ORIGINAL ARTICLE

Periocular Dark Circles: Correlates of Severity

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Background: Periocular dark circles (PDCs) are a common cosmetic complaint. Grading systems based on objective measures have been used but no standard system is in place. **Objective:** To determine factors associated with subjective and objective PDC severity. **Methods:** Enrolled patients (n = 100) completed a questionnaire comprised of demographic variables, medical history, and self-perception of PDC. Those perceiving PDC graded dissatisfaction on a 10-point scale. Clinical severity (grades 0~4) and subtype (constitutional, post-inflammatory, vascular, shadow effects, or others) were determined. A Konica Minolta CR-400 chromameter was used to obtain colorimetry measurements (L*a*b* values). The objective average difference in darkness ($\varDelta$L*) between the periocular region and the cheek was determined. Comparisons were made using Spearman correlation coefficients (r). **Results:** Patient dissatisfaction correlated with both clinical severity (r = 0.46, $p < 0.001$) and the $\varDelta$L* by colorimetry (r = 0.35, $p = 0.004$). Factors associated with subjective dissatisfaction were female sex (r = 0.38, $p = 0.002$), higher Fitzpatrick skin type (r = 0.42, $p = 0.001$), fewer hours of sleep (r = −0.28, $p = 0.03$), and use of concealer (r = 0.35, $p = 0.004$). Factors associated with objective measures were higher Fitzpatrick skin type (r = 0.36, $p = 0.0007$ and r = 0.28, $p = 0.009$, respectively), family history of PDC (r = 0.34, $p < 0.001$ and r = 0.20, $p = 0.05$), and history of eczema (r = 0.45, $p < 0.001$ and r = 0.20, $p = 0.0504$). Clinical severity grading correlated with colorimetric severity (r = 0.36, $p = 0.0003$). **Conclusion:** Overall, subjective dissatisfaction was associated with clinical severity. However, factors associated with subjective severity did not necessarily overlap with factors associated with objective severity. These findings highlight the importance of patient-reported grading. There may be added value in incorporating a component of subjective grading into the traditionally objective PDC grading scales. **(Ann Dermatol 33(5) 393~401, 2021)**

-Keywords-
Blepharoptosis, Pigmentation, Skin aging

INTRODUCTION

Periocular dark circles (PDCs) are a common cosmetic complaint. PDCs contribute to an appearance of fatigue, play a role in perceived age[1-3], affecting emotional well-being and overall quality of life[1-4]. While prevalence studies are scarce, the impact of PDCs is reflected in the cosmetic industry where under eye concealers comprise a large portion of the market[5]. Physicians generally perceive PDCs as a physiologic phenomenon[6] and treatments are often seen as purely cosmetic in nature. PDCs have a multifactorial pathogenesis, stemming from a variety of factors, both physiologic and pathologic. Reports agree that individual differences in anatomic structure, such as bony, ligamentous, subcutaneous, vascular, dermal, and epidermal architecture as well as pigmentation are the underlying cause for most PDCs[1,3,7]. Classically, PDCs have a perceived association with lack of sleep, cigarette smoking, and stress, although these associations have not been validated[8,9]. While PDCs have received much attention in recent years, there is no standard grading or classification system for PDCs. The existing grading systems classify by

subtype, which is determined by causation and clinical appearance. Classification systems are based on the perceived underlying cause of PDCs, whether melanin or overt pigment deposition, vascular congestion, or structural causes such as fatty herniation or skeletal architecture. Identifying the underlying pathology directs therapeutic options[1]. These systems rely solely on physician or observer grading, with or without the use of adjunctive measures (standardized photography, Wood's lamp). However, grading systems at present lack a patient reported component. Physician grading often underestimates or fails to reflect patient perceived disease severity[10,11]. We hypothesize that the addition of patient reported severity would be an asset to existing classification systems.

This study describes the prevalence, subtype, and severity of PDCs in a healthy population. It observes the correlation between physician-graded severity with an objective measure of severity (colorimetry) and with patient reported severity. We also aim to determine the factors associated with subjective and objective severity scores using three different measures: self-reported severity (subjective), clinical and colorimetric analyses (objective).

Fig. 1. Healthy individuals, with and without periocular dark circles (PDCs) were enrolled. Subjective and objective measures of PDC severity were obtained, the former using a survey questionnaire, which also provided data used for severity correlates. Objective severity measures were obtained with a colorimeter and physician grading. Spearman's correlation coefficient (r) was used to assess correlates of subjective and objective measures of severity.

MATERIALS AND METHODS

Study design

This was an observational cross-sectional study. Variables assessed included objective PDC severity scores, determined by physician and colorimetric grading, subjective PDC severity scores, determined by participant grading, and factors associated with severity assessed in the questionnaire provided, acquired from a participant's past medical, personal, and social history (Fig. 1).

Study population

Approval was obtained from the Johns Hopkins Institutional Review Board (NA_00046585) prior to study initiation. Healthy participants were recruited from the Johns Hopkins Department of Dermatology outpatient clinic (Baltimore, MD, USA). Informed consent was given by all subjects before participation. Subjects were at least 18 years of age, with or without perceived PDCs. Individuals with a history of topical medication use in the periocular region, those with recently treated or currently active skin conditions, significant medical history or concurrent illness that could have affected study outcome, and pregnant or nursing subjects were excluded from the study. Enrolled individuals were grouped according to physician assigned Fitzpatrick skin type and self-reported ethnicity.

Survey questionnaire

Enrolled participants (n = 100) completed a questionnaire (Supplementary Materials). The three-part questionnaire comprised of demographic variables, past history, and self-perception of PDCs. Self-perceived PDC indicated that patients believed PDCs to be present, despite the lack of a clinical diagnosis from a physician. Demographic variables assessed included sex, age, weight, height, self-re-

ported ethnicity, and household income. Past history included medical history, with an emphasis of average sleep duration, occupational and recreational sun exposure as well as allergies and contact lens use. Social history was also obtained, which included smoking, alcohol intake, and cosmetic use. Female participants provided a brief gynecological history (pregnancy, oral contraceptive use, menopause). Lastly, individuals were asked to report presence or absence of PDCs, and dissatisfaction from a scale of 1 (no dissatisfaction) to 10 (completely dissatisfied). The level of dissatisfaction provided a marker for patient reported severity. Participants also estimated duration of the condition and reported perceived observations on aggravating and relieving factors, relation of PDC severity to time of day and menstrual cycle (as applicable), as well as self-initiated interventions. Descriptive data from the questionnaire provided the factors associated with severity used in the analyses.

Clinical grading

Individuals were instructed to remove cosmetics or sunscreens prior to clinical and colorimetric evaluation. Clinician graded evaluation was performed in a single room with standard lighting. Clinicians used a combination of two previously reported PDC scales by Ranu et al.[12], which allowed for subtype classification, and Sheth et al.[6], which allowed for severity grading. Severity grading ranged from zero to four (0: skin color comparable to other facial skin; 1: faint pigmentation or change in color of infraorbital fold; 2: more pronounced pigmentation or change in color of the infraorbital fold; 3: deep dark pigmentation or change in color, all four eyelids; 4: grade 3 with pigmentation or change in color spreading beyond eyelids) (Fig. 2)[6] and subtypes were graded as either constitutional, post-inflammatory, vascular, shadow effects, or oth-

Fig. 2. Severity grading for PDCs on a 4-point scale as described by Sheth et al[6]. (A) Grade 1, faint pigmentation or change in color of the lower eyelid. (B) Grade 2, slightly more pronounced pigmentation or change in color of the lower eyelid compared to the cheek. (C) Grade 3, deep pigmentation or change in color of all four eyelids. (D) Grade 4, similar to grade 3 pigmentation extending beyond the eyelids.

Fig. 3. Subtype grading for PDCs as described by Ranu et al[12]. (A) Constitutional subtype, with a band of brown to black pigmentation affecting the upper and lower eyelids following the shape of the orbital rim. (B) Post-inflammatory subtype, with irregular patches of pigmentation demonstrating some lichenification or thickening of the eyelid skin. (C) Shadow effects, due to a shadow caused by overhanging tarsal muscle, eyebags, or a deep tear trough. (D) Vascular, with erythema or bluish veins and thin overlying skin.

er (acanthosis nigricans, skin laxity, anemia) (Fig. 3)[12].

Colorimetric analysis

A tristimulus chromameter (CR-400; Konica Minolta, Osaka, Japan) was used to obtain averaged colorimetry measurements (L*a*b* values, Commission International de l'Eclairage), as previously described in Chien et al.[13] The machine was calibrated prior to each use. Measures of the mid-cheek and infraorbital region were obtained, with care taken to apply minimal pressure to avoid blanching of the skin. The average difference in colorimetry value was calculated by subtracting the colorimetry reading of the mid-cheek from the colorimetry reading of the lower eyelid, both at the level of the midpupillary line, and averaging the results for both sides of the face; a higher average difference in L* value indicated that the area under the eye was darker than the cheek. This number provided the colorimetric marker for severity. Changes in a* and b* values were also assessed in a similar fashion; higher average change in a* indicated decreasing redness and increasing greenness of the skin, while a higher average change in b* indicated decreasing blueness and increasing yellowness of the skin.

Statistical analysis

Means and frequencies were obtained for demographic and descriptive data. Spearman correlation coefficients (r) and associated *p*-values were used to determine correlates or factors associated with severity between reported characteristics and clinical severity scores, as well as reported characteristics and patient reported dissatisfaction. *p*-values < 0.05 were considered statistically significant.

RESULTS

Demographic characteristics

The study population (n=100) comprised of 69.0% females and 31.0% males. A large proportion (58.0%) of the group self-identified as Caucasian, 28.0% as African American or African, 10.0% as Asian, 3.0% as Hispanic and 1.0% as Native American. The mean age of the population was 41.5 years, with the majority (41.0%) falling within the < 35 year category. Based on clinician graded Fitzpatrick skin phototype classification (FSPC), most individuals were FSPC II (41.9%) and VI (14.0%) (Table 1).

Past history

Most individuals reported a family history of dark circles (59.0%). On average, the study population reported 6.7 hours of sleep a night and spent an average of 7.2 hours a day in front of a computer or other digital screen. When asked to grade severity of stress on a three-point scale (<1=low, $1\sim2$=medium, 3=high), most individuals graded themselves on a scale of $1\sim2$ (medium, 58.3%). Although occupational sun exposure was low (11.0%), recreational sun exposure was common in the general population (72.0%). Many participants reported allergies (57.0%), with 55.4% reporting sometimes, often, or always rubbing their eyes and 8% reported a history of an eyelid rash. Almost a quarter of the population (22.4%) had a history of bronchial asthma, with 21.2% reporting a history of eczema of any kind. Twenty-six percent (26.6%) reported smoking.

Self-reported periocular dark circles

Of the population completing the survey, 68 reported self-perceived PDC (68.0%). These individuals graded dis-

satisfaction on a 10-point scale, with an average of 5.9 ('some' dissatisfaction). Most individuals (61.8%) reported PDC duration of greater than 5 years, with 55.9% noting increasing severity over time. Almost half of the population (42.2%) reported PDCs improving with sleep, while 50.0% reported worsening with sleep. Some participants noted PDCs gradually worsening in appearance throughout the day (68.2%). Few (10.3%) participants with self-perceived PDCs sought consult with a physician for this problem. Many (63.2%) had tried the use of a cosmetic concealer, and 29.4% had tried an over the counter remedy for PDCs.

Clinical evaluation

Of the 100 enrolled participants, 97 were clinically assessed to have PDCs (97.0%). Thirty-eight percent of the population had vascular PDCs, 34.0% had constitutional PDCs, 12.2% had shadow effects, and 3.0% had post-inflammatory PDCs. Many (58.2%) had Grade 1, or faint dark circles, with 30.6% having more pronounced (Grade 2) PDCs. Within the study population, vascular PDCs were the most commonly observed (43.8%) followed by constitutional PDCs (37.7%). By race and subtype, the vascular subtype was more frequently seen among Caucasians (62.0%), whereas the constitutional subtype was more common among Africans/African Americans (85.7%).

Factors associated with severity

Physician graded severity showed moderate correlation with colorimetric severity (r=0.36, p=0.0003). Likewise, participant dissatisfaction was moderately correlated with physician graded clinical severity (r=0.46, p<0.001) and colorimetric severity ($\varDelta$L*) (r=0.35, p=0.004). Dissatisfaction demonstrated moderate correlation with female sex (r=0.38, p=0.002), higher FSPC (r=0.42, p=0.001), the use of cosmetic concealers (r=0.35, p=0.004) and was weakly correlated with less sleep (r=−0.28, p=0.03). Objective measures of severity (colorimetric measurements and clinical grading) were moderately correlated with a history of eczema (r=0.45, p<0.001 and r=0.20, p=0.0504, respectively), higher FSPC (r=0.36, p=0.0007 and r=0.28, p=0.001 and p=0.009) and family history of PDCs (r=0.34, p<0.001 and r=0.20, p=0.05) (Table 2). Among individuals with the constitutional subtype of dark circles, a longer duration of sleep was correlated with lower subjective dissatisfaction scores (p=0.01), but did not correlate with objective clinical severity scores (p=0.76) or severity per colorimeter readings (p=0.20).

Table 1. Demographic characteristics of the study population

Variable	Value (n=100)
Sex	
Female	69
Male	31
Mean Age (yr)	41.5
Age (categorical)	
<35 yr	41
35~50 yr	28
>50 yr	31
Race	
African/African American	28
Asian	10
Caucasian	58
Hispanic	3
Native American	1
Fitzpatrick Skin Type (n=86)	
I	9 (10.5)
II	36 (41.9)
III	11 (12.8)
IV	6 (7.0)
V	12 (14.0)
VI	12 (14.0)

Values are presented as number only or number (%).

Table 2. Severity correlates of patient, physician and colorimetric grading

Factors associated with severity	Participant reported dissatisfaction	Physician graded severity	Increasing severity (L*) by colorimetry
Female sex	0.38 (0.002)*	0.02 (0.84)	0.18 (0.09)
Fitzpatrick skin type	0.42 (0.001)*	0.28 (0.009)*	0.36 (0.0007)*
Family history	0.12 (0.33)	0.20 (0.05)	0.34 (<0.001)*
Age	0.35 (0.004)*	0.14 (0.18)	−0.21 (0.04)*
Eczema	0.17 (0.18)	0.20 (0.0504)	0.45 (<0.001)*
Sleep (number of hours)	−0.28 (0.03)*	−0.09 (0.38)	−0.12 (0.25)
Use of concealer	0.35 (0.004)*	0.05 (0.67)	0.18 (0.15)

Values are presented as correlation coefficient (p-value). *Statistically significant (p<0.05).
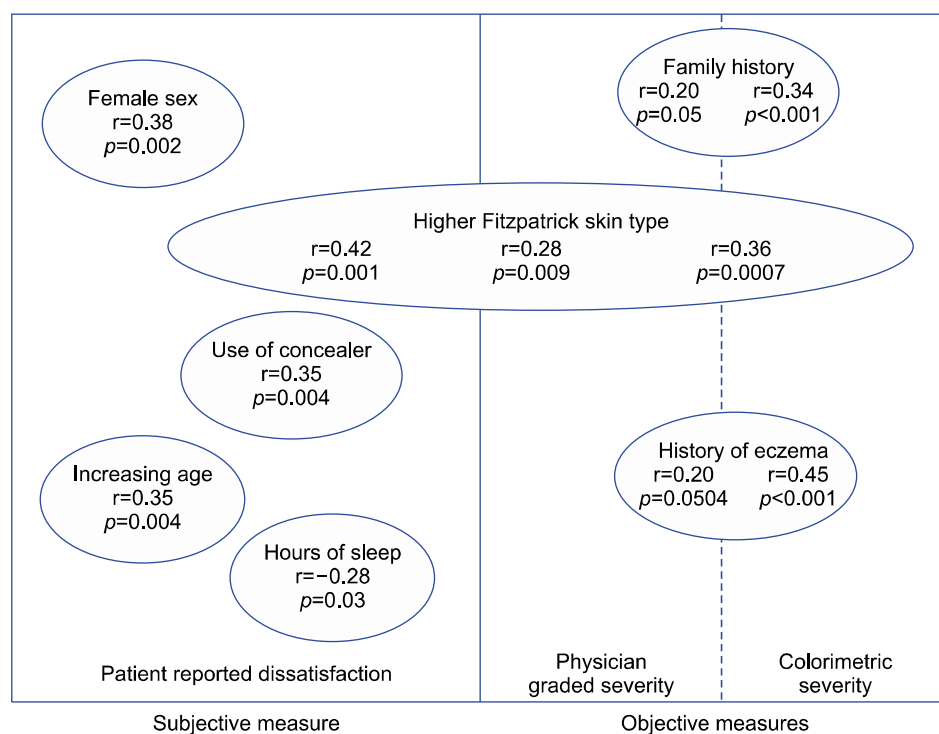
Fig. 4. This figure demonstrates the overlap between subjective and objective severity measures. Ovoid shapes represent correlates of severity. Their placements within the boxes for subjective and objective measures of severity denote presence or absence of overlap. Fitzpatrick skin type was the only correlate to overlap across all measures.

Periocular dark circle subtypes

Constitutional and post-inflammatory subtypes showed an average L* change of 3.75 (standard error of the mean [SEM] = 0.78) and 11.7 (SEM = 2.01) respectively. Vascular, shadow, and post-inflammatory subtypes showed an average a* change of 4.89 (SEM = 0.48), 3.30 (SEM = 0.87) and 4.57 (SEM = 2.62), respectively. An average b* change of 1.59 (SEM = 0.41) and −1.04 (SEM = 0.90) was noted for vascular and post-inflammatory subtypes, respectively (Supplementary Table 1).

DISCUSSION

PDCs were clinically visible in the majority of the patient population (97.0%), however only 68.0% of the population reported perceived PDCs. Only 10.3% of those reporting PDCs had ever seen a physician for that reason, which suggests that patients themselves likely perceive PDCs as cosmetic concerns and may not initiate a clinic visit for this reason. In fact, most respondents (70.6%) had not attempted the use of any over the counter products or patient-initiated at home treatments to remedy their PDCs.

Grouped by race, we found that certain subtypes were seen more often in certain populations. Ranu et al.[12] had similar findings in a mixed Asian population (East Asian, Malay, and Indian), reporting constitutional dark circles to be more commonly found in darker skin types, with vas-

cular subtypes more prominent in lighter skin types. The vascular subtype may be less noticeable in darker skinned populations due to the overlying pigment of the skin obscuring vascularity. This may lead to an overrepresentation of vascular subtypes in light skin and underrepresentation in darker skin types. Constitutional dark circles may be influenced by an individual's capacity to develop pigmentation, as this is the subtype most likely caused by dermal melanocytosis[14]. This may explain why these are more commonly seen in subjects with darker skin[6,12]. Our results also demonstrated that darker skin types correlated with increasing subjective and objective severity. In fact, this was the only factor associated with severity in which all measures overlapped (Fig. 4).

Physician graded severity correlated well with colorimetric severity. Both objective measures of severity correlated well with subjective severity (reported dissatisfaction). Overall, for measures pertaining to PDC severity, physicians, participants, and colorimeter were in agreement. Interestingly, while participant perceived severity was accurately reflected by physician and colorimeter grading, factors associated with participant reported severity differed from factors associated with objective severity (Fig. 4).

Colorimetry also demonstrated subtype specific patterns. Constitutional and post-inflammatory subtypes showed the greatest L* changes, whereas the vascular and shadow subtype, which did not demonstrate significant L* changes, showed changes mostly in a* skewing towards greenness.

In addition to colorimetric differences between subtypes, we also found that the mean age was highest in the shadow subtype compared to others. Overall, there was a greater proportion of smokers and individuals with asthma in the constitutional subtype than in other subtypes, while the average sleep duration and time spent on an electronic device were similar across subtypes (Supplementary Table 1).

Both objective measures found a 'family history of dark circles' as a severity correlate. This correlate has been consistently supported in literature[8,12]. Amini et al.[15] identified polymorphisms in p53 and vascular endothelial growth factor (VEGF) genes as causative factors, and as early as 1969, Goodman reported a familial case of periorbital pigmentation spanning six generations, with autosomal dominant characteristics[16]. Factors that predispose to PDCs such as skeletal and facial architecture, as well as skin thickness and pigmentary characteristics[1] are inherited features and may contribute to the hereditary component of dark circles. A history of eczema, another heritable condition, also correlated with objective measures. This is in agreement with reports of increased vascular congestion as a physiological basis of dark circles[7,8,12,17]. In fact, dark circles are so characteristic of atopy in children that their presence, whether in the form of Dennie–Morgan folds or orbital darkening, is sufficient to elicit a suspicion of atopy[17].

Increasing subjective severity or dissatisfaction correlated with female sex. While dark eye circles are generally considered to affect both sexes equally, most reports have shown a greater overall prevalence in females[6]. Sheth et al.[6] reported an association between dark eye circles and irregular menstruation, premenstrual aggravation, stress, and anemia. In addition, health-seeking behavior and willingness to visit a physician is more often seen in females[18], and this may be reflected in our results.

Unsurprisingly, cosmetic concealers were more often used with increased self-perceived severity. This did not correlate with objective severity measures. Given that concealers and cosmeceuticals are the least invasive form of treatment[3] and may represent the first step for some, this may indicate a lower threshold for self-remedy in affected individuals, regardless of clinical severity.

While fewer hours of sleep correlated with increasing self-perceived severity, it did not correlate with either of the objective severity scores. For individuals with constitutional dark circles, those who slept longer were less dissatisfied with the appearance of their dark circles, although this also did not correlate with either of the objective severity measures. These findings are similar to previous studies, in that patients frequently report lack of sleep as an aggravating factor[12] although no association has been found thus far[8,9]. Oyetakin-White et al.[9] reported no significant difference in dark eye circle severity based on a 9-point severity scale between poor sleepers and good sleepers. Interestingly, good sleepers were more satisfied with appearance than poor sleepers[9]. This correlates with our findings, in that regardless of dark eye circle severity, patient satisfaction was higher in better-rested individuals.

While patients, physicians, and colorimeters may see eye to eye with severity, the disparity lies in the factors associated with severity observed. The evidence shows greater consistency between both objective measures and their associations; however, one must also consider the likelihood that patient reported severity and its association, while undeniably subjective, more astutely represent day-to-day fluctuations in severity. These fluctuations have been observed clinically and may be caused by edema and dermal changes that affect how dermal pigment is perceived[14].

PDCs may be a cosmetic condition, but cosmetic concerns still significantly impact quality of life[19]. Quality of life measures, such as the Skindex and Dermatologic Quality of Life Index are tools that focus on patient perspective on disease impact and severity. Scales such as these are generalizable to various skin conditions, however these do not necessarily correlate with physician reported grading scales[10]. Combined scales, containing components of physician and patient reporting and intended for a specific condition may be more ideal. An example is the Patient Observer Scar Assessment Scale for the evaluation of scars. The addition of patient reported severity gives weight to patient opinion[20], and allows physicians to focus management at the individual most impacted by the condition: the patient. Given the highly subjective nature of cosmetic complaints, we believe that patient reported severity has significant value in the classification, grading, and evaluation of PDCs, both prior to and after the initiation treatment.

Although the investigators did their utmost to minimize bias, the study was subjected to the limitations common to survey studies. In particular, recall bias, as participants were asked to note recent and past observations on their dark circles, as well as inter-observer variability between the three grading clinicians. For the latter, we attempted to minimize these through standardized colorimeter techniques and highly descriptive grading forms with image references. Another limitation was the small population size (n = 100)—while we felt that the ratio between ethnicities was representative of the population seen in our clinic, this may not be generalizable to the general population, especially due to the small sample size of some ethnic groups. Furthermore, the cross-sectional nature of the study allowed evaluation at a single time point but did

not reflect daily and seasonal fluctuations that may occur with PDCs. Due to participant recruitment efforts within the dermatology clinic and convenience sampling therein, the population at hand may have had better health seeking habits compared to the general population.

Periorbital dark circles are multifactorial in nature, and respective subtypes originate from distinct pathogeneses. Variations in inherent pigmentation, skin quality and facial architecture may predispose certain individuals to particular subtypes. Subtype and severity classification of PDCs are important aspects of clinical assessment, and aid in determining appropriate treatment options.

Physician, colorimetric, and patient reported measures are accurate measures of PDC severity. Correlates of these measures, however, do not completely overlap, highlighting differences in perspective and opinion between physician and patient. Of the factors assessed, only Fitzpatrick skin type overlapped across the three measures used. In comparison, both objective measures (clinician grading and colorimetry) strongly correlated with each other and demonstrated similar factors associated with severity. In light of these differences, we believe that patient graded severity is important and should be measured, especially before and after cosmetic procedures. While objective grading is important in the diagnosis and classification of PDCs and directs treatment options, outcome evaluation requires both physician and patient input.

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SUPPLEMENTARY MATERIALS

Supplementary data can be found via http://anndermatol. org/src/sm/ad-33-393-s001.pdf.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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DATA SHARING STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

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