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Eyelid reanimation with gold weight implant and tendon sling suspension: Evaluation of excursion and velocity using the FACIAL CLIMA system

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Summary *Objective:* This study aims to analyse the efficacy of static techniques, namely gold weight implant and tendon sling, in the reanimation of the paralytic eyelid. Upper eyelid rehabilitation in terms of excursion and blinking velocity is performed using the automatic motion capture system, FACIAL CLIMA.
Methods: Seventy-four patients underwent a total of 101 procedures including 58 upper eyelid gold weight implants and 43 lower eyelid tendon suspension with 27 patients undergoing both procedures. The presence of lagophtalmos, eye dryness, corneal ulcer, epiphora and lower lid ptosis/ectropion was assessed preoperatively. The Wilcoxon signed-rank test was used to compare preoperative versus postoperative measurements of upper eyelid excursion and blinking velocity determined with FACIAL CLIMA. Significance was set at $p < 0.05$.
Results: FACIAL CLIMA revealed significant improvement of eyelid excursion and velocity of blinking ($p < 0.001$). Eye dryness improved in 49 patients (90.7%) and corneal ulcer resolved without any further treatment in 12 (85.7%) of those with a gold weight inserted. Implant extrusion was observed in 8.6% of the cases. Of the patients with lower lid tendon suspension, correction of ptosis/ectropion and epiphora was achieved in 93.9% and 91.9% of cases, respectively. In eight patients (18.6%), further surgery was needed to adjust tendon tension.
Conclusions: The paralytic upper and lower eyelid can be successfully managed with gold weight implant and tendon suspension. The FACIAL CLIMA system is a reliable method to quantify upper eyelid excursion and blinking velocity and to detect the exact position of the lower eyelid.

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Patients with facial paralysis frequently present with signs and symptoms derived from impaired eyelid function. Lagophtalmos often results from incomplete or no descent of the upper lid with corneal exposure leading to keratitis, ulceration, perforation and blindness. In turn, problems secondary to inferior eyelid paralysis include punctal eversion, which impedes adequate tear drainage, and varying degrees of lid malposition ranging from mild laxity without scleral show to severe cicatricial ectropion. Furthermore, ptosis of the inferior lid may also contribute to lagophtalmos. Thus, considering the devastating consequences that may occur, prompt reanimation of the eye should be a priority in the management of patients with facial paralysis.

The main goals of surgical treatment of the paralysed eyelid are to preserve or improve vision, decrease or eliminate exposure irritation and maintain or improve appearance.[1] Regarding the upper lid, surgery is aimed at restoring lid descent to protect the otherwise exposed cornea. Options include the use of gold weight implants, wire spring implants, cross-facial nerve grafting and regional or distant muscle transfers.[2–8] However, the goals of lower eyelid reanimation are restoration of eyelid position to improve tear drainage and correction of ptosis or ectropion. For this purposes, a number of procedures have been described such as horizontal eyelid shortening, lateral tarsal suspension, canthoplasties, cartilage grafting and suspension with autogenous or alloplastic materials.[9–14] Traditionally, tarsorrhaphy has been the 'gold standard' regarding protection of the paralysed eyelid[10]; however, nowadays it has been displaced by other techniques that, apart from achieving adequate corneal coverage, produce a much better aesthetic appearance.

An important aspect to consider in eyelid as well as overall facial reanimation is the method of outcomes evaluation. Although qualitative grading and scales are useful, they often fall short in providing quantitative data of blinking, such as excursion and velocity, which are important parameters to consider when attempting to restore eyelid function. To overcome this, we have been using FACIAL CLIMA,[15] an automatic optical motion system that allows objective quantification of movement.

This work presents our experience in eye reanimation with gold weight implants and tendinous suspension during the last 6 years. The main outcomes considered for the purpose of this paper were restoration of upper eyelid excursion and blinking velocity assessed by means of the FACIAL CLIMA system.

Patients and methods

Patients and variables

A retrospective chart review of patients submitted to superior eyelid reanimation with gold weight implant and/or inferior eyelid suspension with a tendon sling between January 2006 and May 2012 was performed. Age at surgery, aetiology and time of evolution of paralysis, complications, revision surgeries and follow-up were registered in all cases. All patients were operated by the senior author. Preoperative assessment included FACIAL CLIMA analysis and physical examination identifying lagophtalmos, eye dryness, corneal ulcer, epiphora and ptosis/ectropion of the lower eyelid. Patients in whom a corneal ulcer was suspected were evaluated by the Ophthalmology Department before surgery. Postoperatively, visits were scheduled generally 1, 3, 6 and 12 months and then once a year, although this varied depending on whether other reanimation procedures of the middle and lower thirds of the face were performed concomitantly. FACIAL CLIMA was conducted during the postoperative visits as well.

Surgical technique

For patients undergoing gold weight implantation, all implants were placed in the tarsal plane, 5 mm cephalad to the free border of the upper eyelid and fixed with non-resorbable sutures to the upper half of the tarsal plate so that when the eyelid is elevated, the bulging produced by the implant is hidden. Layered closure was finally performed, with running resorbable sutures for the orbicularis oculi and a running nylon suture for the skin. Depending on the presence of dermatochalasis and/or brow ptosis, other procedures are performed concomitantly (Table 1).

For patients undergoing lower eyelid suspension, a portion of palmaris longus, plantaris, extensor digitorum longus, flexor carpi radialis Achilles or fascia lata was tunnelled from lateral to medial and fixed to the medial canthal ligament with nylon sutures and to the superolateral orbital rim with a screw anchor.

Movement analysis: FACIAL CLIMA

Movement analysis was assessed pre- and postoperatively using a three-dimensional (3D) automatic capture system of facial movements called FACIAL CLIMA described by the senior author.[15] This is an automatic optical motion system that involves placing special reflecting dots on the patient's face (a total of 18 dots) and video recording with three infrared-light cameras. Patients are asked to perform several facial movements including eye closure. The data are automatically processed and a three-dimensional dynamic template of the face is constructed, resulting in information on areas, velocities and distances between the 18 dots (Figure 1 and Video 1). Regarding accuracy, comparison of a known distance and angle with those obtained by FACIAL CLIMA shows that this system is accurate to within 0.13 mm and 0.41°. This system has been tested in normal patients and was found to have a reliability of 99%. Furthermore, its intra-rater reliability (re-test reliability) is as high as 95% and its inter-rater reliability (agreement between raters) is $>$90%. Such characteristics make FACIAL CLIMA a highly accurate and operator-independent method of movement evaluation. For upper eyelid excursion, the system calculates the mean maximal and minimal distance between the two dots placed on the upper and the lower eyelid, respectively. At the same time, the system calculates the velocity of blinking in millimetres per second. Thus, by comparing preoperative versus postoperative eyelid excursion and blinking velocity, it is possible to determine if there has been improvement in any of these parameters. Furthermore, with the data obtained, it is possible to

Table 1 Rationale for management of the paralytic upper eyelid considering the contribution of eyebrow ptosis to eye closure and the presence of dermatochalasis. Due to the difference in the angle of the skin and the tarsal plate, 0.2 g are routinely added to the weight calculated preoperatively in the office.[5] Patients with type I lagophtalmos with dermatochalasis are best treated with gold weight and upper eyelid blepharoplasty to improve aesthetic appearance, while for those without dermatochalasis, gold weight implant placement alone is indicated. For patients with lagophtalmos type II and dermatochalasis, a heavier gold weight should be placed together with blepharoplasty and brow elevation by elliptic frontal excision. A heavier implant is recommended since in these patients both the eyelid skin excess and brow ptosis are corrected and there is a risk of persistent lagophtalmos if a light weight is used. Finally, for type II lagophtalmos without dermatochalasis, gold weight plus brow elevation produces a good functional and aesthetic result.

	Eyelid dermatochalasis	No eyelid dermatochalasis
Lagophtalmos I (Eyelid dermatochalasis and/or brow ptosis DO NOT aid in eyelid closure)	Gold weight + 0.2 g Upper lid blepharoplasty	Gold weight + 0.2 g
Lagophtalmos II (Eyelid dermatochalasis and/or brow ptosis DO aid in eyelid closure)	Gold weight + 0.4 g Upper lid blepharoplasty Elliptic frontal excision	Gold weight + 0.2 g Elliptic frontal excision

calculate the percentage of recovery of each individual considering his or her healthy side as the reference. This avoids heterogeneous comparisons between patients with different vertical palpebral fissures. In this sense, by calculating each individual's percentage of recovery, a more objective measurement can be obtained, minimising the possible bias from comparing absolute values.

Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.bjps.2012.12.022.

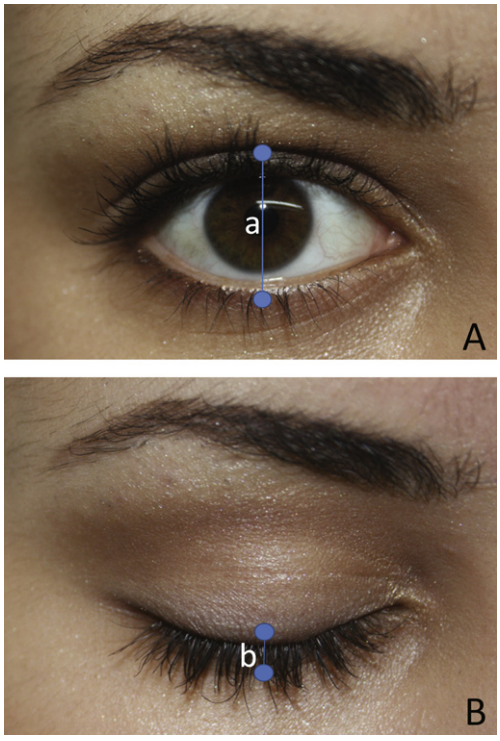

Figure 1 A. Diagram showing upper eyelid excursion with FACIAL CLIMA. A dot is placed in upper and lower eyelid and the system calculates the distances (mm) between them and blinking velocity (mm/s). A. Eyes opened. B. Eyes closed. Upper eyelid excursion = a − b.

Statistical analysis

The Wilcoxon signed-rank test was used to compare preoperative versus postoperative mean eyelid excursion, blinking velocity and percentage of recovery of both parameters in patients with gold weight implants. Significance was set at $p < 0.05$. Statistical Package for Social Sciences (SPSS) v17.0 (SPSS Inc., Chicago, IL, USA) was used to perform all statistical tests.

Results

Between January 2006 and May 2012, a total of 74 patients underwent 101 procedures, including 58 gold weight implants for the upper lid and 43 tendon slings for the lower lid, with 27 patients having both techniques. Data on gender distribution, mean age at surgery, time of evolution of paralysis and follow-up are summarised in Table 2. The aetiology of paralysis is summarised in Table 3.

Table 2 Demographics of the whole sample, patients with gold weight implant and patients with lower eyelid tendon sling. y: years; S.D: standard deviation; m: months.

Variable	Total	Gold weight	Tendon sling
Patients. *n*	74	58	43
Gender. *n* (%)			
Male	33 (44.6)	24 (41.4)	21 (48.8)
Female	41 (55.4)	34 (58.6)	22 (51.2)
Age at surgery. y			
Mean ± S.D	49.97 ± 16.13	49.41 ± 16.37	50.72 ± 15.96
Time of evolution of paralysis. m			
Mean ± S.D	45.8 ± 66.75	36.91 ± 61.9	55.07 ± 66.96
Range	0–300	0–300	3–300
Median	19.5	14.5	34
Follow-up. m			
Mean ± S.D	32.54 ± 34.59	35.29 ± 18.37	31.56 ± 12.02
Range	3–144	3–144	3–73
Median	21.5	23	24

Table 3 Aetiology of paralysis.

Aetiology	*n* (%)
Acoustic neurinoma	31 (44.59)
Parotid surgery	12 (16.21)
Cholesteatoma	8 (10.81)
Bell's palsy	7 (9.46)
Varicella Zoster	6 (8.12)
Posterior fossa/brain surgery	4 (5.41)
Trauma	4 (5.41)
Facial nerve neuroma	2 (2.7)

Data obtained from the FACIAL CLIMA system obtained from patients with gold weight implant revealed significant improvement of eyelid excursion and blinking velocity. Preoperative excursion and velocity showed a mean of 3.49 ± 1.54 mm and 19.38 ± 11.15 mm s^{-1}, respectively. Postoperatively, both parameters improved significantly to a mean excursion of 8.35 ± 3.14 mm ($p < 0.001$) and a mean blinking velocity of 48.28 ± 15.26 mm s^{-1} ($p < 0.001$). Likewise, mean percentage with respect to the contralateral healthy side of eyelid excursion improved from $29.56 \pm 11.09\%$ to $56.72 \pm 15.41\%$ ($p < 0.001$) and mean percentage of blinking velocity from $26.16 \pm 13.59\%$ to $64.32 \pm 23.41\%$ ($p < 0.001$) (Table 4) (Figure 2).

All the 58 patients who submitted to upper eyelid gold weight implantation presented with eye dryness needing artificial tears, and 14 (24.1%) had a corneal ulcer. Implant weight ranged from 1.0 to 1.4 g. On follow-up, five patients (8.6%) suffered implant extrusion of whom three were exchanged without further complications and two were removed without replacement due to material intolerance. In two patients with persistent lagophtalmos, the implant had to be replaced for a heavier one to achieve adequate eye closure and in one case of pseudoptosis the implant had to be replaced for a lighter one. Eye dryness improved in 49 patients (90.7%) and corneal ulcer resolved without any further treatment in 12 of the 14 cases presenting such problem (85.7%).

Regarding the 43 patients with lower eyelid suspension with tendon sling, 33 (76.7%) presented with ptosis or ectropion and 37 (86%) with epiphora. Correction of these conditions was achieved in 31 (93.9%) and 34 (91.9%) patients, respectively. In eight patients (18.6%) further surgery was needed to increase tendon tension. No other complications requiring surgical intervention were registered.

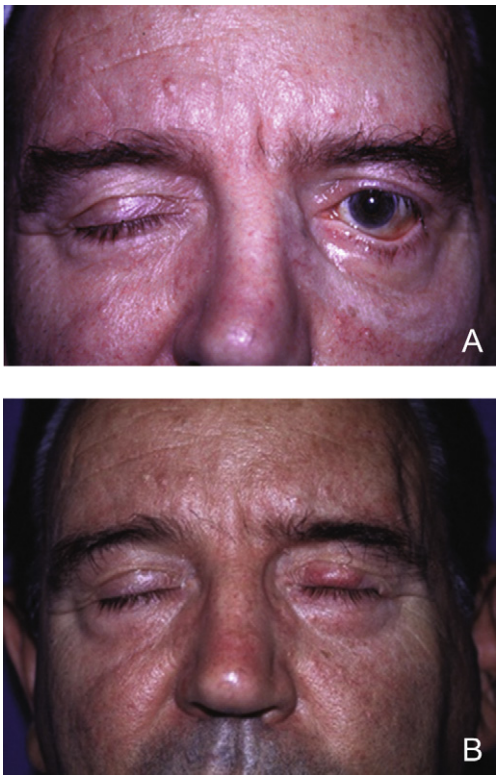

Figure 2 59-year-old male with left facial paralysis secondary to acoustic neurinoma resection. A gold weight was inserted to treat lagophtalmos and a tendon sling was performed to treat lower eyelid ectropion. (A) Preoperative during eye closure. Note lagophtalmos and lower eyelid ectropion. (B) Postoperative situation showing complete eye closure without corneal exposure and adequate correction of lower eyelid ectropion.

Discussion

Restoration of normal eyelid function is frequently one of the first priorities in patients with facial paralysis affecting the upper third of the face. Lagophtalmos, epiphora and ptosis/ectropion are common findings, which, if left untreated, result in corneal exposure that may lead to ulceration and even blindness depending on the severity and denervation time. Furthermore, a paralytic eyelid may produce an important facial disfigurement as not only is its function hampered, but also its position. Currently, a number of medical and surgical alternatives exist to treat the exposed cornea and restore the eyelid function and position when necessary.

Table 4 Wilcoxon signed-rank test shows significant improvement of both eyelid excursion and blinking velocity. S.D: standard deviation.

	Preoperative (mean ± S.D)	Postoperative (mean ± S.D)	*p*
Eyelid excursion (mm)	3.49 ± 1.54	8.35 ± 3.14 mm	<0.001
% Excursion of healthy side (%)	29.56 ± 11.09	56.72 ± 15.41	<0.001
Blinking velocity (mm/s)	19.38 ± 11.15	48.28 ± 15.26	<0.001
% Velocity of healthy side (%)	26.16 ± 13.56	64.32 ± 23.41	<0.001

Lagophtalmos results mainly from the impaired function of the orbicularis oculi muscle and the consequent unopposed action of levator palpebrae superioris. Several techniques have been described to address this condition with varying results. Dynamic options include cross-facial nerve grafting, direct muscle neurotisation, hypoglossal nerve transposition, regional muscle transpositions (i.e., temporalis and frontal) and free muscle transfer.[4,6–8] While with some of these procedures physiological eye closure and corneal reflex are restored, with others such as temporalis transfer or hypoglossal transposition the patient must either masticate or protrude the tongue to produce the desired movement, thus losing corneal reflex. Besides, all these techniques are technically demanding and some of them require long operative times that may not be tolerated by older patients. By contrast, gold weight implant is an effective and relatively easy procedure that restores voluntary eye closure and corneal reflex by allowing the eyelid to fall down by gravity (and weight) when the levator palpebrae superioris relaxes in response to corneal stimulation. Moreover, voluntary closure is usually enough to prevent corneal exposure and is in most cases an effective measure to treat an already ulcerated cornea. Hence, the gold weight implant for paralytic lagophtalmos is currently one of the preferred methods of eye reanimation for several surgeons.[1,16–23] Advantages include straightforward technique, the possibility to be performed under local anaesthesia, absence of donor zone, predictable results, good aesthetic appearance and its reversibility.

An important aspect to consider in overall facial reanimation, including blink restoration, is the method used to evaluate the functional outcomes. When performing dynamic rehabilitation, it is imperative to perform some kind of metric assessment pre- and postoperatively in order to have more objective data regarding the actual improvement. Furthermore, such a system of quantification must be, ideally, operator independent to reduce bias. In this sense, FACIAL CLIMA has shown to be a valuable tool, meeting both of these important criteria, since apart from providing quantitative data on movement (distance and velocity), it is a highly accurate and operator-independent system judging by its high intra- and inter-rater reliabilities. Specifically regarding upper eyelid reanimation with gold weight implants, it is important to note that despite being a static technique, it provides dynamic recovery, since it is designed to improve lid closure. Thus, evaluation of postoperative outcomes in quantitative terms becomes necessary. Even though qualitative evaluations through scores and quality of life (QOL) scales have also been described and proven useful, they assess recovery in terms of resolution of symptoms without informing on the real quantitative improvement.[24] Some have suggested that QOL scales may be equally or even more relevant than objective measurement alone[25]; however, we believe that when movement is restored in any segment of the face, a quantitative metric evaluation is paramount not only to assess recovery of patients individually, but also to compare groups of patients and different techniques, which can ultimately aid in designing a correct surgical plan. In this sense, FACIAL CLIMA has shown to be a reliable method of quantification, allowing objective evaluation and correct comparison of several reanimation procedures.[15,26,27] Data from this system revealed a significant improvement in eyelid excursion and velocity, both being important parameters to consider in eye reanimation. On the one hand, by increasing upper eyelid excursion to a mean higher than 50% of the healthy side, adequate corneal protection is ensued. On the other hand, by enhancing velocity, patients are able to perform a fast voluntary eye closure that does not disturb their normal activity as would happen if they had to close their eyes for a few seconds to allow the reanimated lid to close completely. These findings objectively illustrate that although gold weight implantation is a static technique, it behaves as a dynamic one since it improves movement and not just position, as it would if it was purely static. To our knowledge, data on blinking velocity after eyelid rehabilitation with gold weight implant have not been reported so far and therefore constitute a new aspect to consider when planning eyelid reanimation with this technique. According to our results, this important parameter is adequately restored. In addition, eyelid excursion is also correctly addressed allowing resolution of symptoms derived from corneal exposure.

Regarding complications, the rates of extrusion, persistent lagophtalmos and pseudoptosis in our series (8.6%, 3.4% and 1.7%, respectively) are in our opinion acceptable and compare well to other reports.[1,3,18–23] Fixation of the implant to the tarsal plate and layered closure are important steps that help reduce the possibility of extrusion. Regarding implant migration, it was not present in any of the cases included, probably due to an adequate pocket dissection and correct implant fixation.

Ptosis and ectropion of the paralysed lower eyelid result from a number of factors including loss of tone of orbicularis oculi, the effect of gravity and atrophy of the eyelid's support system with decreased tissue elasticity and increased laxity.[28] Apart from the obvious unsightly appearance that this produces, eyelid malposition also causes epiphora due to eversion of the lachrymal punctum. During the preoperative evaluation, it is important to distinguish between epiphora secondary to punctal eversion and aberrant reinnervation (i.e., crocodile tears) since the latter will not be corrected with eyelid suspension. Currently, there are a number of procedures available to treat the paralysed lower lid, all of them aimed at restoring its position and reinforcing the suspension system depending on the severity of the problem.[9–14] Throughout our experience we have obtained consistently good results with tendon suspension using screw anchors, with a high rate of correction of both ectropion and epiphora and an acceptable rate of minor complications, the most frequent being under- or overcorrection needing revision surgery. Other authors have also reported good results with this procedure.[12,14,29,30] In our opinion, a dynamic technique alone or in combination with tendon suspension to reanimate the lower eyelid is unnecessary considering the fact that during eyelid closure there is little movement of the lower lid. When planning a tendon suspension for paralytic ectropion it is important to consider the patient's skin characteristics, the need for additional procedures and that overcorrection is practically the rule. The degree of overcorrection is decided upon individual characteristics, but in general

terms, men often need more overcorrection than women do. Additional procedures may include those performed on the eyelid and those performed on the midface that may affect the eyelid. The former include mainly blepharoplasty to improve the aesthetic appearance and wedge resection in cases of cutaneous excess. Not performing a wedge resection (when indicated) may result in an unsightly skin fold at the temporal margin of the eyelid. Procedures involving the midface that can affect the lower eyelid position include dynamic and static reanimation. For example, in a patient with short-term paralysis and mild ptosis, recovery of muscle tone through a nerve transposition (i.e., masseteric or hypoglossal) may also serve to restore orbicularis oculi tone enough to allow for adequate eyelid suspension and correction of ptosis. In addition, patients with fat pad dislocation secondary to orbicularis weakening may also benefit from midfacial reinnervation. Thus, in these cases it is advisable to delay lower lid surgery until reinnervation has occurred and the final aspect and position of the lid are established. Similarly, when a static midfacial suspension is planned, it is best to perform it before eyelid suspension since in some cases the former corrects eyelid ptosis as well. If the problem persists, then the eye procedure is done (in the same surgery). Complication rates of autologous tendon suspension are low and can be safely managed with minor surgery under local anaesthesia. Wound problems are infrequent and conservative treatment usually suffices. Other complications requiring tendon removal are extremely rare as was evidenced in the present series.

Conclusions

In conclusion, in light of the results presented in this work, it is fair to say that with static techniques, such as those presented here, the main goals of eye reanimation are addressed and adequately fulfilled. The gold weight implant for lagophtalmos significantly improves eyelid excursion and velocity of blinking without altering the physiological corneal reflex. Good corneal coverage is obtained allowing resolution of eye dryness and ulceration in most cases with an acceptably low rate of complications. Lower eyelid suspension with tendon grafts fully restores lid position correcting ptosis/ectropion and reversing epiphora in a considerable number of patients. Preoperative assessment of the whole paralysed face, an individualised surgical planning, meticulous surgical technique and a quantitative method of outcomes evaluation are essential to obtain the best possible result.

Ethical approval

Not required.

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Conflicts of interest

There is no conflict of interest.

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