The Role of Gravity in Periorbital and Midfacial Aging

Pooja Mally, MD; Craig N. Czyz, DO; and Allan E. Wulc, MD

Abstract

Background: With respect to the pathogenesis of periorbital and midfacial aging, gravity may play a greater role than volume loss.

Objectives: The authors determined the effect of shifting from the upright to the supine position on specific attributes of facial appearance and ascertained whether facial appearance in the supine position bore any resemblance to its appearance in youth.

Methods: Participants who showed signs of midface aging were positioned in the upright and supine positions, and photographs were obtained during smiling and repose. For each photograph, examiners graded the following anatomic parameters, using a standardized scale: brow position, tear trough length and depth, steatoblepharon, cheek volume, malar bags/festoons, and nasolabial folds. Some participants provided photographs of themselves taken 10 to 15 years earlier; these were compared with the study images.

Results: Interobserver correlation was strong. When participants were transferred from upright to supine, all anatomic parameters examined became more youthful in appearance; findings were statistically significant. The grading of anatomic parameters of the earlier photographs most closely matched that of current supine photographs of the subjects smiling.

Conclusions: In the supine position, as opposed to the upright position, participants with signs of midface aging appear to have much more volume in the periorbita and midface. For the subset of participants who provided photographs obtained 10 to 15 years earlier, the appearance of facial volume was similar between those images and the current supine photographs. This suggests that volume displacement due to gravitational forces plays an integral role in the morphogenesis of midface aging.

Keywords
facial aging, midface, periorbita, soft-tissue descent, volume loss

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volume, and we believe that gravity and volume descent play a significant role in the appearance of facial aging. For patients who plan to undergo aesthetic procedures, we routinely demonstrate the anticipated results of brow, midface, and facelift surgery by placing them in the supine position and obtaining photographs. By minimizing the effects of gravity, we have noted that displaced facial volume is restored to a more youthful appearance. Our observations suggest that gravity plays a major role in the pathogenesis of facial aging, because ptotic midfacial volume is redistributed when the vertical vector descent caused by gravity is partially attenuated, as in the supine position. The apparent restoration of facial volume in the supine position implies that volume loss may not be as significant as volume descent in the pathogenesis of facial aging. This study was designed to corroborate our clinical observations in a rigorous manner.

The purpose of this study was to determine the effect of shifting from the upright to the supine position on specific attributes of facial appearance and to ascertain whether facial appearance in the supine position bore any resemblance to its appearance in youth.

METHODS

The institutional review board (IRB) of Abington Memorial Hospital (Abington, Pennsylvania) approved the study protocol before participants were enrolled. Informed consent was obtained for each participant in accordance with the IRB protocol.

Participant Selection

For this observational study, participants aged >30 years who showed signs of midface aging were recruited from female staff at Abington Memorial Hospital from March to June 2011 and the private practice of the senior author (A.E.W.). Those with a history of facial cosmetic surgery, other than rhinoplasty, were excluded. Participants (N = 61) were asked to provide at least 1 facial photograph of themselves taken 10 to 15 years earlier, in a portrait-type setting from an anteroposterior view. Photographs were excluded if any facial features were obstructed or indiscernible due to poor subjective quality.

Acquisition and Manipulation of Photographs

In the study, standardized anteroposterior views were obtained for all 61 participants while in the upright and supine positions; 52 were also photographed while smiling and in repose. Nine subjects declined to be photographed while smiling and in repose. The photographs of each participant were taken during a single session. All photographs were obtained with a Nikon D90 camera equipped with a 60-mm Macro AF micro Nikkor lens (Nikon Corp, Tokyo, Japan); aperture was f/2.8 and shutter speed was 1/60 second. All participants were photographed in an operating room with fluorescent overhead lighting. Cross-lighting was not applied to shadowing. In both positions (supine and upright), the camera was placed 1 meter from the participant’s face, and the lens was oriented in a plane parallel to the face.

The earlier (more youthful) photographs provided by participants were scanned with a Ricoh scanner (700-dot resolution; Ricoh Aficio MP C2551, Ricoh Co Ltd, Tokyo, Japan). All images were viewed on a 27-inch iMac screen (Apple, Inc, Cupertino, California). The image sequence was randomized and presented singly on a full screen to each examiner. No photograph was digitally retouched or enhanced. The earlier photographs were cropped so that only the face was visible.

Study Design

Three independent physician examiners graded each current and youthful photograph independently, in a randomized sequence. One examiner is a practicing facial plastic surgeon for over 20 years (A.E.W.), whereas the other two are in training (P.M. and additional). Examiners assigned a grade to each of the following anatomic features: brow position, tear trough length and depth, steatoblepharon, cheek volume, malar bags/festoons, and nasolabial folds. We surmised that this grading strategy would produce optimal representation of the data.

Grading Scale

Each anatomic site was scored with respect to signs of aging on a standardized Likert-type scale (0 = absent, 1 = mild, 2 = moderate, 3 = severe).

Brow Position

Grade 0 was defined as an arched brow at or above the superior orbital rim; grade 1, reduced brow arch and/or temporal drooping; grade 2, flat arch and presence of horizontal forehead and nasal creases; and grade 3, barely any arch and significant nasal and forehead creases.

Tear Trough Length and Depth

Grade 0 was defined as the absence of infraorbital hollowness; grade 1, hollowness medially and above the infraorbital rim; grade 2, hollow curve extending below the infraorbital rim and/or laterally beyond the pupil; and grade 3, completely visible infraorbital rim.

Steatoblepharon

Grade 0 denoted absence of lower eyelid steatoblepharon; grade 1, mild lower eyelid steatoblepharon; grade 2,
prominent orbital fat; and grade 3, severe fat excess in all lower eyelid fat compartments.

Cheek Volume
Grade 0 was defined as a full round cheek with the widest point of the face being at or above the zygomatic arch; grade 1, flattened cheek contour with decreased prominence at the zygomatic arch; grade 2, submalar hollowing; and grade 3, severe submalar hollowing.

Malar Bags/Festoons
Grade 0 denoted imperceptible transition from the orbit to the cheek; grade 1, defined crease; grade 2, crease accompanied by edema/puffiness; and grade 3, defined crease with pronounced edema/puffiness accompanied by changes in skin color or texture.

Nasolabial Folds
Nasolabial folds were graded on a modified Glogau scale (0 = nearly imperceptible fold, 1 = mild but defined fold, 2 = moderate fold, 3 = severe fold).

Statistical Analysis
Statistical analysis was performed with Prism 5 (GraphPad Software, Inc, La Jolla, California) and SPSS statistical software (version 20; SPSS, Inc, an IBM Company, Chicago, Illinois). Before analysis, it was determined that multiple-comparison correction was not required for the data set. Paired ordinal rating data were analyzed with the Wilcoxon test. Interobserver reliability was determined by an intraclass correlation coefficient (ICC) using a 2-way mixed model with consistency. Two-tailed testing was performed for all analyses, and statistical significance for all tests was defined as $\alpha = .05$ ($P < .05$).

After completion of grading, data for each anatomic site were compared and assessed for possible correlations between the following sets of images: current upright repose vs current supine repose, current upright repose vs current upright smiling, earlier (younger) upright smiling vs current upright smiling, and earlier upright smiling vs current supine smiling.

RESULTS
Participant Demographics
Sixty-one women were enrolled in the study; the mean (SD) age was 51 (7) years (range, 31-77 years). Fifty-nine were white, and 2 were Asian.

Data Reliability
Interobserver correlation among examiners was strong for all image subsets. The average ICCs for upright and supine position grades were 0.921 ($P = .0001$) and 0.897 ($P = .0001$), respectively. For smiling photographs, the ICCs were 0.929 ($P = .0001$) and 0.910 ($P = .0001$) for upright and supine poses, respectively. The ICC for all grades assigned to the earlier photographs was 0.958 ($P = .0001$).

Current Upright Repose vs Current Supine Repose
Mean grades for upright and supine repose photographs are summarized in Table 1.

Of the 61 participants, 59 exhibited loss of cheek volume when upright; the 2 who did not were excluded from the comparative analysis. When these 59 participants were transferred to the supine position, cheek volume appeared to be regained in all (N of grade scores: 177/177; 100%).

When in the upright position, 56 participants had steatoblepharon; the 5 who did not were excluded from the comparative analysis. Steatoblepharon improved with supine positioning in 98% of subjects (N of grade scores: 165/168).

Brow ptosis was evident in 51 participants when upright; the 10 without ptosis were excluded from the comparative analysis. With supine positioning, brows were higher.
(denoting a more youthful position) in 94% of subjects (N of grade scores: 142/151).

All 61 participants had some degree of tear trough hollowing when upright. In 89% of subjects, the length and depth of this hollowing was reduced with supine positioning (N of grade scores: 162/183).

Nasolabial folds were diminished with supine positioning in 86% of the 59 participants who exhibited them (N of grade scores: 153/177). The other 2 subjects were excluded from the comparative analysis.

Malar bags and festoons were observed in 57 participants while upright and became less prominent with supine positioning in 84% of cases (N of grade scores: 143/171). The 4 subjects who had no signs of malar bags or festoons were excluded from the comparative analysis.

Representative photographs appear in Figures 1 to 4.

**Current Upright Repose vs Current Upright Smiling**

Mean grades for upright repose and upright smiling photographs are summarized in Table 2.

Of the 52 participants photographed while smiling, 51 exhibited loss of cheek volume when upright; the other subject was excluded from the comparative analysis. Smiling appeared to increase cheek volume in 25% of subjects (N of grade scores: 38/153).

Forty-nine participants had steatoblepharon, which improved with smiling in 14% (N of grade scores: 21/147). The 3 subjects without steatoblepharon were excluded from the comparative analysis.

Of the 44 participants with brow ptosis, smiling elevated the brow to a more youthful position in 2% of cases (N of grade scores: 2/132). The 8 participants who did not show brow ptosis were excluded from the comparative analysis.

All 52 participants exhibited some degree of tear trough hollowing. The length and depth of the tear trough were reduced by smiling in 15% (N of grade scores: 23/156) but were increased by smiling in 8% (N of grade scores: 13/156).

Of the 50 participants with nasolabial folds, smiling diminished the fold in 3% (N of grade scores: 4/150) and deepened it in 9% (N of grade scores: 14/150). The 2 subjects without nasolabial folds were excluded from the comparative analysis.

**Figure 1.** Facial appearance of a 48-year-old woman while upright (A) and supine (B). In the supine position, the brow is higher, the tear trough is not as deep, the degree of steatoblepharon is diminished, cheek volume is greater, and nasolabial folds are less prominent.
Malar bags and festoons were observed in 48 participants and became less prominent with smiling in 15% (N of grade scores: 21/144). The 4 subjects without malar bags or festoons were excluded from the comparative analysis.

Representative photographs appear in Figure 5.

**Current Upright/Supine Smiling vs Younger Upright Smiling**

Twenty-five of the 61 participants provided photographs of themselves taken 10 to 15 years earlier. Thirty-six participants neglected to supply earlier photographs, were unable to locate appropriate photographs, or submitted photographs that were not eligible for inclusion in the study. All were taken while the subject was smiling and upright. These images were compared with the current upright smiling and supine smiling photographs. For each anatomic parameter, the grades assigned to the earlier photographs most closely matched those for current supine photographs taken while the participant was smiling (Figures 6-8; Table 3).

Similarly, for each anatomic parameter, clinically significant differences were observed between the earlier upright smiling photographs and the current upright smiling photographs (Table 4; Figure 9).

**DISCUSSION**

Supine positioning of study participants with signs of periorbital and midface aging appeared to restore facial volume and achieve a more youthful appearance, consistent with that of photographs taken 10 to 15 years before study commencement (Figures 6-8). In the supine position, the cheeks regained volume, the tear trough diminished, nasolabial folds became less prominent, and steatoblepharon diminished as fat appeared to settle back into the orbit (Figures 1-4); these changes were clinically and statistically significant. The cheeks and lower eyelids demonstrated the most consistent improvement (100% and 98% of participants, respectively). Malar bags showed the least consistent improvement (84% of subjects). Although our study design did not permit comparison of the degree of improvement at each anatomic site, greater improvement...
was observed in the lower lids (vs upper lids) and in the lower face (vs upper face).

Facial aging may be strongly related to gravitational changes, as evidenced by the more youthful appearance and greater facial volume achieved by supine positioning. These findings suggest that facial volume is not “lost” but rather displaced due to gravity, ligamentous laxity, and changes in skin texture.

The act of smiling forcibly elevates facial soft tissues and thus negates some of the effects of gravity. The amount of improvement is limited by the structural quality of the superficial musculoaponeurotic system, the ligamentous attachments of the tissues, and skin quality. Smiling while upright improved certain signs of midface aging in some subjects—most notably cheek volume—albeit to a much lesser extent than supine positioning (Figure 5). Because the act of smiling primarily involves muscles of the midface (e.g., zygomaticus, risorius, levator labii, orbicularis oculi), the changes that occurred with smiling were more visible in the midface than in the jawline or forehead. It has been suggested that repetitive contraction of midfacial muscles (as in facial animation) over the course of a lifetime may contribute to the descent of soft tissues.3-5

We evaluated participants while they were smiling to facilitate comparison with photographs taken many years earlier. All photographs supplied by the study subjects were taken while they were smiling, so it was not possible to compare current and past appearances in repose. Most photographs in personal archives are taken during memorable joyful events; in our experience, patients rarely retain pictures of themselves in repose. The current and previous supine photographs were compared to assess for similarities in facial appearance. For all 25 participants who provided earlier photographs, facial appearance in those images resembled their current facial appearance in the supine position.

Our findings may be reconciled with Lambros’ observations1 by accepting ligamentous attenuation as a primary component of midface aging. Initially characterized by Furnas,6,7 the facial ligaments create a structural network

Figure 3. Facial appearance of a 45-year-old woman while upright (A) and supine (B). In the supine position, cheek volume is greater and the tear trough appearance is improved.
that supports the soft tissues of the midface.\textsuperscript{5,8-13} The concept of facial ligamentous attenuation and dehiscence is not a new one.\textsuperscript{5,8-13} Histologic observations, including unpublished data based on cadaveric dissections from 2011 to present by the senior author (A.E.W.), have demonstrated that attenuation of facial ligaments occurs over time.\textsuperscript{14,15}

The visual signs of midface aging often correspond to the areas of ligamentous attachments. Hollows develop in the sites of the osseous origins of the ligaments, and the bulges beneath them represent areas of ligamentous attenuation where fat compartments have been displaced. Facial hollows and bulges are most visible in the presence of

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**Figure 4.** Facial appearance of a 57-year-old woman while upright (A) and supine (B). Even in this subject, whose face appears very gaunt (and lacking substantial volume) when upright, supine positioning restores cheek volume.

**Table 2.** Mean Grades for Current Upright Repose and Current Upright Smiling Photographs

<table>
<thead>
<tr>
<th>Anatomic Feature</th>
<th>Current Upright Photograph</th>
<th>% of Subjects With Improvement When Smiling</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Repose</td>
<td>Smiling</td>
<td></td>
</tr>
<tr>
<td>Brow position</td>
<td>1.5</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>Tear trough</td>
<td>1.9</td>
<td>1.7</td>
<td>15</td>
</tr>
<tr>
<td>Cheek volume</td>
<td>1.9</td>
<td>1.6</td>
<td>25</td>
</tr>
<tr>
<td>Steatoblepharon</td>
<td>1.6</td>
<td>1.4</td>
<td>14</td>
</tr>
<tr>
<td>Malar bags</td>
<td>1.6</td>
<td>1.5</td>
<td>15</td>
</tr>
<tr>
<td>Nasolabial folds</td>
<td>1.6</td>
<td>1.6</td>
<td>3</td>
</tr>
</tbody>
</table>
intense overhead lighting, which creates shadows that disappear as fat redistributes when switching to supine positioning. In our study, supine positioning improved signs of facial hollowing (eg, in the tear trough and cheek) and signs of inferiorly displaced soft tissues (eg, steatoblepharon, malar bags, nasolabial folds).

The findings suggest that attrition in the dermal attachments of the ligaments to skin results in gravitational descent of midface volume. The fat compartments, supported and surrounded by these ligaments, descend because the nexus of ligaments lengthens and attenuates. Whereas Lambros\(^1\) noted that the lid-cheek junction remained stable, we believe that the skin is a passive envelope held in place by orbital retaining ligaments, canthi, and connective tissue septae within the orbit.\(^{16}\) Although Lambros noted that facial nevi at the lid-cheek junction remain stable over time, we have observed, in a much less rigorous fashion, that nevi do descend over time.\(^{17}\)

**Table 3. Mean Grades for Youthful Upright Smiling and Current Supine Smiling Photographs**

<table>
<thead>
<tr>
<th>Anatomic Feature</th>
<th>Youthful Upright Smiling Photograph</th>
<th>Current Supine Smiling Photograph</th>
<th>(P) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brow position</td>
<td>0.7</td>
<td>0.6</td>
<td>0.1228</td>
</tr>
<tr>
<td>Tear trough</td>
<td>0.8</td>
<td>0.8</td>
<td>0.86</td>
</tr>
<tr>
<td>Cheek volume</td>
<td>0.7</td>
<td>0.8</td>
<td>0.6834</td>
</tr>
<tr>
<td>Steatoblepharon</td>
<td>0.5</td>
<td>0.6</td>
<td>0.16</td>
</tr>
<tr>
<td>Malar bags</td>
<td>0.6</td>
<td>0.7</td>
<td>0.6077</td>
</tr>
<tr>
<td>Nasolabial folds</td>
<td>0.7</td>
<td>0.8</td>
<td>0.53</td>
</tr>
</tbody>
</table>

**Figure 5.** Facial appearance of a 58-year-old woman smiling (A) and in repose (B). Cheek volume appears somewhat greater when the effects of gravity are partially negated (eg, by smiling). Tear trough depth also improves slightly.
Figure 6. Facial appearance of a 54-year-old woman while upright and smiling (A) and supine and smiling (B). Image C, supplied by the subject from personal archives, was taken 15 years before study commencement. In the supine position (B), the brow is elevated, tear trough depth is reduced, and cheek volume resembles that of the earlier photograph.
Figure 7. Facial appearance of a 63-year-old woman while upright and smiling (A) and supine and smiling (B). Image C, supplied by the subject from personal archives, was taken 14 years before study commencement. Although the participant’s gaze is not centered in the supine photograph (B), her appearance in the earlier photograph (C) more closely resembles the supine smiling photograph (B) than the upright smiling photograph (A).
Figure 8. Facial appearance of a 53-year-old woman while upright and smiling (A) and supine and smiling (B). Image C, supplied by the subject from personal archives, was taken 13 years before study commencement. In the supine positioning (B), the brow is elevated and the cheeks appear more youthful.
Our approach to facial rejuvenation has been amended to reflect the observations in this study. We use volume augmentation, in very small quantities, as an adjunct treatment for deep medial fat compartments, the middle fat compartment, and the suborbicularis fat compartment (typically 1-2 mL in the deep medial fat pad, 1 mL in the middle fat pad, and 0.8 mL in the tear trough). Augmentation of the periorbital and midface regions is performed with dermal fillers (hyaluronic acid based) or with fat obtained via a modified Coleman technique. We do not attempt elevation beyond that visualized with the patient in the supine position, because this duplicates the appearance of the patient at a younger age. Based on our findings, we do not augment the nasolabial fold, except for its most superior aspect (for which Pessa et al \(^{18,19}\) have shown recession of the pyriform with aging); this is done not to diminish the fold but to increase projection of the central midface. We are also developing a technique to reinforce and/or reattach attenuated ligaments during facelift surgery, to permit capture and elevation of fat compartments.

A caveat is that these findings are simply generalizations. Aging may affect one area of the face more than another and may occur unpredictably. With aging, some people experience accumulation of fat in the lower eyelids, and others lose fat in this area. Similarly, aging of the skin varies substantially and is affected by many factors, including repetitive facial expressions, skin thickness, and race. Therefore, the treatment approach should be individualized and tailored to each patient’s clinical scenario and goals.

A limitation of our study is the lack of controlled lighting. We consulted with photographers at Canfield Scientific, Inc (Fairfield, New Jersey) about obtaining balanced cross-lighting for the supine position, which would have required creating a photographic studio designed solely for the supine position. Instead, we opted to use the camera’s flash feature when photographing participants, which eliminated some of the shadows caused by ambient room lighting. It is possible that some cast-shadowing seen in the upright photographs may have exaggerated the appearance of the tear trough and nasolabial fold. However, even the areas less affected by cast-shadowing, such as the cheeks, showed improvement in the supine position. Future studies could be conducted with rigorously controlled lighting, in a studio designed specifically for supine-position photography, or with a 3-dimensional (3D) camera. In fact, we repeated this study using the VECTRA H1, a 3D camera by Canfield Scientific, Inc, and plan to publish our data in this journal. Upon preliminary review of that data, we were able to quantify many findings of the present study. Specifically, the volume of the tear trough increased approximately 0.3 mL when participants were switched from the upright to the supine position. The malar region gained approximately 1.0 mL per side. Because much shadow artifact is eliminated with the 3D camera, the tear trough and nasolabial fold (in particular) appear less exaggerated in the upright position (Figure 10).

Other limitations of the present study are the small sample size and the lack of availability of early photographs for many subjects. However, the results were significant both clinically and statistically, indicating that such findings also may be characteristic of larger study populations.

Most of the study participants were white women (59 of 61), reflecting recruitment bias of participants from

### Table 4. Mean Grades for Youthful Upright Smiling and Current Upright Smiling Photographs

<table>
<thead>
<tr>
<th>Anatomic Feature</th>
<th>Youthful Upright Smiling Photograph</th>
<th>Current Upright Smiling Photograph</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brow position</td>
<td>0.7</td>
<td>2.0</td>
<td>.0001</td>
</tr>
<tr>
<td>Tear trough</td>
<td>0.8</td>
<td>2.0</td>
<td>.0001</td>
</tr>
<tr>
<td>Cheek volume</td>
<td>0.7</td>
<td>2.0</td>
<td>.0001</td>
</tr>
<tr>
<td>Steatoblepharon</td>
<td>0.5</td>
<td>1.0</td>
<td>.0001</td>
</tr>
<tr>
<td>Malar bags</td>
<td>0.6</td>
<td>1.0</td>
<td>.0001</td>
</tr>
<tr>
<td>Nasolabial folds</td>
<td>0.7</td>
<td>2.0</td>
<td>.0001</td>
</tr>
</tbody>
</table>

Figure 9. Mean grades for earlier (younger) and current supine smiling and upright smiling photographs. For all anatomic features, the facial grades for earlier photographs more closely resembled those for current supine smiling photographs (vs current upright smiling photographs), suggesting that the supine position reflects a more youthful appearance.
the private practice of the senior author (A.E.W.) and the staff at the hospital where he operates. Despite this, the data are relevant because the majority of cosmetic procedures in the United States are performed on women (91% in 2012) and whites (70% in 2012).20 (Of those who received soft-tissue fillers in 2012, 95% were women and 76.3% were white.20) However, including men and people of diverse ethnicities in future studies would provide valuable insight on the similarities and/or differences in facial aging between sexes and among racial groups.

Furthermore, our participants were not stratified by age, but most were between 45 and 65 years of age. It is possible that volume loss and volume descent occur at different stages of the aging process. Therefore, widening the age range may yield additional pertinent information about the process of midface aging.

Finally, our intentionally simplified grading scale could be regarded as a potential weakness. However, our scale was appropriate for gross characterization of various parameters related to midface aging, and interobserver correlation was strong for all parameters.

Figure 10. Photographs of a 63-year-old woman obtained while upright (A) and supine (B) with the VECTRA H1 3D camera (Canfield Scientific, Inc, Fairfield, New Jersey). In the supine position, tear trough depth is reduced, the cheek appears rounder, and nasolabial folds and marionette lines are softer. A comparison of the accompanying upright (C) and supine (D) 3D grayscale facial casts also demonstrates these shifts in volume.
CONCLUSIONS

Supine positioning can restore the appearance of volume in the periorbital and midface regions in persons with signs of midface aging. It can elevate the brow, diminish the tear trough, and soften the nasolabial folds, resulting in a much more youthful appearance. Our findings suggest that volume displacement (due to gravitational forces), rather than volume loss alone, plays an integral role in the morphogenesis of midface aging. Therefore, volumetric elevation procedures such as brow and midface lifts will remain seminal procedures for rejuvenating the aging midface and periorbital region.

Disclosures

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