Research Article ISSN 2690-537X

Dermatology Research

Influence of Lighting Direction on the Visualization of Facial Volume Deficits: Frontal Flash versus Zenithal Continuous Lighting

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Received: 18 Sep 2026; **Accepted:** 27 Oct 2026; **Published:** 06 Nov 2026

Citation: Jorge Alberto Espinosa-Reyes, Boris Henriquez, Juan Carlos Ochoa Alvarez, et al. Influence of Lighting Direction on the Visualization of Facial Volume Deficits: Frontal Flash versus Zenithal Continuous Lighting. Dermatol Res. 2026; 8(2): 1-10.

ABSTRACT

Background: *Accurate identification of facial volume deficits is essential for the precise placement of injectables. Standard frontal photography may inadequately capture subtle contour irregularities that depend on surface shadowing. The direction of lighting influences how shadows reveal underlying volume loss, yet its impact on the visualization of deficits has not been systematically compared.*

Objectives: *This study aims to compare the efficacy of frontal flash lighting and zenithal (overhead) continuous lighting in visualizing and detecting facial volume deficits in standardized clinical photographs.*

Methods: *Standardized photographs were obtained from 21 participants (16 females, 5 males; mean age 59.5 years, SD ±8.8) under two lighting conditions standard frontal flash and zenithal continuous illumination while maintaining all other acquisition parameters constant. An evaluator independently assessed each image, grading the severity of volume deficits across nine facial regions on a 4-point ordinal scale (0–3) and recording the presence or absence of a deficit in each region. The primary outcome was the per-region detection of facial volume deficits, compared between lighting conditions using the exact McNemar test; the aggregate global deficit score (sum of nine regions, range 0–27) was compared using the paired t-test with Cohen's d as the effect size.*

Results: *Zenithal continuous lighting significantly enhanced the visualization of facial volume deficits compared to frontal flash. The mean global deficit score was higher under zenithal lighting (10.29 ± 4.56) than under frontal flash (6.81 ± 4.74), with a mean paired increase of 3.48 points (95% CI 2.28–4.68; paired t-test $p < 0.001$; Cohen's $d = 1.24$), with a higher score in 18 of 21 subjects (85.7%). The pooled per-region detection rate increased from 43.9% under frontal flash to 62.4% under zenithal lighting, achieving statistical significance in the temporal ($p = 0.016$), infraorbital ($p = 0.008$), and marionette ($p = 0.039$) regions, all favoring zenithal illumination. Zenithal lighting also increased the number of deficits identified (5.62 vs 3.95; $p < 0.001$) and evaluator diagnostic confidence (6.95 vs 5.29; $p < 0.001$) while reducing assessment time (37.4 vs 45.1 s; $p < 0.001$). The effect remained significant after adjustment for age, sex, and body mass index.*

Conclusions: *Lighting direction significantly affects the visualization of facial volume deficits. Theat could function as an effective, low cost adjunct to enhance the identification of these deficits and guide the placement of injectables.*

Level of Evidence: *This study constitutes a prospective, single arm diagnostic comparison in which each subject served as their own control (paired, within subject design), without a comparison group, randomization, or an independent reference standard. Under the levels-of-evidence framework for risk/prognostic and diagnostic studies used in facial plastic and aesthetic surgery, this corresponds to Level IV evidence.*

Key Points

Question: Does the orientation of photographic lighting, specifically, frontal flash compared to zenithal (overhead) continuous illumination affect the visualization and detection of facial volume deficits in standardized clinical photographs?

Findings: In this comparative imaging study involving standardized photographs of 21 subjects, the use of zenithal continuous lighting and frontal flash significantly improved the visibility of facial volume deficits compared to the alternative condition. This enhancement was achieved by accentuating surface shadows that correspond to areas of actual volume loss.

Meaning: Adjusting the direction of photographic lighting, along with the combination of zenithal continuous lighting and frontal flash, can improve the clinical identification of facial volume deficits. This modification offers injectors a straightforward and cost-effective method to guide more precise filler placement.

Keywords

Facial volume deficits, Lighting direction, Zenithal illumination, Standardized photography, Dermal fillers, Aesthetic medicine.

Introduction

Physicians specializing in facial practice must have a comprehensive understanding of photographic principles [1,2]. Facial photography transcends mere documentation; it serves as a crucial clinical instrument for facial analysis, surgical planning, outcome evaluation, and the standardized comparison of preoperative and postoperative results. Precise photographic acquisition allows for the objective assessment of both surgical and nonsurgical interventions and enhances effective communication within the scientific community [1,3].

Although established standards for medical photography are present in several domains of plastic surgery, such as hand surgery, body contouring, and cosmetic procedures [4-6], there is a notable absence of comprehensive literature regarding standardized photographic protocols for patients with scars or those evaluated prior to facial filler treatments [7,8].

In certain cultures, there exists a belief that photography has the potential to capture an individual's soul. This notion aligns with the perspective that the essence of a great portrait lies in its ability to capture the subject's soul [9]. A commonality among individuals who hold this belief is their shared understanding of the profound impact of photography on personal identity [10].

Understanding the significance of photography in contemporary facial analysis and surgical practice necessitates an examination of its historical roots in medicine. The foundational principles of medical photography are largely attributed to the pioneering efforts of the French neurologist Guillaume Benjamin Amand Duchenne de Boulogne [3]. In the mid-nineteenth century, at the Salpêtrière Hospital in Paris, France, Duchenne systematically utilized photography to document his clinical observations.



Figure 1: Frontal portraits by Martin Schoeller illustrate a highly standardized approach to facial positioning and expression. These images, while showcasing meticulous photographic technique and controlled studio lighting, also reveal a limitation inherent in direct frontal illumination: the diminished presence of shadows, which are crucial for perceiving facial volume, contour definition, and surface irregularities. In the fields of facial plastic surgery and aesthetic medicine, lighting strategies are thus developed not only to standardize image acquisition but also to enhance the visualization of facial anatomy, asymmetries, scars, and treatment outcomes. The images are sourced from the official website of Martin Schoeller.

These studies culminated in his seminal work, "Mécanisme de la Physionomie Humaine" (The Mechanism of Human Physiognomy), where he explored facial expressions through the localized electrical stimulation of facial muscles. By selectively activating specific muscle groups, Duchenne aimed to elucidate the anatomical basis of human emotions and their external manifestations. His research established one of the earliest links between photography, facial anatomy, and the scientific study of expression [3]. Duchenne highlighted the face's role as a mirror of human emotion, encapsulated in his frequently cited observation: “Facial expression preserves the essence of the soul”. Although articulated in philosophical terms, this concept remains pertinent in modern facial plastic surgery, where photographic documentation is employed not only to record anatomical features but also to capture the unique characteristics that define individual facial identity [10] Figure 1.

Patients and Methods

Study Design and Ethical Considerations

This prospective comparative imaging study was designed to assess the impact of lighting direction on the visualization of facial volume deficits.

The study protocol received approval from the Instituto Nacional de Oftalmología y Cirugía Plástica and Ethics Committee, and all procedures adhered to the principles outlined in the Declaration of Helsinki. Prior to enrollment, written informed consent was obtained from all participants, which included explicit consent for the acquisition, analysis, and publication of standardized photographs for research purposes.

Each subject was photographed under both lighting conditions, resulting in fully paired observations; consequently, all analyses employed within-subject (paired) methods. Continuous variables are presented as mean ± standard deviation (SD) with 95% confidence intervals (CI) and as median with interquartile range (IQR). Categorical variables are described using frequencies and percentages. Distributional normality was evaluated using the Shapiro–Wilk test, the Kolmogorov–Smirnov test, and visual inspection of histograms and Q–Q plots. The global facial volume-deficit score (sum of nine regional severity scores, range 0–27) was compared between lighting conditions using the paired-samples t-test, with the Wilcoxon signed-rank test serving as a non-parametric confirmation; the standardized effect size is reported as Cohen's d for paired data. Regional severity scores (ordinal, 0–3) were analyzed with the Wilcoxon signed-rank test, with the matched-pairs rank-biserial correlation (r) as the effect size. The primary detection outcome per-region binary detection (deficit present vs. absent) under each lighting condition—was assessed using the exact McNemar test for paired proportions. The independent effect of lighting was estimated using a linear mixed-effects model (global score as outcome; lighting, age, sex, and BMI as fixed effects; a random intercept per subject). Subgroup comparisons were conducted using the Mann Whitney U and Kruskal–Wallis tests. All p-values are two-tailed and reported to three decimal places; $\alpha = 0.05$. Reporting adheres to EQUATOR/STROBE recommendations for observational research.

Legal Considerations and Technical Requirements In Facial Medical Photography

What Camera Do I Need?

Before addressing the optimal camera system for facial plastic surgery, it is essential to comprehend several fundamental principles of photography that directly affect image quality and standardization. High-quality medical photographs rely not only on the camera itself but also on the interaction between the equipment, the environment, and the photographer [11,12]. Three major components should be considered:

Camera Related Factors

a. The camera sensor is a crucial yet often overlooked component of photographic equipment, particularly among healthcare professionals. Analogous to the human eye, the sensor functions similarly to the retina by capturing incoming light and converting it into an image. Sensor size and quality significantly influence image sharpness, dynamic range, color reproduction, and depth perception. Consequently, the sensor often distinguishes between an acceptable clinical photograph and an exceptional one. Larger sensors, such as those found in DSLR and mirrorless cameras, generally provide superior image quality compared to smartphone sensors.

b. Lens The lens is critical in determining facial proportions and minimizing distortion. Although modern smartphones incorporate increasingly sophisticated lenses, many utilize wide-angle optics that may exaggerate facial features when photographs are taken at close distances. To achieve standardized facial photographs, an adequate camera-to-subject distance should be maintained, and longer focal lengths should be preferred whenever possible. Proper lens selection helps preserve anatomical proportions and enhances the reproducibility of preoperative and postoperative comparisons. Figure 2

c. Megapixels Megapixel count is often misunderstood as the primary determinant of image quality. In reality, image quality depends on multiple factors, including sensor size, lens quality, lighting conditions, and image processing. For instance, Full HD resolution (1920 × 1080 pixels) corresponds to approximately 2 megapixels, whereas 4K resolution (3840 × 2160 pixels) corresponds to approximately 8 megapixels. For routine clinical documentation, modern smartphones and digital cameras generally provide sufficient resolution. Higher megapixel counts become more relevant when large-format printing, extensive cropping, or detailed image analysis is required. Therefore, more megapixels do not necessarily translate into better photographs; the optimal resolution depends on the intended clinical application. Figure 2.

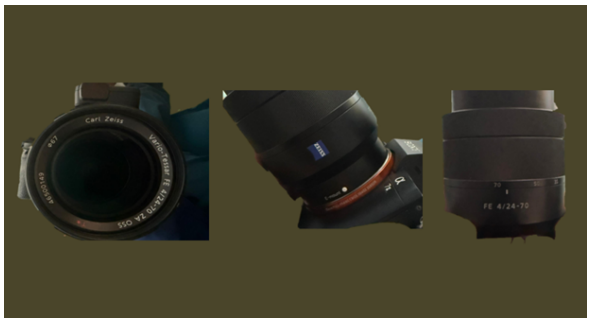


Figure 2: Camera lens utilized for standardized clinical facial photography. Appropriate focal length selection is essential to minimize perspective distortion, preserve true anatomical facial proportions, and ensure reproducible image acquisition for objective preoperative and postoperative comparison.

Environmental Factors

a. Lighting: Lighting is arguably the most important environmental variable in facial photography. Proper illumination reveals surface anatomy, facial contours, skin texture, and asymmetries. A carefully positioned secondary light source behind or lateral to the subject can generate contour illumination, enhancing the perception of facial volume and three-dimensionality. Appropriate lighting allows the observer to appreciate subtle anatomical details that may otherwise be lost in flat illumination.

b. Avoidance of Direct Flash In standardized facial photography, the use of direct on camera flash is typically discouraged. This type of frontal flash illumination tends to eliminate shadows, flatten facial contours, and obscure subtle anatomical landmarks. Instead, illumination should be achieved through diffused light sources, bounced flash techniques, or LED panels positioned approximately 45°–60° from the subject. This approach facilitates the formation of natural shadows and enhances the visualization of facial topography. Additionally, overhead (zenithal) lighting can provide different information that aids in the analysis and treatment of the patient's facial volume. Figure 3.



Figure 3: Representative studio flash unit used for standardized facial photography. Off camera diffused lighting with controlled flash power ensures reproducible illumination, facilitates the assessment of facial contours and skin texture, and minimizes shadow loss associated with direct frontal flash.

Photographer Related Factors

The photographer constitutes the final and often most critical component of the imaging process. Standardization of patient positioning, head orientation, camera distance, focal length, and framing is essential for obtaining reproducible photographs [5,13,14]. Whenever feasible, photographers should maintain a greater working distance and employ optical zoom or longer focal lengths rather than moving physically closer to the subject. This strategy minimizes perspective distortion and yields images that more accurately represent facial anatomy.

Photographic Equipment

All photographs were captured using a Sony Alpha 7 II mirrorless digital camera, equipped with a Sony FE Carl Zeiss Vario-Tessar T* 24–70 mm f/4 ZA OSS telephoto E-mount lens. The camera-to-subject distance was standardized at 150 cm, facilitating a 1:1 life-size portrait frame. The camera was operated in manual mode, and no image processing, retouching, or editing software was applied; all images were evaluated in their native format. Figure 2

Lighting Configurations

Two lighting conditions were compared, with all other acquisition parameters held constant to ensure that lighting direction was the sole experimental variable.

1. **Standard Frontal Flash Setup:** Two Godox SK400II strobe flashes, each fitted with a 60 × 90 cm softbox (Star Company), were positioned symmetrically at a 45-degree angle on either side of the camera, 100 cm from the subject and 1.5 m from the ground. Flash intensity was set at ¼ + 0.3, and exposure was manually calibrated to maintain consistency across sessions (Figure 3).
2. **Overhead Continuous LED Lighting:** A continuous overhead lighting setup was constructed using two Neewer NL660 bi-color LED panels mounted directly above the subject's head at a specified angle and height. Optimal illumination was achieved by blending color temperatures with a dimmer: 3,200 K at ⅗ intensity and 5,600 K at ⅘ intensity. No additional reflectors or fill lights were used.

Camara Settings

The camera was operated in manual mode, with settings calibrated independently for each lighting configuration.

- Overhead continuous LED lighting:
- ISO: 400 - Aperture: f/4 - Shutter speed: 1/80 sec
- Exposure compensation: 0
- Background positioned 150 cm from the subject
- Frontal flash:- ISO: 200 - Aperture: f/18 - Shutter speed: 1/125 sec
- Exposure compensation: 0
- Flash output: ¼ + 0.3
- Two flashes positioned at 45 degrees from the subject, 1.5 m from the ground (Godox SK400II)
- Background positioned 150 cm from the subject

These settings were consistently applied across all subjects and sessions within each configuration.



Figure 3: Representative studio flash unit used for standardized facial photography. Off camera diffused lighting with controlled flash power ensures reproducible illumination, facilitates the assessment of facial contours and skin texture, and minimizes shadow loss associated with direct frontal flash.

Subject Positioning and Framing

Subjects were seated 150 cm from the background to minimize shadow casting. The Frankfort horizontal plane served as the reference for head positioning. Participants were instructed to maintain a neutral facial expression and natural head posture. Frontal, lateral, and basal views were captured to facilitate scale-based measurements during analysis.

Image Selection and Analysis

Despite capturing multiple views, the frontal view was identified as the most diagnostically informative for comparing anatomical details between lighting techniques and was thus selected as the primary image for analysis. A specified number of independent evaluators, blinded to the lighting condition and to each other's assessments, reviewed the images in a randomized order to identify the presence, location, and severity of volume deficits using a standardized grading scale or anatomical mapping template.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. As each subject was imaged under both lighting conditions, differences in deficit detection were assessed using the paired t-test, Wilcoxon signed-rank test, or McNemar's test, as appropriate to the data type and distribution. Inter- and intra-rater reliability were evaluated using Cohen's kappa and the intraclass correlation coefficient (ICC). A p-value < 0.05 was considered statistically significant. All analyses were conducted using statistical software, version, manufacturer.

Outcomes

Between March and May 2024, 21 subjects were enrolled and photographed under both lighting conditions by the senior author. All participants satisfied the inclusion criteria and were photographed without makeup, jewelry, or eyewear, ensuring that the entire face and neck were fully visible within the camera viewfinder. The mean age of the study population was 59.5 years (SD ±8.8; range 40–69), with a predominance of female participants (16 out of 21, 76.2%). According to the Fitzpatrick skin type classification, type IV was most prevalent (n = 9), followed closely by type III (n = 8). Types II (n = 2), I (n = 1), and V (n = 1) were less common. The cohort was ethnically diverse, consisting of Mestizo (47.6%), White (38.1%), and Indigenous (14.3%) participants, with a mean body mass index of 24.4 kg/m² (SD ±3.0). Table 1.

Table 1: Baseline Characteristics of the Study Cohort (N = 21).

Characteristic	Value	
Age, years — mean ± SD	59.5 ± 8.8	95% CI 55.7–63.3
Age — median (IQR); range	62 (55–65)	40–69
Sex — n (%)		
Female	16 (76.2%)	
Male	5 (23.8%)	
BMI, kg/m² — mean ± SD	24.4 ± 3.0	range 19.5–30.9
Ethnicity — n (%)		
Mestizo	10 (47.6%)	
White	8 (38.1%)	
Indigenous	3 (14.3%)	
Fitzpatrick phototype — n		
I / II / III	1 / 2 / 8	
IV / V	9 / 1	
Relevant history — n (%)		
Prior facial surgery	5 (23.8%)	
Prior facial fillers	13 (61.9%)	
Prior fat grafting	2 (9.5%)	

SD: Standard Deviation; CI: Confidence Interval; IQR: Interquartile range; BMI: Body Mass Index.

The analysis of standardized photographs demonstrated that the direction of lighting significantly influenced the visualization of facial volume deficits. The global facial volume deficit score, which aggregates nine regional severity ratings (range 0–27), was normally distributed under both lighting conditions and for the paired difference (Shapiro–Wilk p = 0.395, 0.078, and 0.083, respectively), allowing for parametric inference. Under zenithal continuous lighting, the mean global score was 10.29 (SD ±4.56), compared to 6.81 (SD ±4.74) under standard frontal flash, indicating a mean paired increase of 3.48 points (95% CI 2.28–4.68). This difference was highly significant (paired t-test $t(20) = 5.681$, $p < 0.001$) and of large magnitude (Cohen's d = 1.24). Notably, the deficit score was higher under zenithal illumination in 18 of 21 subjects (85.7%), and lower in none, highlighting the consistency of the effect across the cohort. Table 2 When deficits were evaluated dichotomously (present versus absent) across all nine facial regions, the pooled detection rate increased from 43.9% (83/189) under frontal flash to 62.4% (118/189) under zenithal lighting. In paired analysis, three regions reached statistical significance, all favoring zenithal illumination: the temporal region (7 deficits detected under zenithal but missed under flash versus none in the reverse direction; exact McNemar p = 0.016), the infraorbital region (8 versus 0; p = 0.008), and the marionette region (8 versus 1; p = 0.039). Importantly, in no region did frontal

flash detect significantly more deficits than zenithal lighting; the upper-cheek, midface, tear-trough, prejowl, and mandibular regions all trended toward greater detection under zenithal illumination without reaching significance, and the nasolabial region was equivalent between modalities. Table 3. These detection patterns were mirrored in severity grading. Wilcoxon signed rank testing showed that zenithal lighting significantly increased the rated severity of the temporal ($p = 0.010$; $r = 0.57$) and infraorbital ($p = 0.007$; $r = 0.58$) regions, with a borderline effect in the tear-trough ($p = 0.064$) and marionette ($p = 0.065$) regions. The midface and mandibular regions, already well visualized under flash, showed no appreciable change. This anatomical pattern aligns with the underlying optical principle: regions whose appearance depends on subtle topographic shadowing benefited most from directional overhead light, whereas regions conspicuous under flat frontal illumination did not. Beyond detection, zenithal lighting improved the efficiency and confidence of evaluation. The number of distinct deficits identified per subject increased from a mean of 3.95 (SD ±2.56) under flash to 5.62 (SD ±2.36) under zenithal lighting ($p < 0.001$; $d = 1.44$), while the time required to complete each assessment decreased from 45.1 to 37.4 seconds ($p < 0.001$; $d = −1.08$). Diagnostic confidence, rated on a 10-point scale, rose from 5.29 (SD ±1.10) to 6.95 (SD ±1.02) ($p < 0.001$; $d = 1.09$). Overall subjective image quality was marginally higher under zenithal lighting (7.52 versus 7.14) but did not differ significantly ($p = 0.148$), indicating that the diagnostic gains were not attributable to a generalized improvement in image quality (Table 4).

Regional severity scores

At the regional level, zenithal lighting significantly increased detected severity in the temporal, infraorbital, and (borderline) tear-trough and marionette regions, while midface and mandibular regions—where flash already performed adequately—showed no significant change:

Region	FF median (IQR)	Zen median (IQR)	W	p	r
Temporal hollowing	0 (0–1)	2 (1–3)	12.0	**0.010**	0.57
Upper-cheek deficiency	1 (0–2)	1 (0–2)	28.5	0.392	0.19
Midface volume loss	1 (0–2)	1 (0–2)	21.0	0.855	0.04
Infraorbital hollowing	0 (0–1)	2 (0–2)	11.0	**0.007**	0.58
Tear trough	0 (0–1)	1 (0–2)	16.0	0.064	0.40
Prejowl sulcus	0 (0–1)	1 (0–2)	6.0	0.161	0.31
Mandibular definition loss	0 (0–1)	0 (0–1)	15.5	0.720	0.08
Nasolabial fold	0 (0–1)	0 (0–1)	7.5	0.516	0.14
Marionette line	0 (0–1)	1 (0–2)	16.0	0.065	0.40

FF: Frontal Flash; Zen: Zenithal; W: Wilcoxon signed-rank statistic; r, matched-pairs rank-biserial effect size. Bold = $p < 0.05$.

Per-region detection — primary categorical outcome (exact McNemar)

Across the nine regions, zenithal lighting never detected fewer deficits than flash in any discordant pair favouring flash by more than one case. Pooled across all regions, the deficit-detection rate rose from 43.9% (83/189) under frontal flash to 62.4% (118/189) under zenithal lighting. Three regions reached statistical significance:

Region	Both	Flash only	Zen only	Neither	p (exact)	Favours
Temporal	10	0	7	4	**0.016**	Zenithal
Upper-cheek	14	0	1	6	1.000	Zenithal
Midface	12	0	2	7	0.500	Zenithal
Infraorbital	7	0	8	6	**0.008**	Zenithal
Tear trough	6	1	6	8	0.125	Zenithal
Prejowl	10	0	4	7	0.125	Zenithal
Mandibular	7	0	1	13	1.000	Zenithal
Nasolabial	8	1	1	11	1.000	Tie
Marionette	6	1	8	6	**0.039**	Zenithal

Cells show paired concordant/discordant counts. “Zen only” = regions detected under zenithal but missed under flash. Bold = $p < 0.05$ (exact McNemar).

Secondary evaluator outcomes

Zenithal lighting also improved the efficiency and confidence of assessment. Evaluators identified more distinct deficits, reached their assessment faster, and reported higher diagnostic confidence; overall subjective image quality did not differ significantly.

Outcome	Frontal flash	Zenithal	Δ (Zen–FF)	p
Deficits identified, n	3.95 ± 2.56	5.62 ± 2.36	+1.67	**<0.001**
Evaluation time, s	45.1 ± 6.5	37.4 ± 5.7	−7.76	**<0.001**
Diagnostic confidence (1–10)	5.29 ± 1.10	6.95 ± 1.02	+1.67	**<0.001**
Image quality (1–10)	7.14 ± 1.11	7.52 ± 0.60	+0.38	0.148

Values are mean ± SD. p from paired t-test (Wilcoxon confirmatory, concordant throughout). Cohen's d: deficits 1.44, time −1.08, confidence 1.09 (all large).

In a multivariable analysis employing a linear mixed-effects model with a random intercept for each subject, lighting direction emerged as the sole independent predictor of the deficit score (zenithal effect +3.48 points, 95% CI 2.28–4.68, $p < 0.001$) after adjusting for age, sex, and body mass index. None of these demographic covariates showed a significant association with the score (all $p > 0.40$), confirming that the observed effect was attributable to illumination rather than patient characteristics. Subgroup analyses similarly demonstrated no significant modification of the lighting effect by sex ($p = 0.382$), age group ($p = 0.720$), or ethnicity ($p = 0.228$), indicating a robust and broadly generalizable phenomenon within the studied population. Collectively, these findings suggest that zenithal continuous illumination significantly enhances the detection and grading of facial volume deficits compared to conventional frontal flash photography, with the effect concentrated in shadow-dependent contour regions and accompanied by faster, more confident evaluations. The consistency of the effect across subjects, its independence from demographic factors, and its anatomical coherence collectively endorse directional overhead lighting as a straightforward, reproducible adjunct for the photographic assessment of facial volume, and by extension, for guiding the targeted placement of injectable agents.

Statistical Analysis

All statistical analyses were performed using [IBM SPSS Statistics, version XX (IBM Corp., Armonk, NY) / R version 4.x]. Because each subject was photographed under both lighting conditions, all comparisons employed within-subject (paired) methods. Continuous variables are presented as mean ± standard deviation (SD) with 95% confidence intervals (CI), and as median with interquartile range (IQR) where appropriate; categorical variables are presented as frequencies and percentages. The distributional normality of continuous variables was assessed using the Shapiro Wilk test, the Kolmogorov Smirnov test, and visual inspection of histograms and Q Q plots.

The global facial volume-deficit score (the sum of nine regional severity scores, range 0–27) was compared between lighting conditions using the paired-samples t-test, with the Wilcoxon signed-rank test applied as a non-parametric confirmation; the standardized effect size was expressed as Cohen's d for paired data. Regional severity scores (ordinal, 0–3) were compared using the Wilcoxon signed-rank test, with the matched-pairs rank-biserial correlation (r) reported as the effect size. The primary outcome per-region binary detection of a volume deficit (present vs absent) under each lighting condition was compared using the exact McNemar test for paired proportions. Secondary evaluator outcomes (number of deficits identified, evaluation time, diagnostic confidence, and image quality) were compared using the paired t-test with Wilcoxon confirmation.

To determine whether lighting direction influenced the deficit score independently of patient characteristics, a linear mixed-effects model was constructed with the global score as the dependent variable; lighting condition, age, sex, and body mass index as fixed effects; and a random intercept for each subject. Subgroup effects were explored using the Mann–Whitney U test (sex, age group) and the Kruskal–Wallis test (ethnicity). All tests were two tailed, with statistical significance set at $\alpha = 0.05$, and p-values are reported to three decimal places. Reporting followed the applicable EQUATOR/STROBE recommendations for observational research.

Discussion

High-fidelity photographic documentation is essential for facial analysis, treatment planning, and outcome assessment in facial plastic surgery and aesthetic medicine. This study demonstrates that a single, easily controlled variable, the direction of illuminating light—significantly alters the visualization of facial volume deficits in standardized clinical photographs. Zenithal continuous illumination increased the global volume-deficit score by an average of 3.48 points compared to conventional frontal flash ($p < 0.001$), an effect of large magnitude (Cohen's $d = 1.24$) that was consistent in 18 of 21 subjects and independent of age, sex, and body mass index. These findings suggest that the lighting geometry routinely used for "documentary" facial photography may systematically under-represent the contour deficits that injectable treatments aim to correct. The mechanism underlying this effect is based on a fundamental principle of topographic photography. Volume deficits such as temporal hollowing, infraorbital and tear trough depressions, prejowl and marionette concavities are fundamentally three-dimensional surface depressions whose perceptibility depends on the interplay of light and shadow (Figures 4, 5,6). Frontal flash, particularly when delivered through paired softboxes positioned near the optical axis, produces flat, near-shadowless illumination that fills these depressions with light and flattens the perceived surface relief (Figure 7). In contrast, zenithal (overhead) light strikes the face at an oblique angle from above, casting directional shadows into concavities and thereby accentuating the contour transitions that signal volume loss. This "raking light" effect, long exploited in topographic and forensic photography to reveal subtle surface detail, is applied here to the aesthetic assessment of the face. The anatomical distribution of the effect supports this interpretation and lends the findings internal coherence. The regions that showed the most significant changes—temporal, infraorbital, and marionette—are precisely those whose appearance is governed by shadow-dependent contour transitions, and these were the three regions reaching statistical significance on both detection (exact McNemar $p = 0.016$, 0.008, and 0.039, respectively) and severity grading. Conversely, regions already conspicuous under flat illumination, such as the midface and the mandibular border, exhibited negligible change. The fact that zenithal lighting never detected meaningfully fewer deficits than flash in any region, while detecting substantially more in shadow-dependent zones, suggests that the additional findings reflect genuine surface topography rendered visible rather than random noise. An essential interpretive caveat must be stated clearly. A higher deficit score under zenithal lighting indicates increased detection, but in the absence of an independent reference standard for true volume loss, increased detection cannot be formally distinguished from possible over-detection—that is, the accentuation of shadows that do not correspond to clinically meaningful deficits. The anatomical coherence of the results, the directionality of every discordant comparison toward zenithal lighting, and the accompanying gains in evaluator confidence all support the interpretation of true enhanced sensitivity. Nevertheless, definitive confirmation will require comparison against an objective ground truth, such as three-dimensional surface imaging or soft-tissue ultrasonography [3,15], a point to which we return below.

Zenithal illumination significantly enhanced the evaluation process beyond mere detection. Evaluators identified a greater number of discrete deficits per subject (5.62 compared to 3.95; $p < 0.001$), completed their assessments more rapidly (37.4 versus 45.1 seconds; $p < 0.001$), and reported increased diagnostic confidence (6.95 versus 5.29 on a 10-point scale; $p < 0.001$). Importantly, the overall subjective image quality did not differ significantly between conditions ($p = 0.148$), suggesting that these improvements were specifically due to enhanced rendering of facial relief rather than a general enhancement in image fidelity. For clinicians, this combination—more deficits identified, identified more quickly, with greater confidence, and without additional equipment costs directly translates into a more efficient and informative preoperative

or pre-treatment assessment. These findings have a clear practical application that motivated the study: planning injectable soft-tissue augmentation. Accurate identification of genuine volume deficiencies is crucial for precise filler placement, as localization errors can lead to both under-correction and unnatural results from augmenting incorrect compartments. By making shadow-dependent deficits more visible, zenithal lighting provides injectors with a simple, reproducible method for mapping target regions before treatment and documenting changes afterward. The technique requires only a continuous overhead light source with adjustable color temperature equipment already available in most aesthetic photography studios and is thus easily integrated into routine clinical workflows [8,12].



Figure 4: Representative standardized photographs of a 55-year-old female patient obtained under two different lighting conditions. Frontal illumination (top) provides a flatter appearance, with less conspicuous visualization of the tear trough deformity and upper eyelid skin redundancy. Under Zenital continous illumination, the nasolabial fold appears deeper, while upper eyelid dermatochalasis, infraorbital fat protrusion, and the tear trough deformity are more clearly delineated, illustrating the influence of lighting direction on the perception of facial volume deficiencies.



Figure 5: Representative clinical photographs of a 45-year-old man acquired using frontal (right) and continuous zenithal (left) illumination. Compared with frontal lighting, zenithal illumination accentuates surface topography through shadow formation, revealing subtle upper- and midfacial findings, including tear trough depression, upper eyelid fullness, medial and lateral infraorbital fat protrusion, and residual ice-pick acne scars.



Figure 6: Representative standardized photographs of a 65-year-old female patient obtained under frontal flash (right) and continuous zenithal illumination (left). Compared with frontal flash, zenithal illumination enhances shadow formation and more clearly delineates the severity of facial rhytids, consistent with the Glogau photoaging classification, as well as infraorbital fat protrusion and other age-related facial contour changes. These images demonstrate the critical role of lighting direction in accurately documenting facial aging.

Our findings align with and extend existing literature on photographic standardization in facial plastic surgery, which has long emphasized controlling lighting, background, head position, and camera parameters to ensure reproducibility and inter study comparability [1,4,7,14]. Much of this literature has focused on minimizing shadows to achieve uniform, reproducible documentary images; the present results suggest a complementary role for deliberately introduced directional shadows when the clinical objective is detecting volume deficits rather than neutral documentation. Previous work applying oblique or directional lighting to surface relief in dermatologic and topographic contexts supports the optical basis of our findings, and the broader concept that perceived facial volume is strongly influenced by lighting direction is consistent with both photographic practice and the everyday clinical observation that patients appear more hollow under overhead lighting. To our knowledge, however, this study is among the first to quantify the magnitude of this effect across multiple anatomical regions using a paired, within-subject design. Several strengths support the validity of these conclusions. The within subject paired design eliminated between-patient variability and maximized statistical efficiency, allowing a robust effect to be demonstrated even in a modest sample. Acquisition was rigorously standardized, with lighting direction isolated as the sole experimental variable while camera, lens, distance, head position, and background were held constant. Data quality was high, with no missing values, no internal inconsistencies, and concordant results across parametric and non-parametric analyses, indicating that the findings are not artefacts of distributional assumptions.

This study acknowledges several significant limitations that influence its interpretation and outline the agenda for future research. Firstly, the assessment of all photographs by a single evaluator prevents the estimation of inter-rater reliability and leaves systematic rater tendencies unchecked; thus, independent scoring by multiple evaluators is necessary to establish the reproducibility of the grading. Secondly, and most critically, the absence of an independent reference standard for true deficit presence precluded the computation of diagnostic-accuracy metrics, leaving the distinction between enhanced sensitivity and over-detection unresolved. Thirdly, the visual distinction between

flash and zenithal images prevented the evaluator from being blinded to lighting conditions, introducing a potential source of expectation bias. Fourthly, the sample size of 21 subjects, although sufficient for the large within-subject effect observed, was insufficiently powered for subgroup comparisons none of which reached significance—and the cohort was predominantly female, middle-aged, and characterized by a high prevalence of prior filler treatment, potentially limiting generalizability to other populations. Finally, the nine regional severity tests were not corrected for multiplicity and should be considered exploratory, with the pre-specified global score serving as the confirmatory outcome. These limitations delineate a clear path for future investigation. The most urgent next step is validation against an objective three-dimensional reference such as surface imaging systems or ultrasonography to confirm that the deficits revealed by zenithal lighting correspond to genuine volume loss and to calibrate the technique's true sensitivity and specificity. Independent multi-rater scoring would establish reliability, and blinded or computationally standardized evaluation would mitigate expectation bias. Larger and more demographically diverse cohorts would clarify whether the effect is influenced by age, sex, ethnicity, or skin phototype. Ultimately, a prospective study correlating zenithal shadow maps with actual injection sites and treatment outcomes would test the central clinical hypothesis: that lighting-guided deficit mapping enhances the accuracy and aesthetic results of soft-tissue augmentation. In conclusion, the direction of photographic illumination significantly influences the visualization of facial volume deficits. Zenithal continuous lighting reveals shadow-dependent contour deficits that conventional frontal flash tends to obscure, while simultaneously rendering evaluation faster and more confident, at negligible additional cost. Pending validation against objective volumetric standards, directional overhead lighting represents a simple, reproducible adjunct to facial photographic assessment, with particular promise for guiding the targeted placement of injectable agents.

Limitations

The study's limitations include its single-center design and relatively small sample size. Further multicenter studies with larger cohorts are warranted to validate these findings.

Conclusions

This prospective, paired comparative imaging study examined whether photographic lighting direction alters clinicians' ability to visualize and detect facial volume deficits—an issue that can compromise precise planning of injectable treatments when standard frontal illumination flattens contours by reducing shadow cues. Twenty-one participants (15 women, 6 men) were photographed under two tightly standardized conditions using a Sony Alpha 7 II with a 24–70 mm f/4 lens at a fixed 150 cm camera-to-subject distance, manual exposure, and no post-processing: (1) a "standard" frontal strobe setup with two Godox SK400II flashes in 60×90 cm softboxes placed symmetrically at 45° (ISO 200, f/18, 1/125 s; flash output ¼ + 0.3), and (2) zenithal (overhead) continuous illumination using two Neewer NL660 bi-color LED panels mounted above the head with blended color temperatures (ISO 400, f/4, 1/80 s). Subjects were positioned with the Frankfort horizontal plane, neutral expression, and standardized framing; although multiple views were captured, the frontal view was deemed most diagnostically informative and selected for primary analysis. Blinded evaluators (number not specified) assessed the presence and severity of regional deficits using a structured scoring approach, with planned paired statistical comparisons (paired t-test with Wilcoxon confirmation for global scores; Wilcoxon with rank-biserial r for ordinal regional scores; exact McNemar for per-region detection), reliability assessment (kappa/ICC), and a linear mixed-effects model adjusting for age, sex, and BMI. The primary reported outcome—global facial volume-deficit score (sum of nine regional severity scores; range 0–27)—was normally distributed (Shapiro–Wilk $p=0.395/0.078$; paired difference $p=0.083$) and was significantly higher under zenithal continuous lighting (10.29±4.56) than under frontal flash (6.81±4.74), yielding a mean paired increase of 3.48 points (95% CI 2.28–4.68; $t=5.681$, $p<0.001$; Wilcoxon $p<0.001$) with a large paired effect size (Cohen's $d=1.24$); 85.7% (18/21) of participants showed higher scores with zenithal lighting. These findings support the premise—framed through both historical and artistic perspectives on light, shadow, and perceived three-dimensionality—that overhead continuous illumination enhances clinically relevant shadowing aligned with true volume loss, offering a practical, low-cost adjustment to improve deficit identification and potentially guide more accurate filler placement. Limitations include the single-center design and small sample, warranting larger multicenter validation. Generative AI was used only for language editing of the Introduction and Discussion, not for data analysis or conclusions.

Use of Artificial Intelligence (AI)

During the preparation of this manuscript, generative AI tools were used to assist in the writing and language editing of the Introduction and Discussion sections. Specifically, ChatGPT (OpenAI, GPT-4, accessed on May 20, 2025) was employed to improve grammar and readability in English. No AI tool was used to analyze data, generate figures, or draw scientific conclusions. The authors reviewed and edited all AI-assisted outputs to ensure accuracy and integrity. Potential limitations include the risk of subtle misinterpretation of context by the AI, which was mitigated by thorough manual revision.

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