surgeons with experience assisting during surgery for facial fractures

f: plastic surgeons with experience performing surgery for facial fractures under guidance of another surgeon

g: plastic surgeons with experience in both teaching and performing surgery for facial fractures alone

Q4/4: maximum

Q3/4: upper quartile

Q2/4: median

Q1/4: lower quartile

Q0/4: minimum

Figure 3: Accuracy in determining the surgical site

P=0.02. The P-values were obtained by Kruskal-Wallis analysis. There was no significant difference after post hoc tests.

y-axis: accurate response (side and site of surgery/ incision) (%)

a: non-medical general public

b: medical students

c: surgical residents with no experience with facial fractures

d: plastic surgeons with no experience with facial fractures

e: plastic surgeons with experience assisting during surgery for facial fractures

f: plastic surgeons with experience performing surgery for facial fractures under guidance of another surgeon

g: plastic surgeons with experience in both teaching and performing surgery for facial fracture alone

Q4/4: maximum

Q3/4: upper quartile

Q2/4: median

Q1/4: lower quartile

Q0/4: minimum

Figure 1

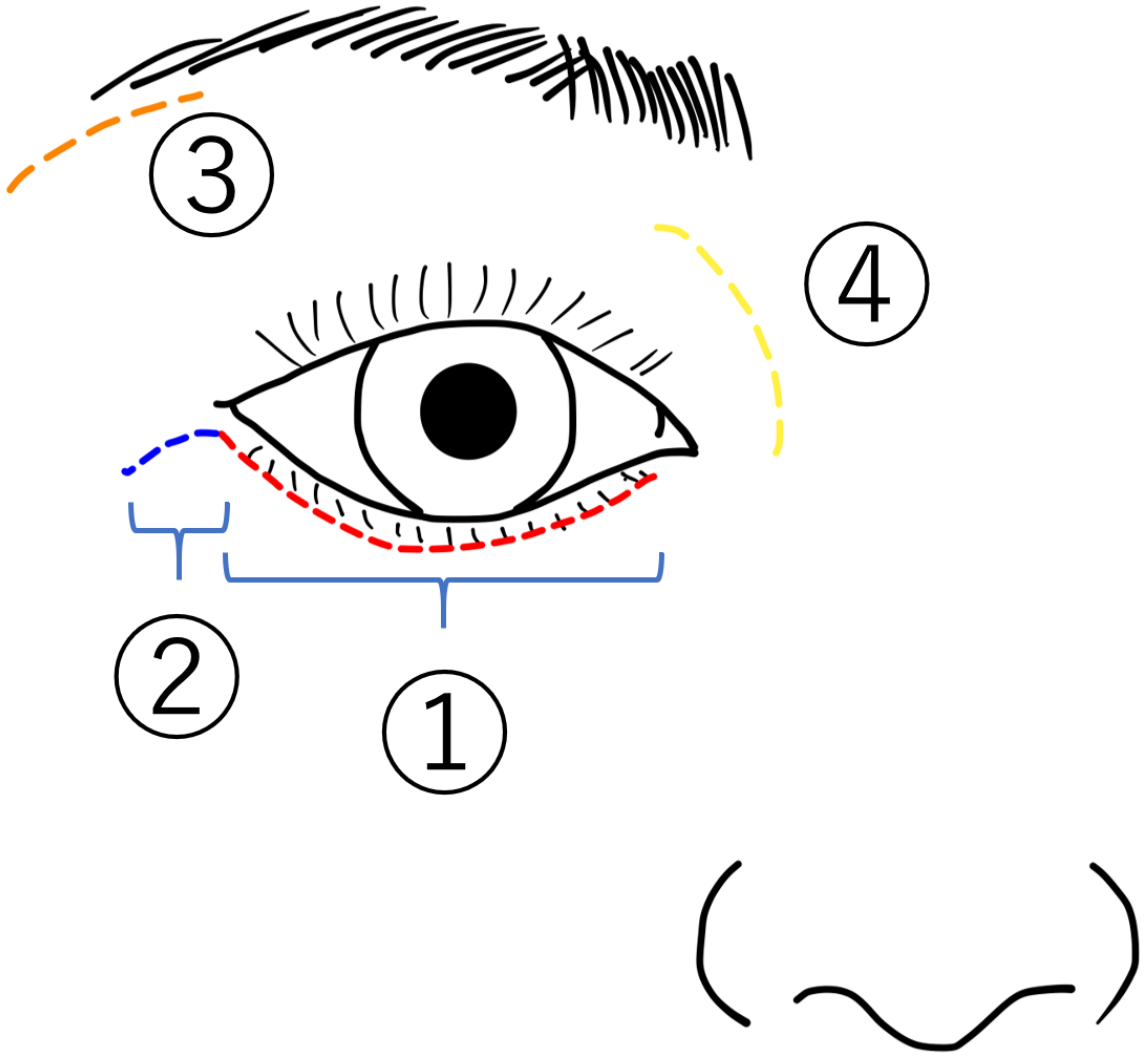

Figure 2

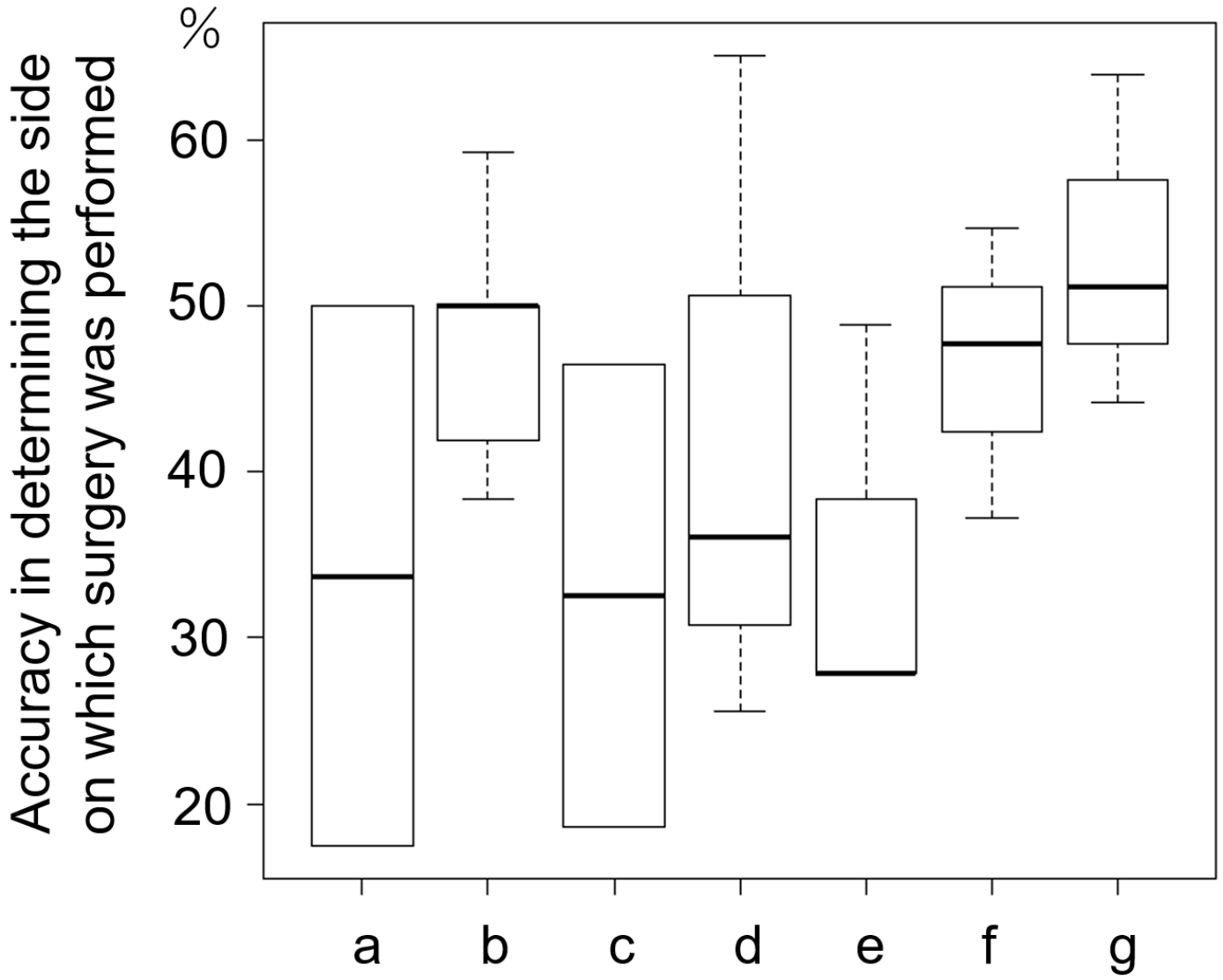
Accuracy in determining the side on which surgery was performed
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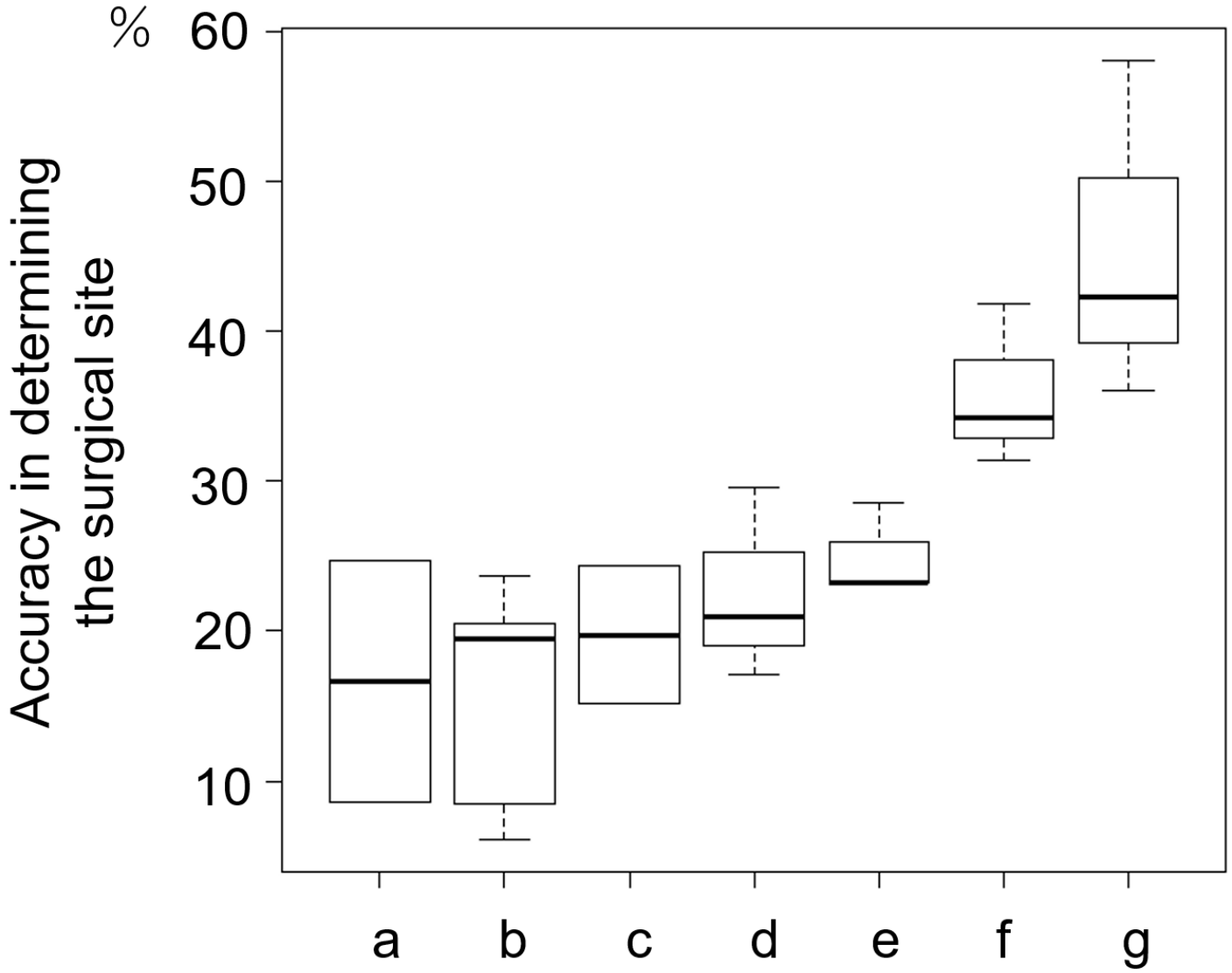
Figure 3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Accuracy in determining
the surgical site
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Supplementary Material

Supplemental figure legends

Figure S1a: Case with minimal scarring by the medial canthal approach. The arrow indicates the site of incision. The patient was a 61-year-old female with fracture of the right medial orbital wall. The photograph was taken 12 months after the surgery.

Figure S1b: Case with depression by the medial canthal approach. The patient was a 21-year-old female with fracture of the right medial orbital wall. The photograph was taken 12 months after the surgery. The arrow indicates the site of scarring.

Figure S1c: Case with white pigmentation by the medial canthal approach. The patient was a 71-year-old male with fracture of the left medial orbital wall. The photograph was taken 12 months after the surgery. The arrow indicates the site of scarring.

Figure S2a: Reconstruction of the epicanthic fold.

a) A hole was made to fix a wire.
b) A schematic for fixing the wire. The blue line indicates the wire.

Figure S3a: Case with minimal scarring by the subciliary approach. The patient was a 25-year-old male with fracture of the left orbital floor. The photograph was taken 12 months after the surgery.

Figure S3b: Case with pigmentation at the site of secondary incision by the subciliary approach. The patient was a 10-year-old female with fracture of the left orbital floor. The photograph was taken 12 months after the surgery. The arrow indicates the site of pigmentation.

Figure S3c: Case with pigmentation outside of the site of incision by the subciliary approach. The patient was a 26-year-old male with fracture of the left orbital floor. The photograph was taken 12 months after the surgery. The arrow indicates the site of pigmentation.

Figure S3d: Case of the subciliary approach performed away from the eyelashes. The patient was an 18-year-old male with fracture of the right orbital floor. The photograph was taken 12 months after the surgery. The arrow indicates the site of scarring.

Figure S3e: Case with ptosis of the lower eyelid by the subciliary approach. The patient was a 26-year-old male with fracture of the left orbital floor. The photograph was taken 12 months after the surgery. The arrow indicates the site of ptosis of the lower eyelid.

Figure S4: Case with pigmentation by the lateral eyebrow approach. The patient was an 18-year-old male with fracture of the left zygomatic bone. The photograph was taken 13 months after the surgery. The arrow indicates the site of pigmentation.

Supplemental Figure 1a

Supplemental Figure 1a: Case with minimal scarring by the medial canthal approach.

The arrow indicates the site of incision. The patient was a 61-year-old female with fracture of the right medial orbital wall. The photograph was taken 12 months after the surgery.

Supplemental Figure 1b

Supplemental Figure 1b: Case with depression by the medial canthal approach.

The patient was a 21-year-old female with fracture of the right medial orbital wall. The photograph was taken 12 months after the surgery. The arrow indicates the site of scarring.

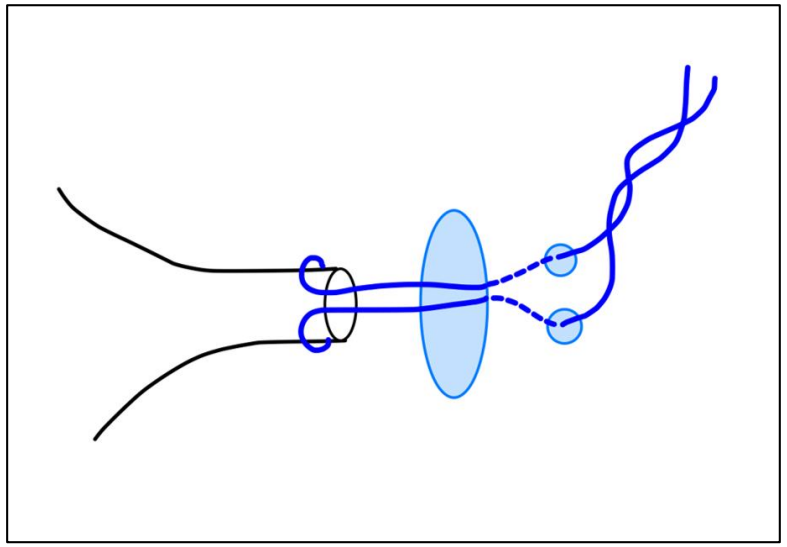
Supplemental Figure 1c

Supplemental Figure 1c: Case with white pigmentation by the medial canthal approach.

The patient was a 71-year-old male with fracture of the left medial orbital wall. The photograph was taken 12 months after the surgery. The arrow indicates the site of scarring.

Supplemental Figure 2a

Supplemental Figure 2b



Supplemental Figure 2: Reconstruction of the epicanthic fold.

a) A hole was made to fix a wire.
b) A schematic for fixing the wire. The blue line indicates the wire.

Supplemental Figure 3a

Supplemental Figure 3a: Case with minimal scarring by the subciliary approach.

The patient was a 25-year-old male with fracture of the left orbital floor. The photograph was taken 12 months after the surgery.

Supplemental Figure 3b

Supplemental Figure 3b: Case with pigmentation at the site of secondary incision by the subciliary approach.

The patient was a 10-year-old female with fracture of the left orbital floor. The photograph was taken 12 months after the surgery. The arrow indicates the site of pigmentation.

Supplemental Figure 3c

Supplemental Figure 3c: Case with pigmentation outside of the site of incision by the subciliary approach. The patient was a 26-year-old male with fracture of the left orbital floor. The photograph was taken 12 months after the surgery. The arrow indicates the site of pigmentation.

Supplemental Figure 3d

Supplemental Figure 3d: Case of the subciliary approach performed away from the eyelashes. The patient was an 18-year-old male with fracture of the right orbital floor. The photograph was taken 12 months after the surgery. The arrow indicates the site of scarring.

Supplemental Figure 3e

Supplemental Figure 3e: Case with ptosis of the lower eyelid by the subciliary approach.

The patient was a 26-year-old male with fracture of the left orbital floor. The photograph was taken 12 months after the surgery. The arrow indicates the site of ptosis of the lower eyelid.

Supplemental Figure 4

Supplemental Figure 4: Case with pigmentation by the lateral eyebrow approach. The patient was an 18-year-old male with fracture of the left zygomatic bone. The photograph was taken 13 months after the surgery. The arrow indicates the site of pigmentation.

Supplemental table 1: Patient characteristics

	Number of cases	Subciliary approach (n)	Lateral eyebrow approach (n)	Medial canthal approach (n)
Orbital floor fracture	54	54	0	0
Medial orbital wall fracture	9	0	0	9
Orbital floor + medial orbital wall fractures	4	4	0	4
Zygomatic bone fracture	19	19	14	0
Total (n)	86	77	14	13

Supplemental table 2: Results

	Number of cases	Surgery side not identified (%)	Surgery side identified and assigned correctly (%)	Surgery side and site of scarring assigned correctly (%)	No distinct deformation (%)	Scarring score (points)
Orbital floor fracture	54	39.9	41.8	23.5	65.3	1.3

Medial orbital wall fracture	9	24.8	60.3	36.0	71.4	1.5
Orbital floor + medial orbital wall fractures	4	36.9	41.7	0.0	63.1	1.5
Zygomatic bone fracture	19	29.8	38.3	22.8	55.6	1.5
Total (n)	86	36	45.5	20.6	63.9	1.4