Three-dimensional changes of scleral show after surgical treatment of endocrine orbitopathy

Matthias Krause a, Daniel Kruber a, Heike Hümpfner-Hierl a, Ina Sterker b, Thomas Hierl a, *

a Department of Oral & Maxillofacial Plastic Surgery (Head: Alexander Hemprich MD DDS PhD), Leipzig University, Liebigstr. 12, 04103, Leipzig, Germany
b Department of Ophthalmology, Leipzig University, Liebigstr. 12, 04103, Leipzig, Germany

A R T I C L E   I N F O
Article history:
Paper received 13 June 2017
Accepted 24 October 2017
Available online 31 October 2017

Keywords:
Endocrine orbitopathy
Decompression
Scleral show

A B S T R A C T
Purpose: Surgery in endocrine orbitopathy should address exophthalmos and adjunct stigmata such as increased lid aperture and scleral show. Secondary to decompression, rehabilitative surgical treatment such as blepharoplasty is routinely used to achieve this goal. Until now, however, there has been no investigation to measure the effect of decompression surgery on scleral show and lid aperture 3-dimensionally.

Materials and methods: Ocular surface area (OSA) and lid aperture of 34 patients (67 orbits) were measured pre and post decompression surgery in a retrospective investigation using 3-dimensional (3D) stereophotogrammetry. The mean follow-up after decompression was 6 ± 4 months.

Results: Mean OSA ranged between 3.1 ± 1.5 cm² (pre orbital decompression) and 2.5 ± 0.6 cm² (post orbital decompression). Orbital decompression caused a statistically significant reduction of the surface area of about 19.4% (p < 0.001). Lid apertures showed average values between 12.7 ± 3.3 mm (pre orbital decompression) and 11.3 ± 2.2 mm (post orbital decompression). Thus orbital decompression led to a statistically significant reduction of the palpebral fissure of about 11% (p < 0.001). OSA correlated with lid aperture pre and post surgery (p < 0.001). The extent of OSA reduction showed no correlation with the amount of exophthalmos reduction.

Conclusion: Our results show that surgical decompression, besides correcting exophthalmos, leads to a significant reduction of scleral show and lid aperture. However, it is not possible to estimate its effect on an individual basis.

© 2017 European Association for Cranio-Maxillo-Facial Surgery. Published by Elsevier Ltd. All rights reserved.

1. Introduction

Endocrine orbitopathy (EO) is a complex inflammatory disorder and the main extrathyroidal manifestation of Graves’ disease. Surgical rehabilitative treatment such as orbital decompression surgery, squint surgery or eyelid surgery is needed in the majority of patients when EO has been conservatively managed and inactivated by immunosuppressive treatment (Bartalena et al., 2016). This treatment follows the algorithm: orbital decompression is first addressed because of its influence on ocular motility and lid position, followed by strabismus surgery, and, last, eyelid surgery. Upper and/or lower eyelid blepharoplasty is frequently needed as the last step for functional and esthetic rehabilitation (Barrio-Barrio et al., 2015).

The prediction of surgical outcome, however, is difficult (Kang et al., 2015). To prevent under- or overcorrection in eyelid surgery, it is important to analyze the eyelid contour and the scleral shape and area.

With the development of digital photography technology and software, the eyelid position can be analyzed more accurately. By now several studies have utilized a two-dimensional (2D) approach to measure lid contour and scleral show (Cruz et al., 1998, 2003; Cruz and Lucchezi, 1999; Koushan et al., 2008; Flynn et al., 2011; Mihlbratz et al., 2012; Nishihira et al., 2014; Prado et al., 2012; Lee et al., 2014; Kang et al., 2015; Tsai et al., 2012; Ahn et al., 2016; Zheng et al., 2016). 2D measurements, however, suffer from...
inherent shortcomings such as changing camera positions, which cause distortions, and metrical calibration can be difficult. Furthermore, it is not possible to calculate spatial changes between two time points.

Therefore the purpose of this study was to measure the real 3-dimensional (3D) ocular surface area (OSA) (the OSA or palpebral fissure is defined as the area between the eyelids) in the treatment of patients with EO for the first time. Here 3D stereophotogrammetry provides an ideal, novel, non-invasive method which can be used for measuring and comparing surgery results (Nkenke et al., 2003; Hontscharuk et al., 2012; Mailey et al., 2016). Besides the absolute changes in OSA, 3D scanning would also allow investigation of whether OSA values would correlate with proptosis and its reduction.

2. Materials and methods

From 2010 to 2015, a total of 34 patients (67 orbits) with endocrine orbitalopathy underwent surgery and were retrospectively evaluated by using the routinely acquired data. All patients who underwent surgery in this period were included. Surgical bony orbital decompression was planned and timed according to the recommendations of guidelines for the management of endocrine orbitalopathy (Bartalena et al., 2016).

Surgery ranged from 1-wall to 3-wall decompression including lateral rim advancement in 61 orbits (1-wall decompression: 6 orbits, 2 walls: 47 orbits, 3 walls: 14 orbits) according to the procedure described earlier (Krause et al., 2017). Lateral rim advancement was performed in all bilateral decompression cases (González-García et al., 2008). In this procedure, the lateral, superolateral and infralateral orbital rim portions are detached during surgery, refixed with microplates at the superolateral and infralateral osteotomies, while the lateral rim pivots anteriorly (González-García et al., 2008; Krause et al., 2017). Thus the orbital depth is increased laterally. During surgery, the attachments of the lower lid were freed from the infraorbital rim, and no kanthopexy was performed. Instead, upper and lower lid were allowed to redrape freely after the transconjunctival suturing. Subcutaneous sutures were used only in the region of the lateral kanthotomy (not in the infraorbital region). After surgery, adhesive strips were fixed to the upper and lower lids for 1 week.

Criteria for decompression surgery were.

- Optic neuropathy with vision impairment (these were the cases with "non-pathologic presurgical exophthalmos values due to a non-existing auto-decompression by way of increased exophthalmos").
- Marked asymmetry in unilateral EO.
- Failed previous therapy and persisting proptosis. All patients had presurgical corticosteroid medication and thyroid surgery, 40% retrobulbar radiation therapy.

Surgery was performed according to the following standards: In all cases except unilateral exophthalmos, lateral rim advancement was performed. The criteria for 1- to 3-wall decompression were:

- 3-wall decompression in acute optic neuropathy with imminent vision loss.
- 1- to 2-wall decompression (lateral or lateral and inferior decompression) according to the amount of proptosis and the patient anatomy. If a proptosis reduction of more than 3–4 mm was needed, 2-wall surgery was chosen.
- All surgeries were planned in iPlan software (Brainlab Co.) with presurgical marking of the resection borders and utilizing intraoperative navigation.

All patients had optical facial 3D images taken with the Vectra M3 passive stereophotogrammetric system (Canfield Scientific Inc., Fairfield, NJ), which were used for this analysis. These scans were used for all measurements of exophthalmos and sclera replacing conventional Hertel or Naugle exophthalmometers. The system consists of 3 acquisition pods taking 9 images simultaneously. Scanning was performed with the patients sitting in repose on a motor-driven, height-adjustable stool. Natural head position was gained by looking in a mirror and at a fixation point marked between the pods. Patients were scanned before orbital decompression, after orbital decompression, and prior to further surgery which was used as the endpoint scan. To measure OSA and lid aperture, the following workflow was used: 3D stereophotogrammetry data were exported into OBJ-format from the Vectra system. Then they were imported into Facial Analyzes Tool (FAT) software (Hierl et al. 2009). After import into FAT software, the ocular surface area (OSA) and the height between the two eyelids, i.e., the lid aperture, were measured (Figs. 1 and 2).

Measurement of OSA was performed by placing landmarks on the scleral–eyelid junction at a 1- to 2-mm distance. These were then connected to define the 3D area as a new object. FAT software allows different ways of area measurement such as marking the polygons of the palpebral fissure or overlaying the area with a “lasso” function. Comparing these with the landmark-based procedure showed that this was the best method. Using landmarks, the polygons of the original surface mesh were cut according to the landmark position and the respective connecting line.

To define lid aperture, the optical scan was registered to a template (Fig. 3) to guarantee proper orientation. Then a grid template was created in FAT software which was projected parallel to the frontal plane (Fig. 2). By changing grid spacing, parallel vertical lines were created which allowed exact vertical landmark placing on the upper and lower eyelid borders. Next the distances between these landmarks were calculated.

Regarding optical scanning of the orbital fissure, 2 problems arise. First, liquid-covered surfaces such as the sclera cause light scattering which results in a non-smooth surface. Therefore single-use lenses could be used to create an even surface. As this could change the upper and lower lid positions, however, lenses were not inserted and the resulting slightly uneven surface was automatically smoothed in FAT software instead. The second problem is caused by the transparency of the lens, which creates a slight inward bulging of the central ocular surface. Again, this could be prevented by using non-transparent lenses with the problem of potential irritation and incorrect lid margins, or by software-based surface correction. When the original surface area was compared to the corrected surface, a uniform 0.1- to 0.09-cm² difference was seen. In relation with our measurements, this would account for a constant 3% area difference. In this study, the original (uncorrected) values were used.

In addition to the measurement of absolute OSA and lid aperture values, we studied pre- and postsurgical symmetry. Therefore the larger value of both eyes was divided by the smaller one before and after decompression to generate an asymmetry score. Values ranging between 1 and 1.1 were classified as score 1, 1.2 as score 2, and larger than 1.2 as 3.

Finally, we wanted to correlate OSA and lid aperture to the extent of pre-surgical exophthalmos and potential OSA changes to proptosis reduction. Correlating OSA and lid aperture changes to surgical procedures would not have been possible due to the small number of each procedure. Therefore the reduction of proptosis was taken as the relevant variable, as it is reasonable to suppose that the change in globe position would affect lid position and not bony changes within the bony orbital cavity.

To define pre-existing exophthalmos and its decrease, the optical 3D scans were used instead of manual devices. As lateral rim
advancement was performed in most orbits, postsurgical values using a Hertel exophthalmometer would have been misleading, as the lateral orbital rim position was changed during surgery. Therefore a 3D cephalometric analysis was implemented in FAT software, which exactly matched the definition of the Hertel exophthalmos value to permit comparison with previous studies. The results of this 3D analysis served as the preoperative exophthalmos evaluation. Next the pre-to postsurgical changes in proptosis were calculated without referring to the changing lateral rim position (Fig. 4). This was achieved by registration and superimposition of the pre- and postsurgical optical scans. Here non-changing surfaces such as the forehead and nose were utilized. After superimposition, the presurgical reference was used on the postsurgical scans to measure the new value of proptosis and subsequently its decrease.

Statistical analysis was performed with SPSS 14.0 (Statistic Package for the Social Sciences; SPSS Inc., Chicago, IL, USA). Concerning statistical evaluation, we decided not to combine the left and right sides to achieve higher numbers, but to evaluate both sides individually.

This retrospective study was approved by the Local Ethic Committee and followed the Declaration of Helsinki on medical protocol and ethics.

3. Results

OSA and lid apertures of 67 orbits (33 right orbits, 34 left orbits) were analyzed pre and post orbital decompression according to the above-mentioned workflow. The mean patient age was 51.0 years (range 31–76, 51.0 ± 8.6) and the group consisted of 24 women (71%) and 10 men (29%). Eight patients (23.5 %) had dysthyroid optic neuropathy. The mean follow up was 6.2 ± 3.9 months after surgical decompression. A longer follow-up period would have been
desirable, but most patients chose further surgery such as squint procedures or blepharoplasty. As these interfere with our outcome targets, only this follow-up period was available.

Additionally, presurgical exophthalmos and proptosis reduction were calculated. Table 1 shows the mean values and the corresponding standard deviations. The stated proptosis figures equal Hertel values. As explained before, these were calculated by way of 3D cephalometry. The postsurgical proptosis values equal values taken with a Hertel device if no changes of the lateral orbital rim had taken place.

The mean ocular surface areas ranged between 3.1 cm² (pre orbital decompression) and 2.5 cm² (post orbital decompression). Thus an average reduction of OSA of about 14% was seen after orbital decompression surgery. The mean lid apertures showed values between 12.7 mm (pre orbital decompression) and 11.3 mm (post orbital decompression). Orbital decompression led to a reduction of the palpebral fissure of about 11.1%. Decompression surgery led to a change in proptosis of almost 7 mm. Values were calculated for all orbits (stated above) and for those with lateral rim advancement. As the number of orbits without lateral rim advancement was too small, no advancement. As the number of orbits without lateral rim advancement was too small, no advancement. As the number of orbits without lateral rim advancement was too small, no advancement. As the number of orbits without lateral rim advancement was too small, no advancement. As the number of orbits without lateral rim advancement was too small, no advancement. As the number of orbits without lateral rim advancement was too small, no advancement.

Regarding symmetry, Table 2 shows the results. The percentage of a class 1 asymmetry (i.e. no asymmetry) was increased from 70% to 81%, and a concomitant decrease of the more severe classed was noticed also. However, no statistical significance was seen. Regarding lid aperture, no change in asymmetry was seen.

A typical patient case is shown in Fig. 5. Here a bilateral 2-wall decompression of the lateral and inferior orbital walls led to a marked proptosis and OSA reduction. The effect of lateral rim advancement is visible also, as the presurgical lateroorbital skin retractions are leveled after surgery.

The measured changes for OSA and lid aperture were statistically significant (p > 0.0001, paired Student test; all statistical results in Table 3). As expected, OSA and lid aperture measurements correlated significantly pre and post surgery. Furthermore, values were symmetrical in most instances, i.e., both sides reacted similarly for identical surgery.

Considering OSA changes of 0.1 cm² as clinically arbitrary, 17 of 67 orbits (25%) in 15 patients presented no changes after surgery (i.e. minimal or no changes were rarely bilateral). Three of 67 orbits (2 patients) showed an increase in OSA; one case measured 0.7 cm² on the right side, and one patient (i.e. 3% of the total patient group or 3% of all orbits) had a bilateral OSA increase of 0.6 cm² on the right and 0.5 cm² on the left side. Thus in 72% of all orbits, a decrease in OSA resulted; in 25% cases there was no change, and in 3% there was worsening.

Considering lid aperture results, 34 orbits (15 patients bilaterally, 4 patients unilaterally) presented with values of 12 mm or lower before surgery, which is said to be the upper threshold in non-EO patients (Farkas 1994). Post surgery, 46 orbits (20 patients bilaterally, 6 patients unilaterally) reached these values.

Regarding pre-existing OSA (and lid aperture) and the amount of exophthalmos, a significant correlation was found for both sides. After surgery, a weak correlation was seen for the left side and no correlation for the right side. Correlating the decrease of OSA with the achieved proptosis reduction, no statistical significance was seen in all correlations according to Pearson.

4. Discussion

Although increased scleral show (OSA) and the deriving symptoms have been included within several classifications of endocrine orbitopathy (Barrio-Barrio et al., 2015), exact measurements could not be found by the authors of this study. Investigations on OSA changes in non-EO patient groups after certain procedures (Cruz et al., 1998; Milbrat et al., 2012; Kang et al., 2015) have been based on 2D photographs using calibration rulers or iris diameter as references or for defining relative distances. Thus this investigation provides new data in 2 respects. First, it is the first study stating presented with comparable changes induced by surgery as shown in Table 1. Due to the unbalanced patient group composition, no statistical analysis of gender differences was performed.

Table 1

<table>
<thead>
<tr>
<th>OSA (cm²)</th>
<th>Lid aperture (mm)</th>
<th>Proptosis (mm)</th>
<th>Proptosis reduction (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre surgery (all, n = 67)</td>
<td>3.1 ± 1.5 (min: 1.9; max: 13.2)</td>
<td>12.7 ± 3.3 (min: 8.2; max: 30.2)</td>
<td>25.7 ± 3.7 (min: 17.5; max: 33.7)</td>
</tr>
<tr>
<td>pre surgery (LARA, n = 62)</td>
<td>3.1 ± 1.5 (min: 1.4; max: 13.2)</td>
<td>12.8 ± 3.3 (min: 8.6; max: 30.2)</td>
<td>26.105 ± 3.6 (min: 17.0; max: 33.6)</td>
</tr>
<tr>
<td>pre surgery (female, n = 42)</td>
<td>2.8 ± 0.8 (min: 1.4; max: 13.2)</td>
<td>12.0 ± 2.3 (min: 8.0; max: 18.5)</td>
<td>24.8 ± 3.3 (min: 17.4; max: 33.0)</td>
</tr>
<tr>
<td>pre surgery (male, n = 20)</td>
<td>3.9 ± 2.3 (min: 2.2; max: 13.2)</td>
<td>14.5 ± 4.4 (min: 9.0; max: 30.2)</td>
<td>28.5 ± 2.8 (min: 19.1; max: 33.6)</td>
</tr>
<tr>
<td>post surgery (all, n = 67)</td>
<td>2.5 ± 0.6 (min: 1.6; max: 4.5)</td>
<td>11.3 ± 2.2 (min: 7; max: 16.7)</td>
<td>18.9 ± 3.7 (min: 10.7; max: 26.9)</td>
</tr>
<tr>
<td>post surgery (LARA, n = 62)</td>
<td>2.5 ± 0.6 (min: 1.4; max: 4.5)</td>
<td>11.5 ± 2.1 (min: 7.6; max: 16.7)</td>
<td>18.9 ± 3.7 (min: 10.7; max: 26.9)</td>
</tr>
<tr>
<td>post surgery (female, n = 42)</td>
<td>2.3 ± 0.6 (min: 1.4; max: 4.5)</td>
<td>11.1 ± 2.1 (min: 7.6; max: 16.7)</td>
<td>18.6 ± 3.3 (min: 10.7; max: 26.8)</td>
</tr>
<tr>
<td>post surgery (male, n = 20)</td>
<td>2.8 ± 0.5 (min: 2.2; max: 3.9)</td>
<td>12.2 ± 2.0 (min: 9.1; max: 16.5)</td>
<td>19.6 ± 4.4 (min: 12.5; max: 26.9)</td>
</tr>
</tbody>
</table>

Data are given for all orbits, the orbits with lateral rim advancement (LARA), and for both female and male patients. No statistically significant differences were found between these subgroups.
OSA values in 3D using stereophotogrammetry, and it is the first such study regarding EO patients. The results show that decompression surgery is an effective means to reduce scleral show in EO in most of our patients. Furthermore, our results indicate that increased scleral show accompanied increased exophthalmos preoperatively. Interestingly, the amount of OSA reduction did not correlate with the extent of proptosis reduction. Possible causes relating to the surgical procedure were that the soft tissue was allowed to redrape freely and no fixation sutures were used. Our surgical procedure, which includes an anterior swiveling of the total lateral orbital rim (Krause et al., 2017), may further contribute to the measured effect of OSA decrease, as the more anteriorly positioned mediolateral infraorbital and lateral orbital rim could provide better support for the soft tissues of the lower lid. As our patient group without lateral rim advancement is small, a statistical analysis was not possible.

Regarding asymmetry of scleral show, a tendency toward increased symmetry was seen. Pre-existing marked asymmetry was reduced in some cases but tended to persist as OSA was reduced in both sides. This is demonstrated in the patient example in Fig. 5. Concerning lid aperture, no changes in symmetry were seen. One explanation is that OSA is most pronounced in the lateral

**Table 2**

<table>
<thead>
<tr>
<th></th>
<th>OSA AS mean</th>
<th>OSA AS 1 (1.0-1.1)</th>
<th>OSA AS 2 (1.2)</th>
<th>OSA AS 3 (≥1.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-surgery</td>
<td>1.1±0.2</td>
<td>23</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>postsurgery</td>
<td>1.1±0.2</td>
<td>27</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>LA AS mean</th>
<th>LA AS 1 (1.0-1.1)</th>
<th>LA AS 2 (1.2)</th>
<th>LA AS 3 (≥1.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-surgery</td>
<td>1.1±0.1</td>
<td>25</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>postsurgery</td>
<td>1.1±0.1</td>
<td>25</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

An asymmetry score (AS) was created by dividing the larger value of both eyes by the smaller one. Although the number of more pronounced asymmetry in OSA decreased, no statistical significant changes were seen.

**Fig. 5.** Comparison of presurgical (A) and postsurgical (B) optical scans in a patient. After a bilateral 2-wall decompression including the lateral and inferior walls, a distinct reduction in proptosis and ocular surface area (OSA) is seen. On the left side, which presented with a larger OSA preoperatively, adjunct lid surgery is still needed. Red arrows highlight the effect of lateral rim advancement, as the presurgical skin retraction is leveled due to the forward rotation of the lateral rim.

**Table 3**

<table>
<thead>
<tr>
<th></th>
<th>LA pre</th>
<th>Pro pre</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSA pre</td>
<td>R</td>
<td>p &lt; 0.001; r = 0.942</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>p &lt; 0.001; r = 0.905</td>
<td></td>
</tr>
<tr>
<td>OSA post</td>
<td>R</td>
<td>p &lt; 0.001; r = 0.952</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>p &lt; 0.001; r = 0.930</td>
<td></td>
</tr>
<tr>
<td>OSA change</td>
<td>R</td>
<td>p &lt; 0.79; r = -0.46</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>p &lt; 0.82; r = -0.4</td>
<td></td>
</tr>
<tr>
<td>Pro change R</td>
<td>p &lt; 0.001; r = 0.867</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSA post</td>
<td></td>
<td>p &lt; 0.02; r = 0.396</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>LA post</td>
<td>p &lt; 0.004; r = 0.352</td>
<td>2</td>
</tr>
<tr>
<td>OSA change</td>
<td></td>
<td>p &lt; 0.001; r = 0.631</td>
<td>2</td>
</tr>
<tr>
<td>Pro change L</td>
<td></td>
<td>p &lt; 0.001; r = 0.387</td>
<td>2</td>
</tr>
<tr>
<td>OSA pre</td>
<td>R</td>
<td>p &lt; 0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>p &lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>LA pre</td>
<td>R</td>
<td>p &lt; 0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>p &lt; 0.001</td>
<td></td>
</tr>
</tbody>
</table>

scleral aspect (lateral flaring) and not in the central aspect where lid aperture is measured. The study results suggest an individualized staged procedure as proposed within the known guidelines (Bartalena et al., 2016). Thus patients can be informed that there is a strong possibility that scleral show will decrease due to decomposition surgery, but that, as the exact outcome cannot be foreseen, ancillary surgery might still be needed. As no values of "normal" OSA are known to the authors at this point, only lid aperture values can be used to define the patient group, in which "normal" scleral values were reached after EO surgery (i.e. the group that benefited not only regarding proptosis but changed from pathological scleral show to non-pathological values). Here almost 19% of all orbits (34 orbits pre surgery, 46 orbits post surgery) showed this improvement if the 12-mm threshold is used. Although Hontscharuk et al. suggested optical 3D scanning to measure OSA and lid aperture and reported on a study on 26 patients, they did not state any absolute values; only differences between both sides were given and correlated with a disfigurement questionnaire. Furthermore, their values regarding OSA asymmetry are difficult to understand, as the authors stated an absolute asymmetry of OSA area in a control group to be 0.22 mm, which relates to a distance and not an area. Thus our findings cannot be compared with theirs.

OSA and lid aperture showed a high correlation, which was not surprising. Although lid aperture is easier to calculate, we think that OSA is an important variable for future investigations, as OSA includes features such as lateral scleral show, which is missed in singular lid aperture measurements.

3D measurements appear to be a noninvasive, easy-to-perform means to investigate OSA and lid changes. Calibration is not needed; errors due to improper photography techniques are nonexistent and pre and postsurgical 3D scans can be registered, allowing even more detailed investigations. With our proposed steps to minimize the inherent problems of optical 3D measurements of the sclera and lens, technical errors are small. Our results can be seen as a first step toward exact data acquisition concerning upper and lower lid position and contour and potential changes caused by different surgical procedures in EO. Future investigations will deal with the effects of blepharoplasty and lid procedures and will compare the results to values in non-EO patients. Furthermore our workflow permits the analysis of changes in lid contour 3-dimensionally. This will show to which extent upper and lower lid changes contribute to OSA changes, and the results may influence our surgical procedures.

5. Conclusion

The results of this investigation demonstrate that most patients benefit not only from proptosis reduction but also from OSA improvement after EO decompression surgery. As a prediction on the amount of improvement was not possible, a staged procedure in rehabilitative surgery in EO seems adequate. Optical 3D scanning proved to be an effective means in data acquisition, as it allowed exact proptosis measurement and comparison even in cases in which the bony orbit was changed.

Conflict of interest

The authors declare no conflicts of interest.

Acknowledgements

The development of the 3D analysis software (FAT) is partially funded by German Federal Ministry of Economics and Technology ZIM KF2036708SS0.

References