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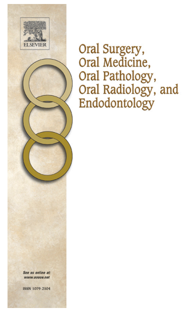

Changes in scleral exposure following modified Le Fort III osteotomy

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Changes in scleral exposure following modified Le Fort III osteotomy

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Abstract

Purpose: The Kufner modified Le Fort III osteotomy (LFIII) can be used to address midface deficiency, which is often accompanied by excessive scleral exposure. The purpose of this project is to analyze the changes in scleral exposure after a LFIII.

Methods: Thirteen subjects with midface hypoplasia were treated with LFIII. Scleral surface area (SSA) was determined by pixel count and the distance from the inferior eyelid margin to the center of the pupil (MED) was measured pre- and postoperatively. Intraclass correlation coefficients were calculated to assess measurement reliability and repeated measures ANOVA were determined to assess systematic difference among the replicates.

Results: The interquartile range for change in SSA ranged from -31% to -7%, median -20% (P=0.002) and the interquartile range for change in MED ranged from -21% to -12%, median -18% (P=0.0002).

Conclusions: SSA and MED can be reliably determined using the aforementioned method. The LFIII decreases scleral exposure.

Introduction

The Le Fort III osteotomy mobilizes the entire midface including the nose, orbits, zygomas, and maxilla. Kufner's operation is a modification that is used to correct deficiencies of midface projection that do not involve the nasal subunit (**Figure 1**) [1]. This modification involves an osteotomy through the zygoma and lateral orbital rim with the superior extension adjusted to the amount of lateral orbital rim deficiency and an oblique osteotomy across the floor of the orbit through the inferior orbital fissure and through the maxilla to the lateral wall of the nasal cavity, leaving the nose in its original position. Because the modified Le Fort III changes midface and orbital rim projection, it has the ability to influence the appearance of the periorbital region without alternating the projection or length of the nasal bridge [2-4].

The appearance of the face is greatly influenced by the periorbital region as well as the relationship of the maxilla and mandible. This region includes the globes, eyelids, eyebrows, and cheeks. The symmetry, shape, and position of these components are important and abnormalities in any of these parts can contribute to adverse appearance [5]. Individuals with skeletal facial deformities often suffer from multiple unattractive features related to periorbital structure, including exorbitism.

Exorbitism, a word coined by Tessier, is the relative protrusion of the orbital contents and ocular globe due to decreased orbital volume [6]. Abnormal globe projection has both functional and aesthetic consequences. Functional complications include dryness, corneal ulcers and exposure keratitis secondary to inability of the eyelids to properly protect the globe [7]. Exorbitism in individuals with skeletal facial deformities appears to be related to both orbital and midface deficiencies [2]. In fact, increased sclera exposure below the iris is characteristic of midfacial hypoplasia in patients without excessive laxity of the lateral canthus [5]. Midface hypoplasia can be surgically treated with the modified Le Fort III osteotomy as described by Kufner. Excessive scleral exposure can change after maxillary surgery secondary to the additional skeletal support for the position of the lower eyelid [8].

The normal appearance of the periorbital region has been studied extensively. The distance from the central aspect of the lower eyelid to the central aspect of the upper eyelid usually measures 10 mm. The distance from the central aspect of the lower eyelid to the center of the pupil is approximately 5 to 5.5 mm and the lower eyelid is generally found at the level of the inferior limbus of the iris. Normally, the upper eyelid overlaps the iris by 2 mm [2,9,10].

The effects of various maxillary osteotomies on exorbitism have been studied. Soydan et al. 2014 found a reduction in visible inferior sclera in individuals with midface deficiency that underwent traditional Le Fort I osteotomies[5]. Alyamani et al. 2012 found that the intraoral modified Le Fort III osteotomy followed by midface distraction osteogenesis resulted in increased orbital volume[7]. To date, no studies have analyzed the changes in medial, lateral, and inferior scleral exposure after the modified Le Fort III osteotomy as described by Kufner.

Materials and Methods

This retrospective study was approved by the Biomedical Institutional Review Board at the author's university. Thirteen subjects (26 eyes) with Class III skeletal facial deformities were treated with extraorally performed modified Le Fort III osteotomies as described by Kufner by one surgeon at a single academic center (**Figure 1**). Inclusion criteria consisted of: (1) young adults (<30 years old) with midface deficiency involving the cheeks, inferior orbital rim, and maxilla; (2) adequate records for evaluation including facial photographs and lateral cephalometric radiographs at least 3 months postoperatively. Exclusion criteria included previous facial trauma and orbital surgery.

Standardized frontal facial photographs were obtained preoperatively (within 8 weeks before surgery) and postoperatively (at least 3 months after surgery) by a professional photographer in natural head position using a Nikon D300S camera with a 100 mm Nikor lens. The camera was placed 7 feet from the subject and 8 feet from the background at eye level and focused on the subject's midface. The subject was lighted with 2 umbrella flashes set 45 degrees up and 45 degrees to the side of the camera axis. Subjects were told to look straight ahead at the camera while relaxing their forehead, eyebrows, nose and lips. The photographs were enlarged and cropped to include both entire orbits and the nasal bridge.

The photographs were analyzed and landmarks were placed using Adobe Photoshop CS5 software. Landmarks included the center of the pupil, inferior iris limbus, and 8 points on the eyelid margins (two of which are directly inferior and superior to a line drawn through the center of the pupil). The amount of scleral exposure was calculated by two measurement techniques. First, the total visible scleral surface area (SSA) in each eye was determined by pixel count. The number of pixels within the palpebral fissure and the number of pixels in the pupil and iris were calculated. The SSA is the number of pixels within the palpebral fissure minus the pupil and iris pixel count (**Figure 2**). Second, the mid pupil to eyelid distance (MED) was computed by determining the distance from the center of the pupil to a point on the lower eyelid inferior to the center of the pupil (**Figure 3**). All measurements were obtained on three different occasions, with one-week intervals between the replicate measures by a single clinician.

The mean SSA and MED were calculated for each eye both preoperatively and postoperatively by averaging the three replicate SSA and MED measurements. The average percent change in SSA and MED (postoperative/preoperative) values was calculated for each eye. The percent change in SSA (ΔSSA) is the postoperative SSA divided by the preoperative SSA ($\Delta SSA = SSA_{postoperative}/SSA_{preoperative} \times 100$) (**Figure 2**). The percent change in MED (ΔMED) is the postoperative MED divided by the preoperative MED ($\Delta MED = MED_{postoperative}/MED_{preoperative} \times 100$) (**Figure 3**). The ΔSSA represents the overall change in scleral surface area (medial, lateral, and inferior) whereas the ΔMED correlates to the change in inferior scleral exposure. A decrease in percent change of ≥ 5% was considered clinically important. Cephalometric analysis was completed on lateral cephalometric radiographs to evaluate the amount of midface advancement in each subject using the following points: A, tip of upper incisor (U1), ANS, and orbitale (Or).

To determine the reliability of the aforementioned method, intra-class correlation coefficients (ICC) and repeated measures analysis of variance (ANOVA) were computed for each of the replicated measurements to assess concordance and systematic bias. A doubly repeated measures analysis of variance using Proc Mixed (SAS v9.2) with an unstructured covariance structure was performed to assess the effect of side (right vs. left eye) and visit (preoperative vs. postoperative) on the SSA and MED. A p value of <0.05 was considered to be statistically significant for all analyses.

Results

This retrospective analysis included thirteen subjects, 7 females and 6 males. Mean age at the time of surgery was 17 years ± 2.5. All subjects underwent extraorally performed modified Le Fort III osteotomities as described by Kufner by a single surgeon with bone grafting to the osseous gaps. Seven subjects had bone graft harvested from the cranium whereas six subjects had bone graft harvested from the anterior iliac crest. Three subjects had craniofacial syndromes (2 Crouzon and 1 Binder). Additional procedures completed at the time of surgery included septorhinoplasty, frontal bone setback, cranioplasty, mandibular osteotomies including sagittal split osteotomy, genioplasty, condylectomy, and simultaneous Le Fort I osteotomy.

All preoperative and postoperative ICC values were above 0.94. There was no indication of a systematic difference among the replicate original measures (p > 0.05) except left eye post-operative iris (p = 0.01). Although statistically significant, the largest difference in means among the 3 sets of replicates was small, 79 pixels. The percent change from preoperative to postoperative was statistically significant for both SSA (p =0.002) and MED (p =0.0002) controlling for eye (**Table 1**). The 25% to 75% interquartile range for the average percent change in total SSA ranged from -31% to -7% (median -20%), with 22/26 eyes demonstrating clinically important decreases in ΔSSA (**Table 2**). The 25% to 75% interquartile range for percent change in MED ranged from -21% to -12% (median -18%), with 23/26 eyes demonstrating clinically important percent decreases in ΔMED (**Table 2**).

The mean amount of midface advancement (change in A point) was 7.4 ± 5.7. The mean change in U1 was 8.7 ± 5. The mean change in ANS was 6 ± 5.1. The mean change in Or was 3.5 ± 2.9. Subject 2 had the largest amount of midface advancement and also had the largest decrease in scleral exposure. Subject 2 had a change in A point of 19.2, change in U1 point of 16, change in ANS of 16.9, change in Or of 9.2 with percent change in SSA of -43.0% (right eye) and -45.6% (left eye) and percent change in MED of -33.3% (right eye) and -44.4% (left eye) (**supplemental table 1 and 2**). However, some subjects with less midface advancement had large reductions in scleral exposure (e.g., subject 1) whereas others did not (e.g., subject 13) (**supplemental table 1 and 2**). Cephalometric analysis could not be carried out on four subjects because their radiographic images could not be superimposed (**supplemental table 2**).

Discussion

Clinical evaluation of the periorbital region is a critical component in determining the optimal treatment of midface deficiency since excessive scleral exposure has both esthetic and functional implications. Physical examination can be complemented by comprehensive evaluation of standardized facial photographs, as described here. The clinician should anticipate changes in the periorbital region related to midface osteotomies and inform patients accordingly.

Though excessive scleral exposure is associated with midface deficiency, it is also associated with lower eyelid laxity (older age), exophthalmos, facial trauma, and prior surgery. Subjects with a history of facial trauma or surgery in the periorbital region were excluded from this study. Lower eyelid laxity as a contributor to the increased scleral exposure is unlikely since the subjects included in the study were young adults with a mean age of 17 years ± 2.5. No subjects included in the present study had a history of endocrine disorders, vasculitis, or periorbital infections making exophthalmos related to a secondary cause unlikely.

Here we describe a novel method of evaluating scleral exposure using SSA. Preoperative and postoperative ICC values of > 0.94 indicate that the measurement of SSA and MRD to determine sclera exposure is reliable. SSA is a useful adjunct to MED in the evaluation of scleral exposure because it evaluates total (inferior, medial and lateral) scleral exposure as opposed to just inferior scleral exposure as is the case with MED.

Soydan et al. 2014 used similar methodology to MED to evaluate changes in inferior scleral exposure in subjects with midface deficiency that underwent traditional Le Fort I osteotomies. However, the distance from the inferior limbus to the lower eyelid margin was measured instead of the center of the pupil to the lower eyelid margin. Alyamani et al. 2012 evaluated the improvement in orbital volume after intraoral modified Le Fort III osteotomies followed by midface distraction osteogenesis using CT imaging. No analysis of orbital volume using radiographic imaging was completed in the present study.

There are several advantages to evaluating scleral exposure as described here, using SSA and MED. First, this process is time efficient and utilizes facial photographs that are obtained during a standard preoperative work-up. Comprehensive evaluation of the photographs can supplement physical exam findings to allow the clinician to better appreciate the degree of the deformity as it extends into the periorbital region and may also assist the clinician in educating the patient as to what periorbital changes to expect. Second, in contrast to orbital volume analysis, which does not measure exorbitism, there is no radiation exposure with this analysis since no additional radiographic imaging is required. Finally, this methodology focuses directly on exposed sclera not orbital volume, and exposed sclera is more clinically significant esthetically and functionally. The primary limitation of this methodology is that its accuracy requires obtaining standardized facial photographs in natural head position with relaxed facial expression and eyelids open. The other limitation is that the photographic image is linear and the globe is a convex structure. Perhaps 3-D photographs with topographic mapping will advance this methodology in the future.

Cephalometric analysis did not elucidate a defined relationship between the amount of midface advancement and changes in scleral exposure. Though the subject with the largest midface advancement also demonstrated the largest reduction in scleral exposure, the reverse was not necessarily true. However, the assessment of this relationship was limited by a small sample size and the fact that the preoperative and postoperative radiographic images of four subjects could not be superimposed. It is likely that a larger sample size would help clarify this relationship though future investigators should be cautioned that modified Le Fort III osteotomies are preformed less frequently than other midface osteotomies.

This study is the first to evaluate changes in the scleral exposure after a modified Le Fort III osteotomy. For the majority of subjects both ΔSSA (22/26) and ΔMED (23/26) were reduced by a clinically important amount (>5%) postoperatively. Although the median ΔSSA and ΔMED appear small (-20 and -18, respectively), evaluation of surgical results demonstrates that the reduction in scleral exposure can be appreciated clinically (**Figures 4 and 5**). Not all subjects in the present study showed a clinically important reduction in scleral exposure. Subjects with less scleral exposure preoperatively demonstrated less reduction in scleral exposure postoperatively (**Figure 6**). This could be related to the amount of lateral orbital rim advancement, which varied considerably among subjects.

The discrepancy between the number of subjects demonstrating clinically important decreases in ΔSSA compared to ΔMED is likely related to the fact that SSA evaluated total changes in scleral exposure (inferior, medial and lateral) whereas the MED only evaluated changes in inferior scleral exposure. This data suggests that although the modified Le Fort III osteotomy decreases inferior, medial, and lateral scleral exposure it reduces the inferior sclera to a greater degree than medial or lateral exposure.

The osseous gaps were grafted with either cranial bone or anterior iliac crest. Variations in the amount of graft placed, location of grafting, and remodeling related to graft source may have also contributed to differences in ΔSSA and ΔMED. These differences in bone grafting may also contribute to the lack of linearity between the amount of midface advancement and change in scleral exposure. Additional limitations of this study include its retrospective design, low power (thirteen subjects, 26 eyes), demographic concerns (all Caucasian subjects, three subjects diagnosed with craniofacial syndromes), the fact that postoperative photographs utilized were from a single point in time, and variations in the amount of midface advancement as well as the amount of lateral orbital rim included in the osteotomy.

Conclusions

Excessive scleral exposure can accompany midface deficiency especially when the deformity extends to the orbit. Careful evaluation of the periorbital region should be completed preoperatively using standardized facial photographs to supplement physical exam findings. Clinicians should anticipate a reduction in scleral exposure after midface advancement. The high concordance and the lack of systematic bias indicate that SSA and MED are reliable methods for evaluating scleral exposure. Analysis of preoperative and postoperative ΔSSA and ΔMED measurements indicated that the modified Le Fort III osteotomy decreases medial, lateral, and inferior scleral exposure. The reduction in scleral exposure appears to be more substantial inferiorly than laterally or medially. Individuals with a greater amount of sclera exposed preoperatively appear to have a larger reduction in scleral exposure after a modified Le Fort III osteotomy.

Figures

Figure 1. (A) Photograph of Kufner's original description of midface advancement. **(B, C)** Various modifications of Kufner's osteotomy performed in the subjects in this study. Notice that the modified osteotomy extends thru the inferior orbital fissure and always includes the cheek prominence. The extent of lateral orbital wall inclusion varies.

Figure 2. The scleral surface area (SSA) in each eye was determined by pixel count. The number of pixels within the palpebral fissure **(A)** and the number of pixels in the pupil and iris **(B)** were determined. The SSA is the difference between the number of pixels within the palpebral fissure and the pupil and iris (SSA = A – B). The percent change in SSA (ΔSSA) is the mean postoperative SSA divided by the mean preoperative SSA ($\Delta SSA = SSA_{postoperative}/SSA_{preoperative} \times 100$).

Figure 3. The mid pupil to eyelid distance (MED) was computed by determining the distance from the center of the pupil to point on the lower eyelid inferior to the center of the pupil (A). The percent change in MED (ΔMED) is the mean postoperative MED divided by the mean preoperative MED ($\Delta MED = MED_{postoperative}/MED_{preoperative} \times 100$).

Figure 4. Preoperative **(A)** and postoperative **(B)** frontal facial photographs of subject 1. Average percent changes in SSA and MED were found to be clinically important in both eyes.

Figure 5. Preoperative **(A)** and postoperative **(B)** frontal facial photographs of subject 4. Average percent changes in SSA and MED were found to be clinically important in both eyes.

Figure 6. Preoperative **(A)** and postoperative **(B)** frontal facial photographs of subject 9. Average percent changes in SSA and MED were not clinically important except ΔSSA in the right eye.

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Table 1. Results of the doubly repeated measures analysis of variance and estimates for visit (preoperative versus postoperative) and eye (right versus left) on SSA and MED.

SSA

Effect	Num DF	Den DF	F value	*p* value
Visit	1	12	16.8	0.002
Eye	1	12	0.8	0.37
Effect	**Eye/Visit**	**Standard Estimate (pixels)**	**Error (pixels)**	
Visit	Preop	2817.7	260.5	
Visit	Postop	2259.5	202.5	
Eye	L	2566.4	230.3	
Eye	R	2510.8	219.8	

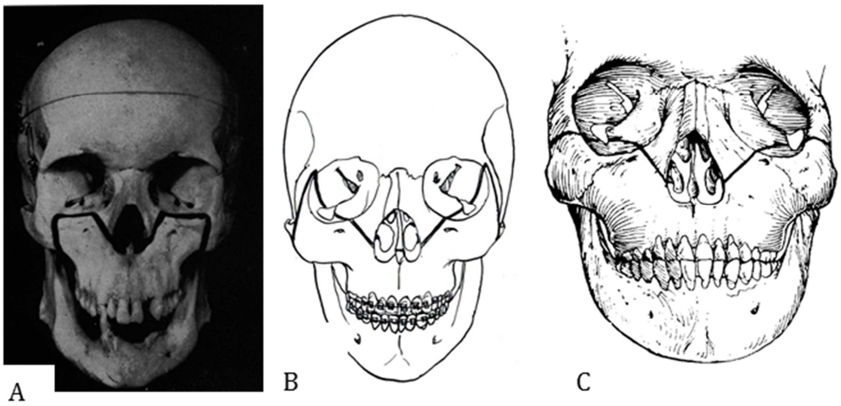
MED

Effect	Num DF	Den DF	F value	*p* value
Visit	1	12	27.8	0.0002
Eye	1	12	2.1	0.17
Effect	**Eye/Visit**	**Standard Estimate (mm)**	**Error (mm)**	
Visit	Preop	6.5	0.3	
Visit	Postop	5.4	0.3	
Eye	L	5.9	0.3	
Eye	R	6.0	0.3	

Degrees of freedom (DF); Numerator (Num); Denominator (Den); Preoperative (Preop); Postoperative (Postop); Right eye (R); Left eye (L)

Table 2. Results of overall percent change in SSA (ΔSSA) and MED (ΔMED) for subjects postoperatively after a modified Le Fort III osteotomy (n = 13).

	ΔSSA	**ΔMED**
Median	-20%	-18%
Interquartile Range (25% - 75%)	-31% to -7%	-21% to -12%
Range	-45.6% to 36.1%	-44.4% to 12.5%
Eyes with clinically important reduction (≥5%)	22/26	23/26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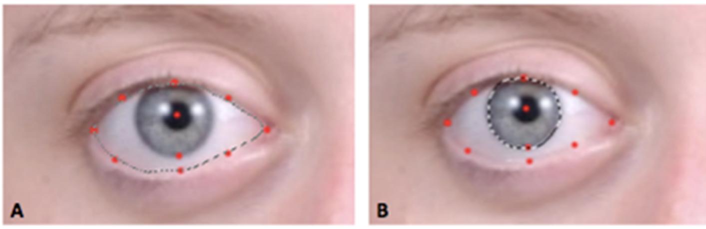
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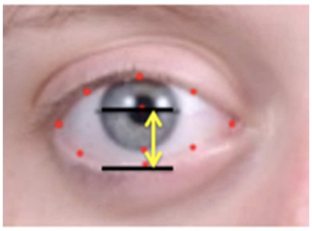


A
B


A
B

Excessive scleral exposure commonly accompanies midface deficiency. A modified LeFort III osteotomy (Kufner) can be used to address this deformity. The purpose of this project is to analyze the changes in scleral exposure after a modified Le Fort III osteotomy.

Supplemental Table 1. Results of average percent change in SSA (ΔSSA) and MED (ΔMED) in right and left eye postoperatively by subject (n = 13, 26 eyes).

Subject - Eye	**ΔSSA**	**ΔMED**
1-R	-11.2*	-19.0*
1-L	-20.8*	-18.9*
2-R	-43.0*	-33.3*
2-L	-45.6*	-44.4*
3-R	-31.6*	-32.6*
3-L	-20.8*	-25.5*
4-R	-25.6*	-18.4*
4-L	-11.8*	-13.2*
5-R	-7.7*	-9.7*
5-L	-18.7*	-12.1*
6-R	-12.8*	-16.0*
6-L	-16.6*	-11.5*
7-R	-31.1*	-21.4*
7-L	-27.2*	-20.5*
8-R	-35.1*	-34.0*
8-L	-31.8*	-18.2*
9-R	-5.5*	12.5
9-L	4.1	-2.5
10-R	-31.2*	-18.2*
10-L	-19.9*	-18.8*
11-R	25.1	-22.2*
11-L	36.1	-12.5*
12-R	-23.2*	-18.2*
12-L	-23.6*	-17.6*
13-R	0.5	-4.5
13-L	-7.1*	-9.5*

Right eye (R); Left eye (L)
*Clinically important reduction in scleral exposure (≥5%).

Supplemental Table 2. Change in lateral cephalometric points A, upper incisor Tip (U1), ANS, Orbitale (Or) from preoperative to postoperative in subjects after a modified Le Fort III osteotomy (n = 13).

Subject	ΔA	ΔU1	ΔANS	ΔOr
1*	1.9	4.5	0.5	1.1
2*	19.2	16	16.9	9.2
3*	7.1	8.7	3.4	3.7
4*	#	#	#	#
5	7.3	8.2	6.1	1.5
6*	11.6	16.7	8.6	7.6
7*	4.4	4.8	3	0.8
8*	8.4	11	9.8	2.7
9	#	#	#	#
10*	1.6	4.9	2.1	2
11	#	#	#	#
12*	#	#	#	#
13	5.2	3.1	3.6	3.3

*Clinically important reduction in scleral exposure.
#No data. Unable to superimpose lateral radiographs.