ORIGINAL CONTRIBUTION

Strength of Occipital Hair as an Explanation for Pilonidal Sinus Disease Caused by Intruding Hair

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BACKGROUND: Pilonidal sinus disease is thought to be caused by intrusion of hair into healthy skin; loose hair in the intergluteal fold is thought to promote disease. However, compelling evidence to support these postulates is lacking; the cause of pilonidal sinus disease remains uncertain.

OBJECTIVE: To determine whether particular properties of hair are associated with susceptibility to pilonidal sinus disease, we compared physical properties of hairs of patients with pilonidal sinus disease with hairs from control subjects who were matched for sex, BMI, and age.

DESIGN: This was an experimental study with establishment of a mechanical strength test for single hairs to quantify the maximum vertical force that a hair could exert, following tests of strength of occipital, lumbar, and intergluteal hair.

SETTINGS: Hair from patients with pilonidal sinus disease and matched control subjects were harvested from patients of the St. Marienhospital Vechta Department of Procto-Surgery.

PATIENTS: A total of 17 adult patients with pilonidal sinus disease and 217 control subjects were included.

MAIN OUTCOME MEASURES: ANOVA and intraclass and interclass variations of data gained from mechanical strength tests of occipital, lumbar, and intergluteal hair were included.

RESULTS: Vertical hair strength was significantly greater in patients with pilonidal sinus disease. Occipital hair exhibited 20% greater, glabella sacralis 1.1 times greater, and intergluteal hair 2 times greater strength in patients with pilonidal sinus disease than in matched control subjects (all $p = 0.0001$). In addition, patients with pilonidal sinus disease presented with significantly more hair at the glabella sacralis and in the intergluteal fold.

LIMITATIONS: The study was limited by its relatively small number of patients from a specific cohort of European patients.

CONCLUSIONS: Occipital hair exhibited considerable vertical strength. Because occipital hair exerted the greatest force and cut hair fragments were found in the pilonidal nest in large quantities, these data suggest that pilonidal sinus disease is promoted by occipital hair (**see Video Abstract,** http://links.lww.com/DCR/A329).

KEY WORDS: Hair; Karydakis; Pilonidal sinus; Scalp; Vertical strength.

Different theories regarding the etiology of pilonidal sinus disease (PSD) have been postulated. Although familial clustering of pilonidal disease is common, hereditary factors have not been identified.[1] Bascom[2] and others argued that midline pits occurred as a

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result of follicle occlusion, inflammation, and rupture and suggested that loose hairs intruded through already existing pits. However, the fact that PSD also occurs in patients whose natal cleft is bald seriously challenges this theory.[3,4] Karydakis[5] suggested that intruding hair was the cause of PSD. He described a number of hair-related factors of pathogenetic importance (Table 1).

Some methods to prevent recurrent PSD, such as razor depilation/shaving, have been associated with increased recurrence[6,7]; in addition, depilation with cream, x-rays,[8] and lasers[9] have been used, but the effectiveness of these has not been conclusively confirmed.[4] Overall, the cause of both primary and recurrent PSD remains uncertain. Investigations aimed at elucidating the pathogenesis of the disease are needed, because the incidence of PSD is rising, and surgical interventions in Germany, for example, have doubled between 2000 and 2012.[10] The purpose of this study was to examine the strength of hair; specifically, we wanted to test the capacity of hair to resist a vertical (trajectory) or rotational (drilling) force and to compare hairs of patients with PSD with control subjects matched by sex, BMI, and age. In addition, we aimed to study the hair density between the head and anus along the dorsal sweat crest in patients with PSD and control subjects and to correlate these densities with the occurrence of PSD.

PATIENTS AND METHODS

Institutional Review Board Approval and Informed Consent

The ethics committee of the Medical Association of Niedersachsen, Berliner Allee 20, 30175 Hannover, Germany (Prof. Dr. med. Andreas Creutzig, chair) fully and unanimously approved the study based on § 15 of the Niedersachsen Medical Association's professional code of conduct. The ethics committee of the Medical Association of Niedersachsen, Berliner Allee 20, 30175 Hannover, Germany (Prof. Dr. med. Andreas Creutzig, chair) fully and unanimously approved the study based on § 15 of the Niedersachsen Medical Association's professional code of conduct. Patient consent for hair usage was obtained after the surgeries to guarantee that they did not feel any preoperative pressure.

Patients

Patients were recruited at the Department of Proctosurgery at St. Marienhospital Vechta, a 321-bed academic teaching hospital of the University of Hannover (Germany). Adult patients with PSD (15 men and 2 women) were enrolled between September 2014 and July 2015. All 17 of the patients experienced primary PSD. An additional 33 patients with PSD (28 men and 5 women) were enrolled for hair distribution analysis but not hair sampling (Table 2). Control subjects without PSD (102 men and 115 women) were recruited from the same department and matched with the 17 patients with PSD for sex, BMI, and age at date of surgery.

TABLE 1. Factors promoting PSD as postulated by Karydakis[5]

Factors	
Hair-related factors (H)	
H1	The number of loose hairs collected in the natal cleft
H2	The more or less acuteness of the root end of hair
H3	The kind of hair (tough or silky)
H4	The shape of the hair (straight hair, not curly, is the type liable to insert)
H5	Scaliness of air, more marked in 10–22 y
Force-related factors (F)	
F1	Depth
F2	Narrowness of the natal cleft
F3	Friction movements between the sides of the cleft
Vulnerability-related factors (V)	
V1	Softness
V2	Maceration
V3	Erosions
V4	Splits
V5	Wide pores
V6	Wounds
V7	Scars at the natal cleft

Table is adapted with permission from Karydakis.[5]
PSD = pilonidal sinus disease.

Hair Samples

Terminal hair, defined as thick hairs found on specific body sites, which develops during and after puberty on an increase in androgen levels,[11,12] was plucked with soft plastic-covered anatomical forceps (see Fig. S1, Supplemental Digital Content 2, http://links.lww.com/DCR/A312) from 3 body regions, including the occipital scalp overlying the protuberantia occipitalis externa (POE), the lumbar region glabella sacralis, and the upper third of the intergluteal fold. Plucking was used as a method to ensure harvesting of the entire hair. To avoid any bias in measuring, the pinched part of the hair was cut off. Six hairs at a minimum per region were epilated for testing. Vellus hair,

TABLE 2. Hairiness in a larger population cohort without performance of physical hair tests

No. of regions with hair	*Men*	*Women*	*Total*
Unmatched patients with PSD			
1	0	3	3
2	10	1	11
3	18	1	19
Total	28	5	33
Unmatched patients without PSD			
1	16	72	88
2	18	25	43
3	54	15	69
Total	88	112	200

Regions of interest were protuberantia occipitalis externa, glabella sacralis, and upper third of intergluteal fold. Patients were stratified according to number of regions with terminal hair present (1, 2, or 3). There was no performance of physical hair tests in these cohorts (cohorts with physical hair tests are shown in Table 3).
PSD = pilonidal sinus disease.

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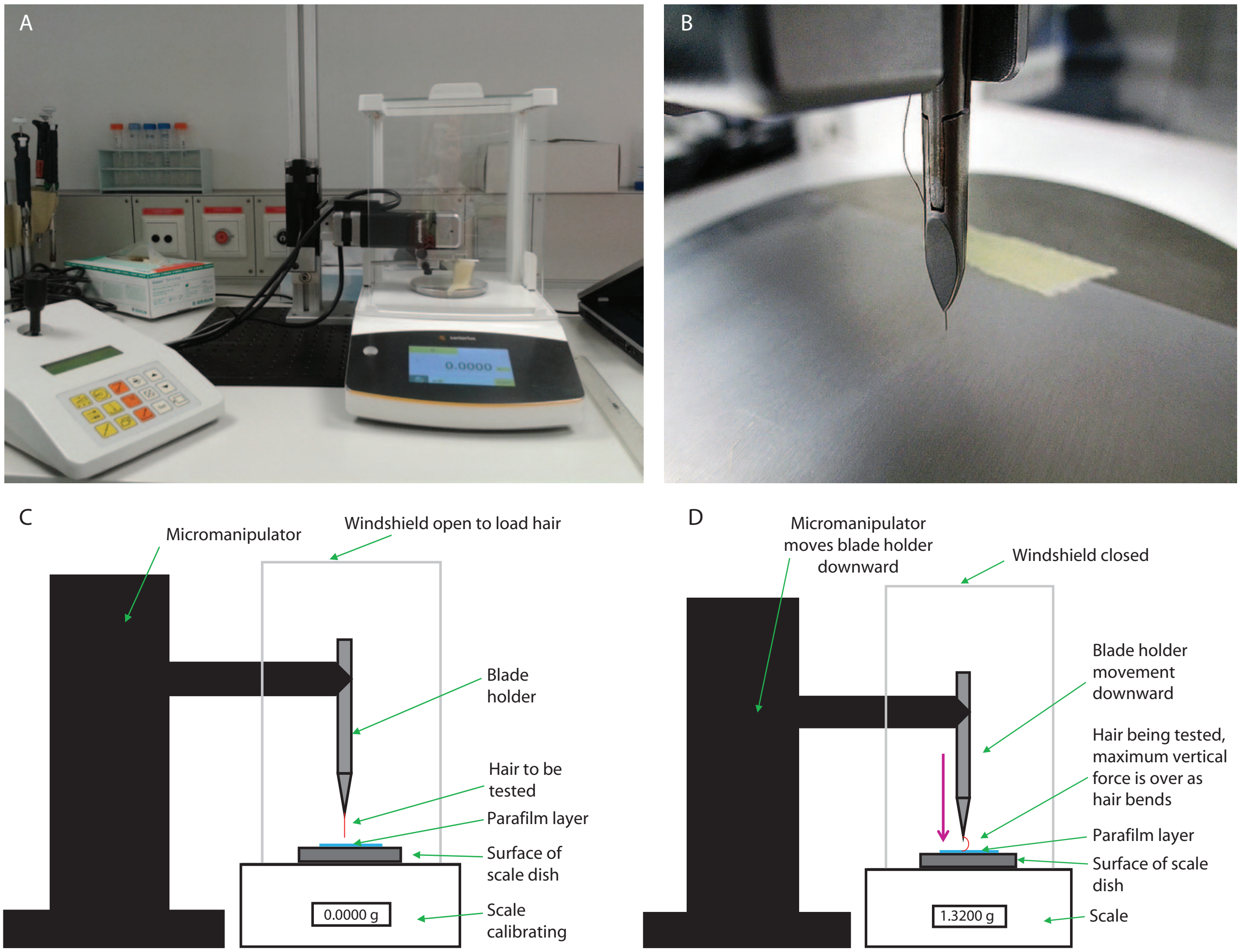

FIGURE 1. Instrumental design to test vertical hair strength, gripped once, tested 6 times per hair shaft. A, The tested hair was driven slowly vertically with an Eppendorf micromanipulator onto the microscale. B, Close-up view of the tested hair, fixed with an eye surgery forceps, with a parafilm layer fixed to the scale surface to prevent slipping. C, Experimental setup of vertical force test with hair ready to be lowered (left), and D, after exerting a maximal vertical force onto the scale at the moment when the hair starts to bend (right).

defined as soft curly white hair <2 mm in length,[13] was not harvested. Body regions with solely vellus hair or no hair at all were defined as terminally bald. Factors of hair aging[14] or dyeing were not suspected in our PSD population, which was predominantly young and male.

Hair Strength Test

To measure vertical hair strength, a single hair probe (hair root and 1 mm of the hair shaft) was fixed with a micromanipulator (Eppendorf, Hamburg, Germany) and slowly lowered onto the platform of a microscale (Eppendorf). A layer of parafilm was fixed to the scale surface to prevent slippage. Hair strength, expressed as pressure exerted by hair, was calculated as $P = F/A$, where P = pressure, F = force, and $A = \pi * r^2$ (area of a circle, where r = radius and d = diameter). Figure 1 provides an overview of the procedures described.

Repeated testing of single hairs (≤20 times) showed that the vertical strength changed with repetition. Therefore, only results from the first 6 tests per single hair were considered to be reliable for additional analysis (Fig. 2A). Repeated repositioning (regripping) of the hair within the forceps led to significant measurement bias because of hair contusion and mechanical alteration (Fig. 2B). Therefore, hair was tested without regripping. Wet hair was found to be softer and exhibited diminished vertical force strength, detectable within minutes of wetting (Fig. 2C). Accordingly, all of the hairs were dried passively for 12 hours at room temperature and kept in a dry and vented environment. The strength of hairs did not decay over months when kept between layers of gauze at room temperature under dry conditions after collection (Fig. 2D). Thus, we considered that test results obtained within 2 weeks after hair collection were reliable.

In addition, a larger (unmatched) cohort was studied for the presence of hairs in the 3 body regions without collection of hair for strength testing. A body region, specifically protuberantia occipitalis externa (POE), glabella sacralis (GS), and intergluteal fold (IGF), was defined as hairy if terminal hair was observed (Table 2).

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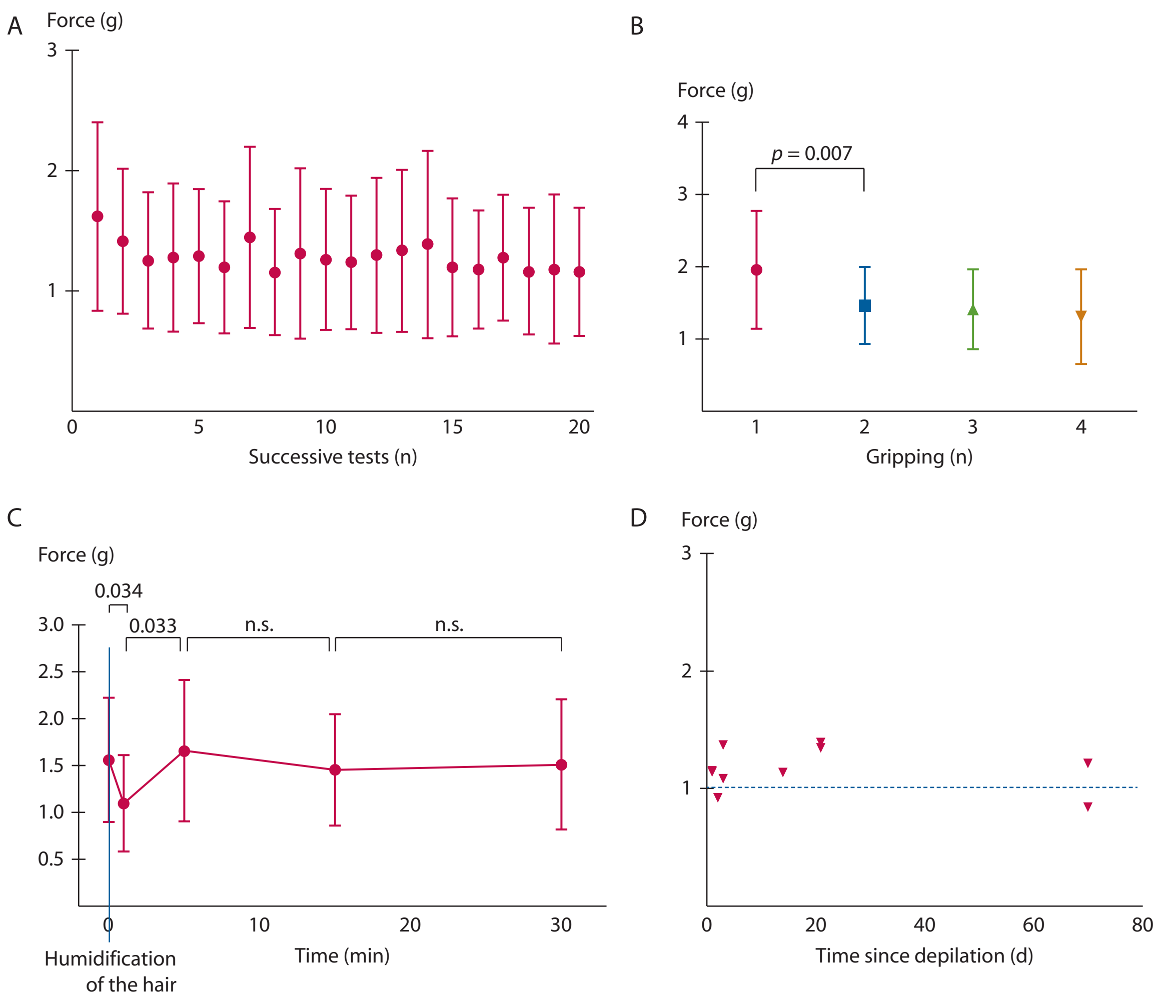

FIGURE 2. A, Hair force and multiple testing (vertical orientation) with dry hair shafts, single first grip; n = 10 hairs. B, Hair force and multiple grippings (0.2 cm free length, 0.2 cm from hair follicle; dry vertical testing); n = 10 hair shafts. C, Hair force and hair humidification with water. Blue line indicates the time of hair humidification, followed by drying time (x axis). Vertical testing, single first grip, 0.2 cm free hair length, 0.2 cm from follicle; n = 10 hair shafts. D, Hair strength and time since depilation; n = 10 hair shafts.

To allow short hair fragments to be tested, minimal free hair length (from tip of hair to tip of forceps) for examination was set to 2 mm. Also, if a full hair including the hair follicle was harvested, the follicle was decapitated and discarded at 2 mm. Hair without follicle was tested with the thicker end downward to scale. Pilonidal hair was sometimes found in clusters and sometimes contained dust, dirt, or cell debris. In these cases hair was rinsed with tap water, separated hair by hair, and then counted and dried accordingly.

Data Analysis and Statistics

We used R software (www.r-project.org, Vienna, Austria) for ANOVA testing for intraclass and interclass variation of hair strength. Permutation tests were applied for intraclass variance testing, because this method is more precise than the F test. F tests were performed for estimating interclass variance. After the null hypothesis that each hair had its origin from the place that the experiment claimed, significance for both tests was set as $p < 0.01$.

RESULTS

A single investigator (F.D.B.) performed 12,000 tests of hair strength in this study. The hair of 17 adult patients with PSD (14 men and 3 women) and 217 volunteers (102 men and 115 women) was tested. Hair was present in all 3 of the regions (protuberantia occipitalis, glabella sacralis, and upper third of intergluteal fold) in 11 of 17 patients with PSD and 8 of 17 matched patients without PSD (Table 3). All of the male patients with PSD (14/14) and 11 of 14 matched pair male patients had more than occipital hair. Female patients were less hairy at the glabella sacralis and intergluteal fold compared with men. Table 3 provides an overview of the hairiness among the patients tested.

Concerning hairiness (Table 2), all of the male patients with PSD exhibited terminal hair in at least 2 regions of the dorsal sweat crest, and 64% (18/33) of male patients with PSD had terminal hair present in all 3 of the regions. Among

TABLE 3. Hairiness among 17 patients with PSD and their matched pairs

Regions with hair	*Men*	*Women*	*Total*
Patients with PSD			
1	0	2	2
2	3	1	4
3	11	0	11
Total	14	3	17
Matched patients without PSD			
1	3	3	6
2	3	0	3
3	8	0	8
Total	14	3	17

Regions of interest were protuberantia occipitalis externa, glabella sacralis, and upper third of intergluteal fold. Patients were stratified according to number of regions with terminal hair present (1, 2, or 3).
PSD = pilonidal sinus disease.

male non-PSD subjects, 61% (54/88) had terminal hair present in all 3 of the regions, and 13% (15/112) of female non-PSD subjects had terminal hair present in all 3 of the regions.

POE hair of patients with PSD was able to sustain significantly stronger vertical force than POE hair of matched pairs ($p < 0.0001$; *t* test). We found that hair from the region of the POE, one of the stiffest hair regions, was able to exert a vertical force of >1 g. Taking into account the average diameter of hair at 65 µm, pressure was ≈300 g/mm^2 (30 kg/cm^2). Significantly stronger hair was present in patients with PSD all along the dorsal sweat crest. The hair of the lower back exerted a vertical force of ≈0.5 g per hair. Intergluteal hair was significantly different in patients with PSD than in matched control subjects (Fig. 3). Maximum vertical hair force did not correlate with the number of pori seen in the upper third of the intergluteal fold (Fig. 4).

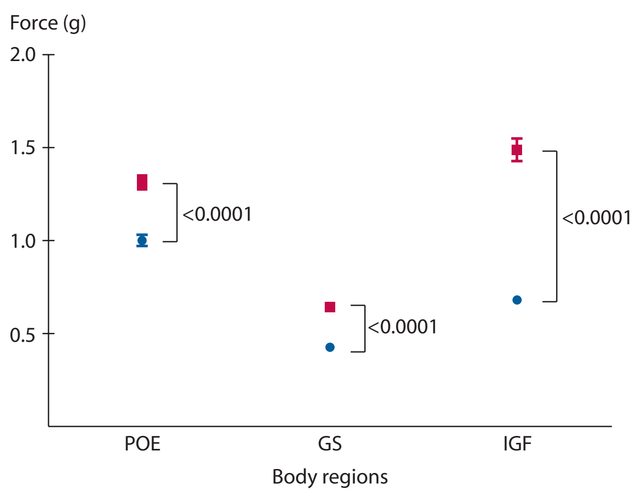

FIGURE 3. Hair from 3 different body regions compared between patients with pilonidal sinus disease (PSD,red squares) and matched control subjects (MP, blue dots); n = 17 PSD-MP pairs. POE = protuberantia occipitalis externa; GS = glabella sacralis; IGF = intergluteal fold.

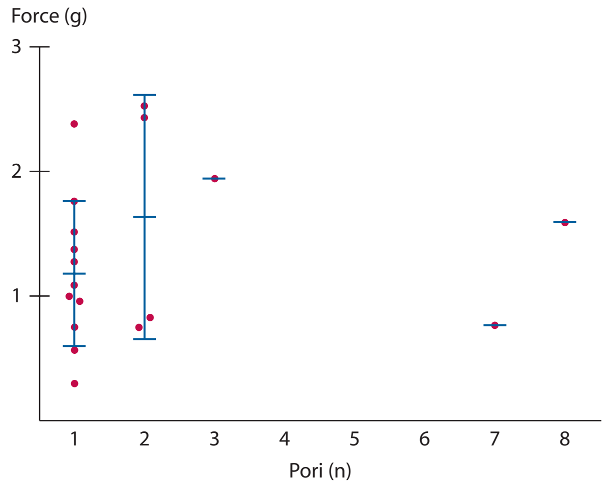

FIGURE 4. Maximal vertical hair force and number of pori in 17 patients with pilonidal sinus disease.

Based on the data, we rejected the null hypothesis and conclude that some occipital hairs must have found their way to the pilonidal region. We found an average of 21 hairs (range, 1–415 hairs) within the sinus of the 17 patients analyzed (Fig. 6). Most of the hairs were fragments with sharp cut ends (Fig. 5). Occipital hair is the likely source of pilonidal sinus generation, especially in patients where there is no lumbar or intergluteal hair, which was true for the 2 female patients in our series and for >83% of all non-PSD women and 21% of all non-PSD men seen.

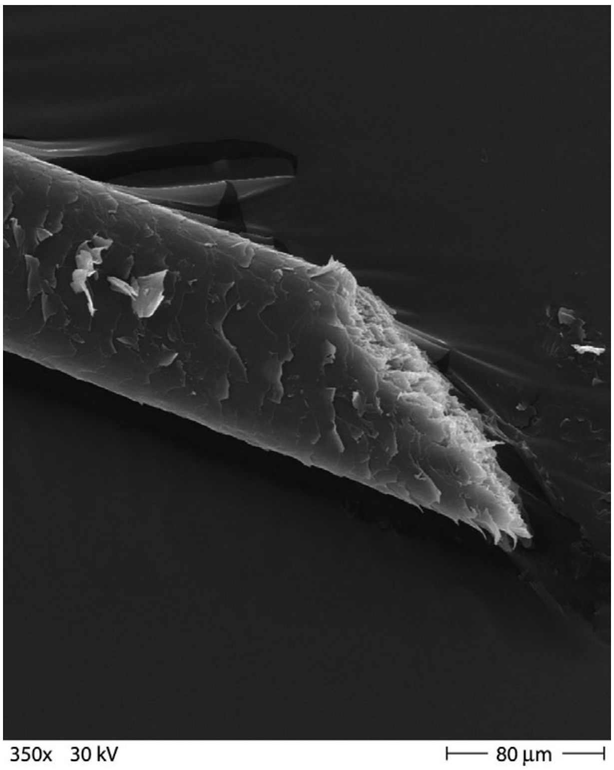

FIGURE 5. Freshly cut terminal hair end, scanning electron microscopy picture.

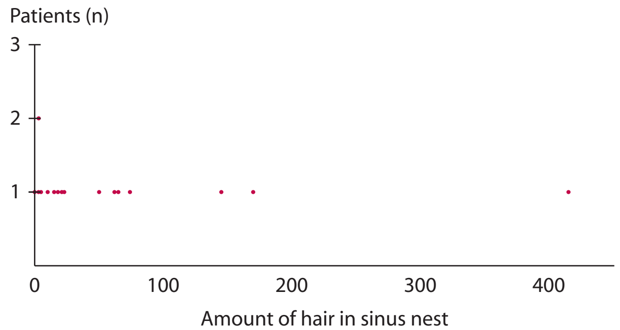

FIGURE 6. Amount of hair intraoperatively found in pilonidal sinus nest.

DISCUSSION

The purpose of this study was to examine PSD patient hair strength as an etiologic factor in PSD, as hypothesized by Karydakis[5] in 1992. We established a mechanical strength test for single occipital, lumbar, and intergluteal hair to quantify the maximum vertical force that single hairs could exert. Our results show that vertical strength of occipital, lumbar, and intergluteal hair from patients with PSD was significantly greater than hair from their matched pairs.

A limitation of our study lies within the small number of patients who we were able to study. In addition, this study represents a specific cohort of Northern European patients with PSD and matched control subjects. Clearly, the work could be strengthened by including a larger and ethnically more diverse population. Hair characteristics may differ among other ethnically distinct cohorts, which remains to be investigated. Plucking as a harvesting method could potentially stretch the hair. However, given the setting of the study, this theoretical effect would be equal in both the PSD and the control groups. In addition, there is no definitive evidence that the strongest hair found in the sinus was the one that generated the tract and enabled the establishment of the hair nest. In 2 patients we found only 1 stiff hair in the sinus, which was embedded in a large scar. Even if only 1 hair was found, we cannot rule out observer bias, because softer hairs may be difficult to recover from a thick, fibrous tissue block. Scars and infection are present in every sinus, even in clinically inapparent patients.[15] The maximum trajectory force depicts the maximum force that a hair may exert vertically, which will most probably never be reached in the everyday setting in patients with PSD. However, normal intergluteal hair may help to catch and retain occipital hair.[16] If this caught hair has been cut, it will pinch easily into formerly healthy tissue, as described as early as 1946.[17]

Traditionally, PSD has been described as an occlusive, hyperkeratinizing follicular disorder along with acne inversa, acne conglobata, and dissecting cellulitis. Bascom[2] and others suggested that midline pits occur as a result of follicle occlusion, inflammation, and rupture and that loose hairs intrude through already existing pits; therefore, locoregional depilation has been promoted.[18–21] However, the evidence is not encouraging.[22,23] Moderate sweating prevents hair fragments from sliding down,[24] which explains the suspected but never proven weak link between obesity and PSD incidence.[25–27] A wide intergluteal fold is advantageous, whereas a narrow steep fold retains more hair.[16] Local cutaneous fat thickness in patients with PSD appears to add to hair retention, but the mechanism is not fully understood.[25] Hair is generally caught at the upper end of the intergluteal fold, because most sinuses are typically present there. Cut hair is only occasionally caught below the upper third of the intergluteal fold, where it may give rise to pilonidal sinus in hairless areas, such as the anal canal.[28]

The idea that upper back crest and head hair is the source of an intergluteal puncture sinus is not new.[29] Hair from the neck or the skin over the back will find its way to the same region,[30] where stiffer and sharp hair chisels itself into the skin.[31] Lord[32] has found head hair in a sinus nest of greater length than the patients' own hair, concluding that foreign hair may trigger a sinus. "Very short stiff hairs as the fragments to which barbers are exposed[33]" can puncture intact skin. Every haircut client is exposed, especially young men who regularly renew their short haircut. This may be a reason why PSD commonly occurs within military cohorts worldwide.[34,35]

We found that the strongest hairs in the sinus were predominantly of occipital origin. Because large numbers of short hair fragments (from haircut, showing freshly cut sharp ends) were found in the sinus, we postulate that PSD is likely generated by occipital hair. Undoubtedly, there is a mechanical aspect in sinus pathogenesis related to the intruder or arrow injection of hair into the skin, which suggests cofactors that might enable easier injection, including softer skin, or skin macerated through a steeper anal cleft and continuous sweating. Akinci et al[16] have shown that a deeper natal cleft predisposes to PSD, which may enable the full erection of cut hair (hair parallel to the skin will not be able to pierce the surface, but perpendicularly upright hair may).

There would be no PSD in bald persons if the theory by Karydakis[5] was fully correct. Thus, both occlusive follicular disease and the Karydakis theory[5] can explain PSD pathogenesis. A combined pathogenesis with occipital hairs perforating intergluteal skin at multiple sites is possible. However, the Karydakis[5] theory does not fully explain why and how multiple midline pits occur at the beginning of the disease, whereas the hyperkeratinization theory does. However, most tracts point cranially, because the hair nests are situated cranial to the pori as well. Although the sacrococcygeal angle does not seem to influence sinus incidence,[36] Akinci et al[16] showed that patients with PSD have deeper natal clefts than a control group. It has been shown that BMI does not impact PSD incidence,[37] and bigger thickness of sacrococcygeal fat has been associated with PSD.[25] In any case, as Eryilmaz et al[36] point out, the hair approaches the intergluteal fold from the head, not from the perineal side. Assuming

PSD as a disease promoted by fragments from cut hair, the following measures may help prevent PSD: 1) reducing the production of hair fragments (which are especially prevalent with machine cut), 2) removing cut hair along the dorsal sweat crest, 3) reducing contact time of capital hair within the intergluteal fold, 4) preventing erection and injection of cut hair within the intergluteal fold, and 5) protecting skin at risk with shielding or hardening substances. Specifically, we suggest that clinicians recommend to patients at risk to promptly take an extensive shower after a haircut. Although laser epilation has not been proven to decrease recurrent PSD yet,[38] it certainly enables a shorter contact time of hair derived from other locations[4] and can be recommended to patients at risk.

CONCLUSION

Occipital and intergluteal hair appear to be of increased stiffness in patients with PSD, which might enable easier puncture and sinus generation. If occipital hair slides down the dorsal sweat crest and is erected intragluteally, it may exert a strong local force onto the skin. Occipital hair may be caught intragluteally significantly more often in individuals predisposed to PSD, because patients with PSD present with significantly more hair at this location. The number of loose hairs collected in the natal cleft (Karydakis factor H1), the kind of hair (Karydakis factor H3), and the shape of the hair (Karydakis factor H4) appear to be risk factors in PSD generation. Because occipital hair exerts the strongest force, and because cut hair fragments are found in the pilonidal nest in large quantities, our data suggest that PSD could be promoted by occipital hair. Certainly, other factors described by Karydakis[5] keep the justification in the pathogenesis of PSD.

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