



The Injection for the Lower Eyelid Retraction: A Mechanical Analysis of the Lifting Effect of the Hyaluronic Acid

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Abstract

Background It has been reported that the injection of the hyaluronic acid (HA) into the lower lid area could improve lower eyelid retraction. However, the published studies offered few insights into the mechanism of this treatment. When the underlying mechanism is not clear, many surgeons will not trust the method enough to apply it in their clinical practice. The purpose of this article was to propose a possible explanation for the underlying mechanism of the treatment and further verify the method by a series of cases.

Methods The authors performed a mechanical analysis on the physical impact of HA on the lower eyelid. In the

clinical cases, we injected the fillers under the orbicularis muscle to correct lower lid retraction. The results were evaluated by the standardized marginal reflex distance 2 (MRD2) immediately and 9 months later.

Results From October 2013 to October 2015, the injections were carried out in 27 cases (14 post-blepharoplasty and 13 involuntary). In 26 cases (96.3%), the retraction was completely corrected and did not recur through the last follow-up. The average improvement of the standardized MRD2 was 0.84 mm immediately after the injection and 1.19 mm 9 months later. Complications were not reported.

Conclusion Lower eyelid retraction could be treated by the injection of HA under the orbicularis muscle. The filler in this situation acted as a lifter because the filler changed the balance of force of the lower lid, forcing it to shift upward to gain the new balance. The ‘lifter’ mechanism could be applicable to other facial injections that generate elevating effects.

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Introduction

Lower eyelid retraction is usually demonstrated as scleral show and bowing in the lateral third of the eyelid. It imparts the eye a sad and angry look and is often regarded as an annoyance by the patients. Since 2007, a series of articles have reported that hyaluronic acid (HA) injection

in the lower eyelid could effectively improve lower eyelid retraction [1–7].

There are two primary injection methods for lower eyelid treatment in the published literature (Table 1). They differ in terms of injection planes. Five out of seven authors chose to inject under the orbicularis muscle and reported satisfactory results [1–4, 7]. The other two studies implemented injection under the skin [5, 6]. Both studies reported positive results but also some complications such as lumpiness and the Tyndall effect. The review showed that injection beneath the orbicularis muscle was the more popular choice and had a lower complication incidence.

Although the treatment has been reported to be effective, the published studies have offered few insights into its mechanism. There were two main explanations of the mechanism in the published articles. Goldberg et al. [3], Fezza [5] and Romero et al. [6] mentioned that the fillers expand the anterior lamella. Another interpretation was that the fillers support or push the anterior lamella up [5, 7]. Although the expander theory is straightforward and acceptable, it is not sufficient to account for the phenomenon alone, because the shortage of the tissue volume was not the only contributing factor to the lower lid retraction. In cases of senile retraction, patients who were not lacking in tissue volume were still bothered by the condition. We suppose that the support offered by the fillers played a more important role in the treatment. However, the support theory in the current literature was not concrete enough to explain the observed phenomenon.

When the underlying mechanism is not clear, many surgeons will not trust the method enough to apply it in their clinical practice.

The purpose of this article was to clarify the biophysical basis of the hyaluronic acid placed beneath the orbicularis muscle. It is beneficial to establish a more solid theoretical basis for the correction of lower lid via injection methods.

A mechanical analysis of the fillers injected in the lower eyelid was performed in our study. Based on the analysis, we further clarified the indication of the treatment and the key technical points of the injection method. The efficacy of the method was further verified by a series of clinical cases.

Mechanical Analysis of the Injection Method

The Anatomy of the Lower Eyelid

The lower eyelid consists of the anterior, middle and posterior lamellae. The skin and the underlying orbicularis muscle constitute the anterior lamella. The middle lamella refers to the orbital septum, whereas the posterior lamella is composed of the tarsus and conjunctiva [8]. The fillers were injected under the orbicularis muscle.

Hooke's Law

The stretching offered by the muscles was one of the important forces that impacted the lower eyelid, and

Table 1 The review of published studies on the lower eyelid injection

Year	Authors	Material	Num. of eyes	Diagnosis	Volume injected per eye	Injection method	Results
2016	Skippen et al.	Fat	20	Retraction	Average 3.5 ml	Deep to the ob muscle / surgical procedure combined	Lower eyelid elevation 4–6 mm
2014	Thao Phuong Le et al.	Fat	70	Retraction	0–2 cc in tear trough 3–7 cc in malar area	Deep to ob muscle	Scleral show improved by average of 0.5 mm
2013	Romero et al.	HA	12	Ectropion	1 cc	Under the skin	27.3% total correction and 72.7% partial correction; 63.7% irregular fullness
2010	Peckinpaugh et al.	HA	1	Retraction	1 cc	Deep to ob muscle and periosteal	Scleral show corrected
2008	Zamani et al.	HA	8	Retraction	0.925–0.824 ml	Deep to ob muscle	Scleral show improved by 1.08 mm
2008	Fezza et al.	HA	15	Ectropion	1 cc	Under the skin	11 corrected and 4 improved; 4 Tyndall effect and 3 filler lump
2007	Goldberg et al.	HA	65	Retraction	0.9 cc	Deep to ob muscle	Scleral show improved by 1.04 mm

Hooke's law was involved in the alteration of the stretching.

Hooke [9] stated that the force (F) needed to extend or compress a spring by some distance (x) is proportional to that distance. Later with the development of the solid mechanics, Hooke's law evolved into 'the generalized Hooke's law' [10] which was applicable to slender objects (Eq. 1).

$$F = -k(x) \cdot \Delta x \quad (1)$$

The ' k ' in the equation represented the elasticity of the spring (Fig. 1). Hooke's equation held in many situations where an elastic body was deformed. Taking our case for example, the anterior lamella was stretched by the hyaluronic acid injected beneath it (Fig. 1), which means the ' x ' in Hooke's equation was increased. The ' k ' remained the same in each particular patient. As a result, the stretching offered by the orbicularis muscle (force F in Fig. 1) was enhanced.

The Analysis of the Forces

We took a typical point on the lower eyelid, element 'A' to perform a qualitative analysis of forces. On the lateral view, before injection (Fig. 2a), 'A' maintained its position with the balance of mainly two forces, f_1 and f_2 . f_1 was the support offered by the soft tissue behind the lower eyelid pointing slightly left upward, and f_2 was the stretching offered by the orbicularis muscle pointing right downward.

After the injection of HA beneath the orbicularis muscle (Fig. 2a), because element A was above the equatorial plane of the filler, the filler offered element A a supporting force f_1' . And because the supporting force should be perpendicular to the surface of the supporter, the direction of force f_1' changed after the injection of the HA. As stated

previously in the "Hooke's Law" section, the orbicularis muscle as an elastic body was stretched by the filler, and providing the element A an enhanced f_2' , the direction of the stretching was also changed by the filler. Due to the alteration of direction and magnitude of the supporting and stretching force, element 'A' could no longer maintain the balance in the original position, and it had to shift upward to obtain a new balance of forces (Fig. 2a after injection). Comparing to merely fat or skin, if the fillers were placed under the muscle, the variation of the stretching forces caused by the fillers was greater, resulting in a greater upward displacement of element 'A.'

Patients and Methods

Patients

We carried out a retrospective review on patients who underwent lower eyelid injection of hyaluronic acid from October 2013 to October 2015. During this period, 27 patients diagnosed with lower eyelid retraction were included in the study. The etiology of the lower eyelid retraction includes both involuntary ($n = 13$) and post-blepharoplasty ($n = 14$). The exclusion criteria were lower eyelid laxity (distraction and snap test positive) (Table 2).

Injection Technique

A compound of 5% lidocaine cream was applied to the skin in the lower lid and orbitozygomatic area for 30 min before injection. We injected a total of 1–1.5 ml of Restylane Type II hyaluronic acid (HA) on each side. The injection was made in three separate points along the bone margin in the lower eyelid area. We injected 0.4–0.6 ml of HA in the

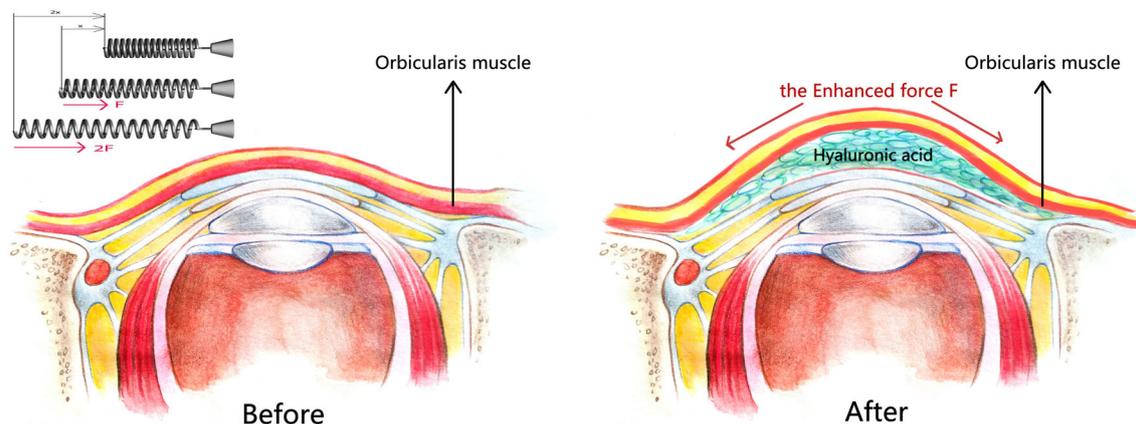


Fig. 1 The upper left figure is an example of Hooke's law in springs, and the force (F) needed to extend or compress a spring by some distance (x) is proportional to that distance. The before and after pictures demonstrate Hooke's law in the scenario of the injection

treatment. In the corneal view of the eye, it can be seen that the injected hyaluronic acid lengthened the muscle and thus enhanced force F

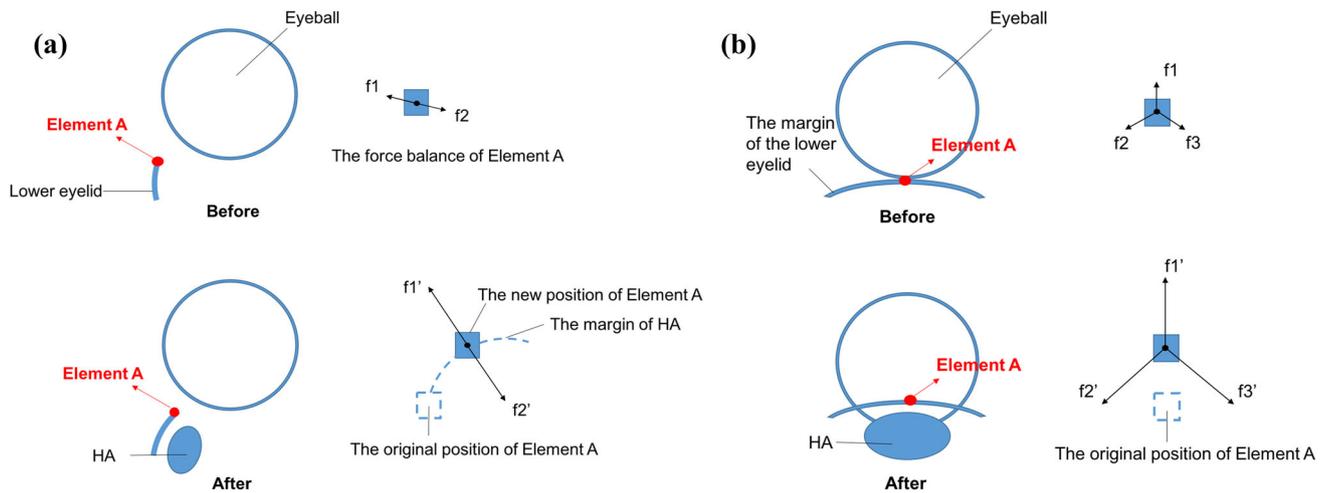


Fig. 2 The balance of forces of the element ‘A,’ a typical point of the lower eyelid, before and after the injection. **a** Lateral view: f_1 was the support offered by the tissue under the lower eyelid. f_2 was the stretching offered by the orbicularis muscle. Both forces were relatively small before injection. After injection. f_1' was the support offered by the injected hyaluronic acid. f_2' was the new stretching

provided by the orbicularis muscle after the injection. Both the direction and the magnitude of f_1' and f_2' were different from those of f_1 and f_2 before injection. **b** Frontal view: f_1 was the supporting force of the element ‘A.’ f_2 and f_3 were the stretching force of the orbicularis muscle. f_1' , f_2' and f_3' were the supporting and stretching forces after the injection

Table 2 Demographics and the treatment results of the patients

Characteristic	No (%)
No. of patients	27
Age (year)	
Mean	40.6
Range	32–54
Sex	
Female	27 (100%)
Male	0
Cause of lower eyelid retraction	
Previous blepharoplasty	14
Injection more than 12 months after the surgery	13
Injection less than 12 months after the surgery	1
Involuntary	13
Results	
Average improvement of S-MRD2 immediate after injection	0.84 mm
Average improvement of S-MRD2 after 9 months	1.19 mm
Correction of retraction after 9 months	26 (96.3%)
Previous blepharoplasty	
Injection more than 12 months after the surgery	13 (100%)
Injection less than 12 months after the surgery	0 (0%)
Involuntary	13 (100%)
Complications	
Tyndall	0 (0%)

middle point which was under the pupil, 0.4–0.6 ml in the outer point and 0.1–0.2 ml in the inner point. During the injection, the needle was inserted vertical to the skin surface to the bone surface. The HA was placed on the plane deep to the orbicularis muscle (Fig. 3). The injection

amount was individualized in each case. We usually started the injection from the lateral point, observed the position of the lower eyelid margin closely during the procedure and stopped when sufficient improvement and symmetry on both sides were attained. The injection on the inner point

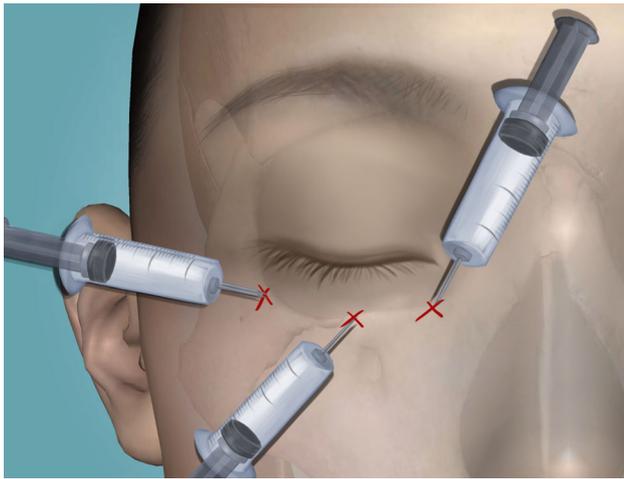


Fig. 3 Injection technique. Fillers injected in three separate points in the lower eyelid area. Needles inserted vertical to the skin to the bone surface

could be omitted if there was no obvious deficiency of soft tissue. Ice compression was applied afterward. All treatments in this study were performed by one senior surgeon (H.S.).

Evaluation Methods

All of the patients in the study were followed up for 9 months. The results were evaluated according to the standardized preoperative, postoperative and follow-up photographs.

Quantitative measurements were obtained from the photographs via Adobe Photoshop CS6 (Adobe Systems Software Ltd., USA) by two independent investigators. The measurements taken were marginal reflex distance 2(MRD2), inferior scleral show (SS) and horizontal corneal diameter (HCD). MRD2 is the vertical distance from the center of the corneal to the lower lid margin. The ratio of MRD2 or SS to the HCD was calculated and used as the primary reference in the evaluation of the treatment results. We multiplied the ratio by 11 to standardize to an arbitrary corneal diameter of 11 mm as stated in Goldberg's method [3].

Results

Among all 27 patients who underwent the treatment, 26 patients (96.3%) saw immediate correction of the lower eyelid retraction, and there was no recurrence of the retraction at the follow-up of 9 months after the treatment.

With regard to the quantitative evaluation, the average improvement of the standardized MRD2 immediately after the injection was 0.84 mm. The average improvement of

the standardized MRD2 9 months after injection was 1.19 mm (Table 2) (Fig. 4).

In our series, we observed only one case where the retraction was not effectively relieved after the treatment. The situation remains the same at the 9-month follow-up. We checked the history of the patient and noted that the injection took place 3 months after her previous lower eyelid blepharoplasty. This case will be discussed in detail in the “Discussion” section.

Discussion

It has been observed that the injection of fillers in the lower eyelid area could improve or cure the condition of lower eyelid retraction. However, a few literature reports have pointed out that the direction of elevation in those cases was different from other filling procedures. To be more specific, in the lower eyelid cases the lid margins were pushed up and the direction of elevation was parallel to the skin surface, while in other filling procedures the direction of elevation was usually vertical to the skin surface. Even fewer articles tried to explain the cause behind the phenomenon. In our article, we conducted a mechanical analysis to provide a possible explanation for the mechanism behind the treatment. The injected fillers altered the

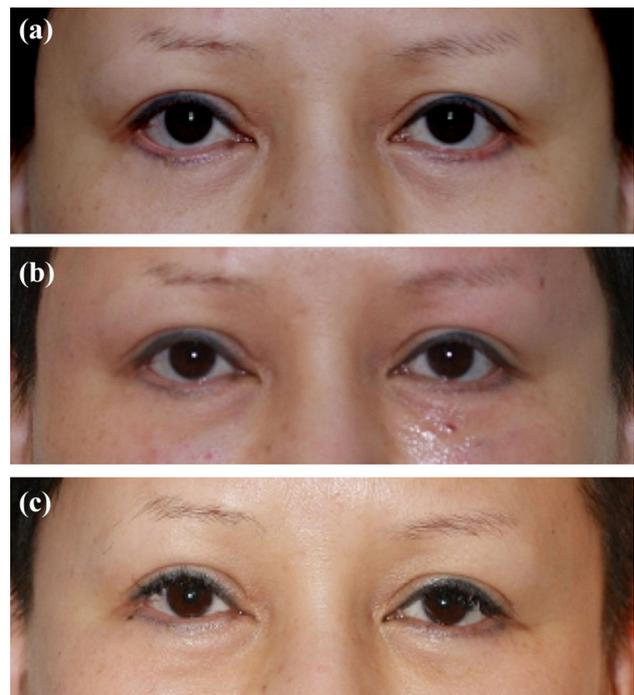


Fig. 4 A 45-year-old female, 13 months after lower blepharoplasty. **a** Lower eyelid retraction presented on both sides before injection. **b** Lower eyelid retraction corrected immediately after injection of 1 ml hyaluronic acid on each side. **c** The follow-up at 9 months after the procedure showed no recurrence of the retraction

direction and the magnitude of the supporting and stretching forces impacting the lower eyelid; as a result, the lower eyelid lost its balance of force in the original position and had to shift position to gain a new balance of force.

In our clinical review of 27 cases, the average improvement of standardized MRD2 9 months after injection was 1.19 mm. The result was consistent with previous reports in the literature [1–7], which further confirmed the effectiveness of the treatment. One interesting fact in our review was that most cases of retraction did not recur after 9 months when theoretically the hyaluronic acid should be totally absorbed. One possible explanation was that though the 6-month absorption time was indicated in the product instruction, there was some residue effect after the indicated absorption date [11, 12]. The remaining filler in the tissue was functioning as the lifter of the eyelid. Another explanation was that it was highly possible that there was some extent of shortage in soft tissue in the retraction cases, the fillers acted as an expander. Though the volume of the expander (filler) had shrunk at that point, the soft tissue in the lower lid had already been expanded.

Lower eyelid retraction is a condition caused by complex contributing factors. Though the injection of filler was effective in most cases in our study, not all retractions could be corrected by this method. To further clarify the indication of the treatment, we summarized the contributing factors of different kinds of retractions as well as the impact of fillers in Table 3.

In senile retractions, the pathophysiological reason was either the lack of tension of the orbicularis muscle or the lack of support by the middle face [13–15]. Carraway also mentioned in 1990 that the position of the lower eyelid margin was based on the balance of forces [13] (Fig. 5):

(1) the support of the tarsal and the canthus ligament (upward); (2) the support by the tension of the orbicularis muscle (upward); (3) the retracting forces of the scars between the skin and septum (downward). The injection of hyaluronic acid added to the support of the lid; hence, the retraction was improved (Fig. 6a, b). Though our case

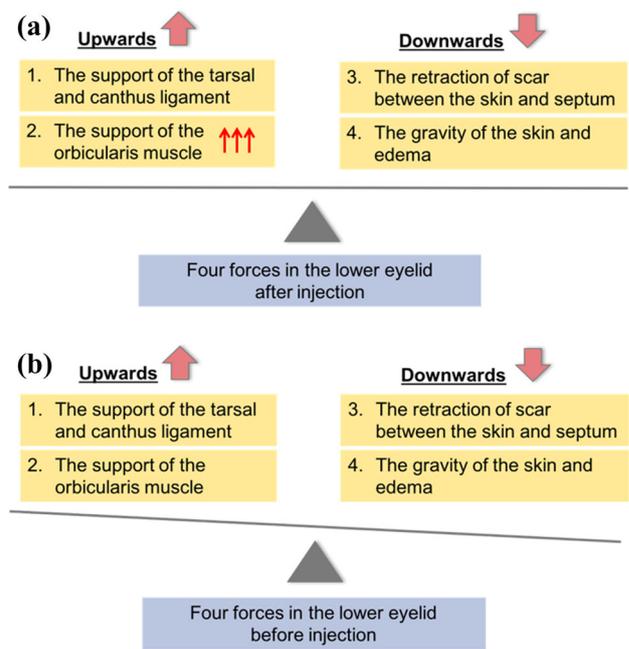


Fig. 5 The position of the lower eyelid depends on the balance of the four forces. **a** In cases of lower eyelid retraction, the downward forces are greater than the upward forces, resulting in the retraction of the lower lid. **b** After the injection of the hyaluronic acid, the supporting force provided by the orbicularis muscle was enhanced. Balance between the upward and downward forces was achieved

review and mechanism analysis showed that the injection methods worked well in cases with mild senile/congenital retraction, we still recommend caution in the application of the method in cases with severe lid laxity (distraction and snap test positive). Because according to Eq. 1, the ‘*k*’ value was too small in atonic tissue, the support added by the hyaluronic acid was too small to pull up the lid.

The postsurgical retractions were due to more complex reasons concerning all three lamellas. To elaborate, there could be shortage of skin in the first lamella, the cicatricial forces in the second and third lamella and edema in all three layers. There was one ineffective case in our case review. The injection of that case took place only 3 months after the surgery. It gave us a hint that the supporting force

Table 3 The pathogenic factors of the different kinds of lower eyelid retraction as well as the effects brought by the injection

Contributing factors		Classification of retractions		
		Senile retractions	Postsurgical retractions	Impact of the fillers
Mechanics				
Upward	Tension/support	Lack	/	Increase
Downward	Edema	/	✓	/
	Scar contracture	/	✓	/
Tissue volume	Short in soft tissue volume	/	✓	expand



Fig. 6 A 40-year-old female, lower eyelid retraction after blepharoplasty. **a** Lower eyelid retraction presented on both sides before injection. **b** The follow-up at 9 months after the procedure showed improvement

brought by the injection may not be sufficient to overcome the edema and scar contracture which was pulling inferiorly. In our review, the outcome was much better in cases in which the injection took place 12 months after the surgery. The possible reasons were that the scars that caused contracture were softened and the edema was resolved by then. When the forces pulling downward were not that strong, the support brought by the injected fillers was more likely to take effect. Besides, the fillers could also act as an expander of the first lamella to compensate for the mild shortage in the skin.

To summarize, we consider the hyaluronic acid injection as an effective treatment for both senile and postsurgical retractions when certain conditions were excluded.

- For senile/congenital retractions, snap and retraction test should be performed to eliminate cases with obvious lid laxity.
- For postsurgical retractions, the injection should be carried out at least one year post previous blepharoplasty, and the vertical traction test should be performed to eliminate cases with persisting cicatrice force.

In addition to the lower eyelid lifting, the mechanical analysis in this article could also be applied to explain the mechanism of other facial injections. Facial volumization by injection is popular in the clinical practice nowadays. One instance is the injection in the sub-aponeurotic layer in the malar area would result in the improvement of the nasolabial groove [16, 17]. We suggest that a similar analysis could shed light on the underlying mechanism. Fillers changed the supporting and stretching forces that impacted the tissue, causing the soft tissue in the middle face to shift upward to obtain a new balance of force. It

consequently led to the shallowing of the nasolabial groove.

Based on our biophysical analysis, there were two technical suggestions to obtain a lifting effect by injecting fillers. Firstly, the fillers should be placed at the lower part of the target, because the analysis showed that only to the elements above the equatorial plane the filler would shift upward. Secondly, it is possible that we could gain a better lifting effect by placing the fillers under the muscle. The reason was that the ‘*k*’ value in muscles was probably larger in muscles than that of fat and skin (Eq. 1), the same amount of stretch would yield more stretching force in muscles, and the direction of the stretching force also changed more drastically, causing more upward displacement of the target.

The most common complications in lower eyelid injections were the Tyndall effect and shifting of filler position. In our experience, the key to elimination of those complications was to avoid injecting too much filler. We recommend starting from the lateral point, observe the position of the lower eyelid margin closely during the procedure and stop when sufficient improvement is attained. The medial injection point was in fact an optional one, and if deciding to inject, the amount should be very conservative. Other safety precautions such as aspiration and the pressure on the infraorbital foramen during injection were also recommended.

In this manuscript, the explanation of the treatment effect is based on qualitative analysis, which is valid no matter which specific constitutive relationship is applied on the tissue. In some articles [18–21] published before, some medical versions of the ‘general Hooke’s physical law’ have been utilized.

The strength of the article was its application of Hooke’s law in the analysis of the mechanism of the facial/lower eyelid lifting by hyaluronic acid. We were familiar with the role of hyaluronic acid as a *filler* to hollow or sunken areas. In this article, we proposed that it also played the role of a *lifter* when placed beneath an elastic body such as the muscles. The shortcomings of the article were as follows: the patient follow-up span was short, and we did not study the injection under the skin, which according to some published articles [5, 7] was also effective. Because the skin was also a kind of elastic body, Hooke’s law was also applicable here. We did not include the under-the-skin method because injection under the skin was reported to have higher rates of complications such as the Tyndall effect [5]. Future study could include longer patient follow-up to observe the treatment effect after the hyaluronic acid was fully absorbed.

Conclusion

Lower eyelid retraction (lid laxity, scar contracture and edema excluded) could be treated by the injection of hyaluronic acid under the orbicularis muscle. The hyaluronic acid in this situation acted as a lifter because the filler changed the balance of force of the lower lid, forcing it to shift upward to gain the new balance. The ‘lifter’ mechanism was also applicable to other facial injections procedures that generate lifting effects, such as the injection in the middle face to improve the nasolabial groove.

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Compliance with Ethical Standards

Conflict of interest None of the authors has financial conflicts or interests to report in association with the contents of this paper.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent For this type of study formal consent is not required.

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