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ORIGINAL SCIENTIFIC REPORT

The Hair in the Sinus: Sharp-Ended Rootless Head Hair Fragments can be Found in Large Amounts in Pilonidal Sinus Nests

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Abstract

Purpose Hair has been identified as the causative agent of Pilonidal Sinus Disease (PSD). Stiffer, dark hair as well as hairiness has been postulated as causative factors. Astonishingly, despite the early clinical significance of this condition (Hodges in Boston Med Surg J 2:485–486, 1880), macroscopic and microscopic examinations of hair inside pilonidal sinus cavities have been scarce. The purpose of this study was to study the morphological aspects of the hair found in PSD in order to determine the origin of the hair.

Methods Hair from inside pilonidal sinus cavities was collected intraoperatively from 20 PSD patients. Additionally, occipital, lumbar and intergluteal hair was harvested from the same patients and compared to the hair of volunteer-matched pair patients admitted to the hospital at the same time for non-PSD surgery. Intra- and intergroup variations of hair length were characterized with analysis of variance. Numbers and lengths of pilonidal sinus nest hair were recorded. Hair was examined clinically and with light and scanning electron microscopy using surface enhancing gold and carbon dust coating techniques.

Results Analysis of 624 pilonidal sinus nest hair samples from 20 independent sinus cavities revealed that hair within pilonidal sinus nests is rootless in 74%. Shorter hair was found inside the pilonidal sinus compared to other sites (length 0.9 ± 0.7 cm $p < 0.0001$). Furthermore, hair found inside of the sinus was significantly shorter than hair protruding from pores ($p < 0.000$). Hair samples show razor sharp but no broken or split ends. On electron microscopy, these spiky hair ends resemble cut hair ends. Pilonidal hair nests contained between 1 and over 400 hair fragments.

Conclusion Short hair fragments with rootless sharp cut ends were found within pilonidal sinus cavities. Morphologically, these fragments resemble short cut rather than intact body hair. Since short cut hair, e.g., derived from the head potentially enters the pilonidal cavity more easily than longer hair, the source of these cut hair fragments needs to be eliminated when aiming to prevent Pilonidal Sinus Disease.

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Introduction

Hair has been identified as the key component in Pilonidal Sinus Disease (PSD), which blights mostly young men [2], as hair is commonly found in the pilonidal cavity [3–5]. The entry mechanism of hair into already existing sinus tracts seems to have been proven by Page [6], but the mechanism of the first tract is still unclear. Several authors identified common and uncommon sources of contents in PSD, where the uncommon include a 37-cm long—most probably female—hair in a male sinus (Lord) [7], and Elliot reporting a feather in the sinus of a 19-year-old girl [8]. Individual hair characteristics have not been recently studied.

Karydakis hypothesized multiple hair-related factors promoting PSD [9–11], but only one study has evaluated the microscopic morphology of hair found inside the sinus [12]. It may be easy to differentiate between hair of Asian, African and Caucasian individuals [13], but not if the individual is a genetic blend [14]. Even the Federal Bureau of Investigation acknowledges that "..some people can share the same microscopic characteristics [of hair], and shorter hair fragments are notoriously difficult to describe" [15]. Evidence from case reports [16] and current original research [17] suggests that hair originating away from the intergluteal fold is responsible for the pathogenesis of PSD. Electron scanning microscopy evolved significantly since the publications by Dahl, and new techniques such as "coating" have been developed to examine hair [18, 19]. The purpose of this study was to evaluate pilonidal nests' hair microscopic morphology to explain PSD's pathogenesis.

Materials and methods

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.

Hair samples from inside the pilonidal sinus cavity were collected intraoperatively from 20 PSD patients. All patients underwent an asymmetric modified Limberg or modified Dufourmentel closure following excision of the pilonidal sinus, and it is fistula system following toluidine blue injection. The sinus nest was excised in toto and opened at the end of procedure by the surgeon (DD). To avoid "producing" cut hair ourselves, we opened the fistula tract and nest step by step from within. Explicit care was taken to ensure every hair from the sinus cavity, and from the surrounding scar tissue was extracted. Hair samples were labeled as "in" when the hair was within the sinus, and hair sticking out of the pores was labeled as "out." All hair samples were separated, washed, dried and stored in a plastic bag at room temperature hidden from sunlight. Hair was handled according to established methods. [17].

Fig. 1 Number of hair samples derived from within the sinus cavity without (*black*) or with (*red*) a root (624 hair samples derived from 20 individual PSD patients)

Additionally, hair from every PSD patient was epilated from: posterior scalp (external occipital protuberance (EOP), the lumbar lower back region (LL) and the cephalad third of the intergluteal fold (IGF). From each region, six hairs were epilated (if present). Following light microscopic examination, every hair from the sinus was designated as "rootless" or with the root present. Each hair's length was measured, and selected good quality hair samples were further examined using a Leica DM2500 light microscope and a scanning electron microscope (EM). Light microscopic pictures were taken using the photograph program, Leica Application Suite Version 2.8.1. The scanning EM pictures were taken with a Hitachi S5000 after covering the hair samples with a gold layer (working distance 8 mm; EM examination done using acceleration voltage 30 kV). A second sample of hair was dust coated with coal and examined using the FEI XL-30 Emission Gun ESEM electron microscope with a working distance of 9.8–12.7 mm and acceleration voltage of 1.5–1.7 kV in order to allow a more detailed examination of the hair surface.

Scanning electron microscopic pictures were also taken of cut and epilated hair from 20 healthy volunteers to compare potential different morphological aspects.

Excel and Graphpad Prism were used to collect and analyze data and to design the graphics. *T*-tests were conducted to compare two groups of data, and significance was set at $p \geq 0.05$.

Results

Six hundred and twenty-four hairs were harvested from sinus cavities of 20 individual PSD patients. None of these patients reported razor depilation of the intergluteal fold,

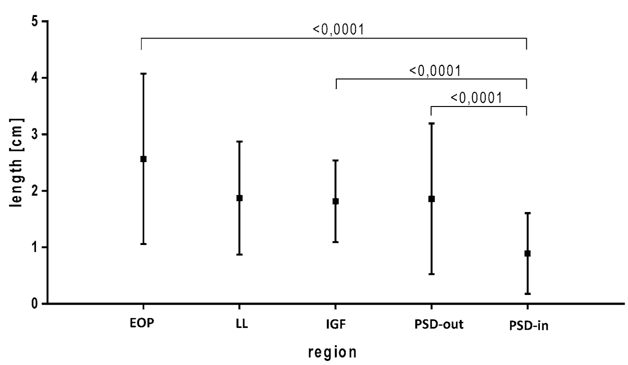

Fig. 2 Subjects' hair length of samples derived from different body regions, including hair from the outer sinus opening ("PSD-out") and the sinus cavity or surrounding scar ("PSD-in"); n = 20 pts. (EOP = external occipital protuberance; lumbar lower back, glabella sacralis; IGF = intergluteal fold; PSD-out = hair partially sticking in the sinus tract; PSD-in = hair within the sinus cavity

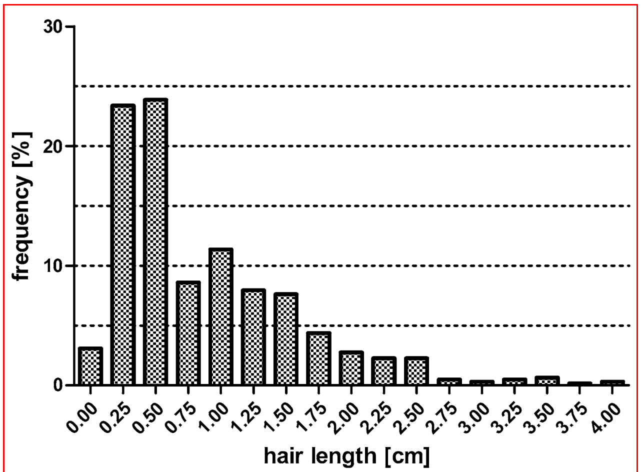

Fig. 3 Frequency distribution of hair length found in the sinus cavity. Please note that 93% of the total hair in the sinus cavities comprise of hair fragments with a length of 2 cm and less

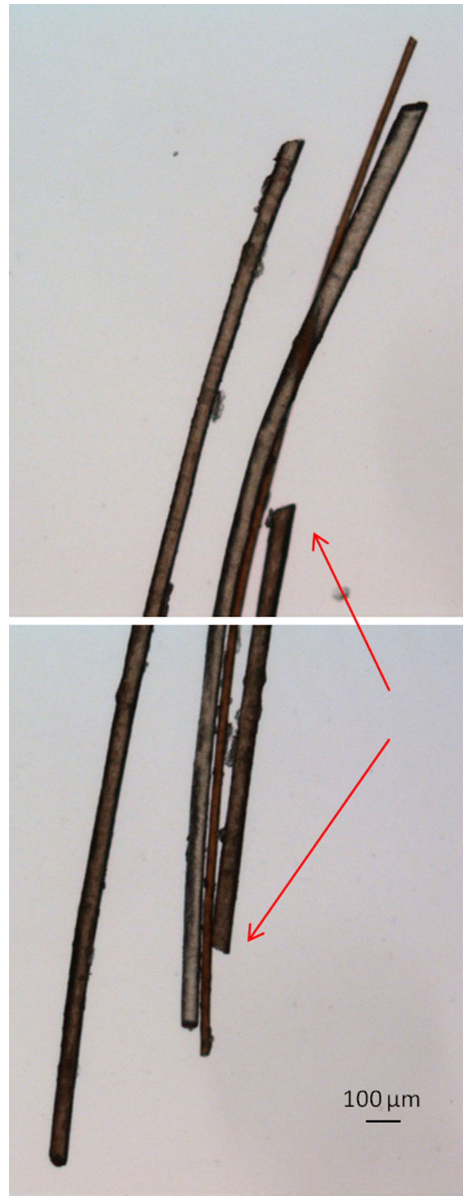

Fig. 4 Light microscopic examination pictures of hair from the sinus cavity, composed of two photographs to show both ends of each hair. All four hairs are rootless. Importantly, both ends of hair are cut ends (*red arrows*) due to a haircut

the nates or their back. The majority of hair samples (462; 74%) were rootless. A root was identified in only 26% (162 hair samples) (Fig. 1).

Figure 2 shows hair lengths according to the body regions. With a mean length of 0.9 ± 0.7 cm ($p < 0.0001$), the shortest hair was found inside the sinus compared to EOP, LL and IGF. Furthermore, the hair samples inside the sinus ("in") were significantly shorter than the hair sticking inside the pores ("out") ($p < 0.0001$). Pore diameter was ≤3 mm in all 20 patients.

The histogram showing distribution of hair length inside of the sinus is displayed in Fig. 3. The frequency of hair within the sinus was greatest of short hair fragments: More than 70% of all hairs were 1 cm in length or shorter, while 93% of all sinus hairs examined were 2 cm or shorter.

Figure 4 displays a typical light microscopic picture composed of two individual photographs of PSD-derived hair samples. The pictures were combined to show both ends of each hair. The four hair samples shown are all rootless, and especially the shortest hair seems to have sharp, cut ends. As a comparison, a scanning electron microscopic picture of an epilated (i.e., pulled out) hair still bearing its root is shown in Fig. 5. To confirm that the samples' ends were cut rather than broken, electron microscopic pictures of iatrogenic cut and broken hair are provided in Figs. 6 and 7. The hair in Fig. 6 was freshly cut with scissors, whereas the hair in Fig. 7 was repeatedly bent 180° in both directions

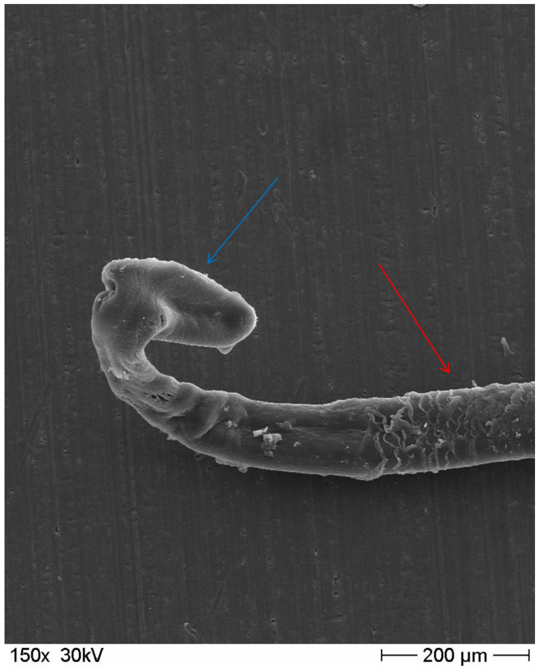

Fig. 5 Hair with typical bent root appendix (scanning electron microscopy, gold covered, 150×). *Blue arrow* root; *red arrow* shaft

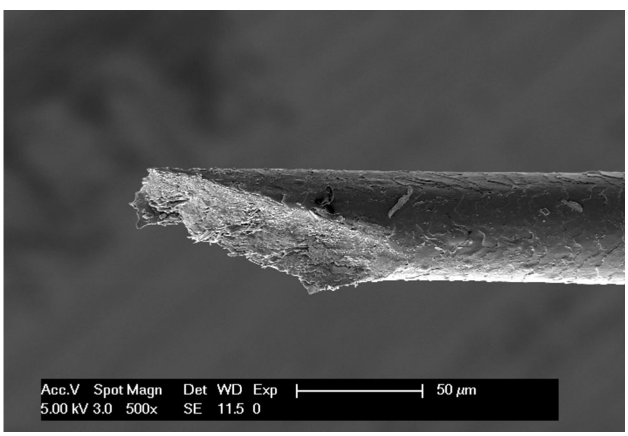

Fig. 6 Hair cut with scissors (scanning electron microscopy, gold covered, 500x)

until breakage occurred. Broken ends were examined using gold-layered electron microscopy. It appeared that broken or split hair does not have sharp ends.

Further electron microscopic investigation of PSD-derived hair (Fig. 4) was conducted. Using higher-resolution analysis, the sinus hair samples show a spiky end that appears to have been cut with a sharp tool (Fig. 8), mimicking cut hair as shown in Fig. 6. Another hair from the same sinus is depicted in Fig. 9, which also appears to be cut at the end. One hair has also been found inside the sinus which resembles a hair sheared or transected with a semi-sharp device (Fig. 10).

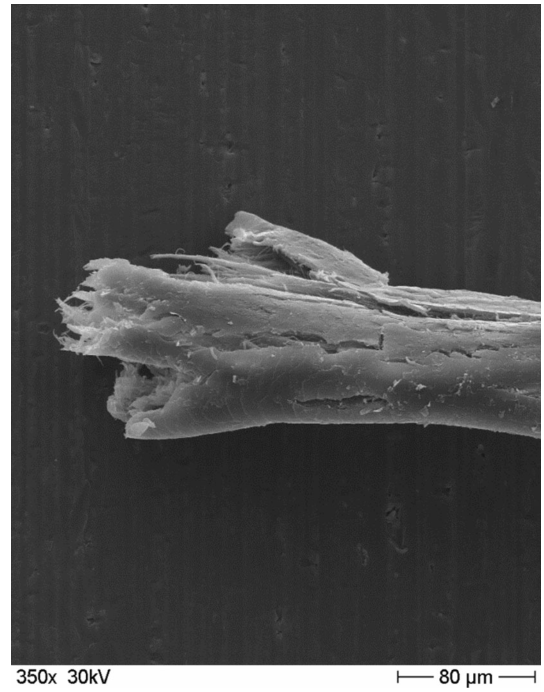

Fig. 7 Hair with broken end using forceps to create blunt force (scanning electron microscopy, gold covered, 350x). The strings sticking out of the broken hair ends are called macrofibrills

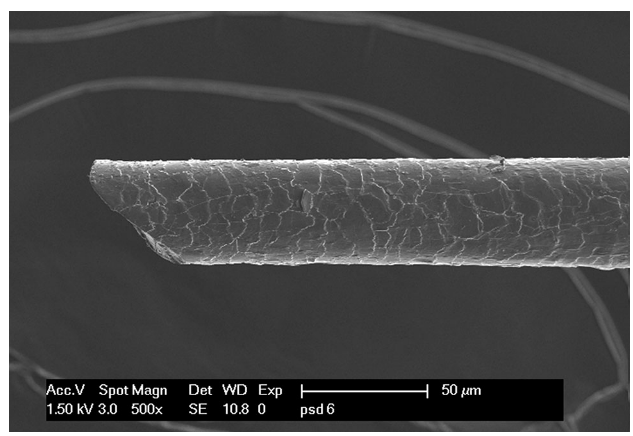

Fig. 8 Hair found in pilonidal sinus with sharp cut end (scanning electron microscopy, gold covered, 500x)

Discussion

The current study examined hair samples from 20 pilonidal sinuses using light- and electron scanning microscopy using gold and coal dust plating techniques. We demonstrated that short hair fragments are found in the sinus cavity (hair fragments <1 cm in length comprising 70% of all hairs). The majority of hair samples in the sinus were rootless with sharp cut ends, while broken hair was not present in the pilonidal cavity (Fig. 7).

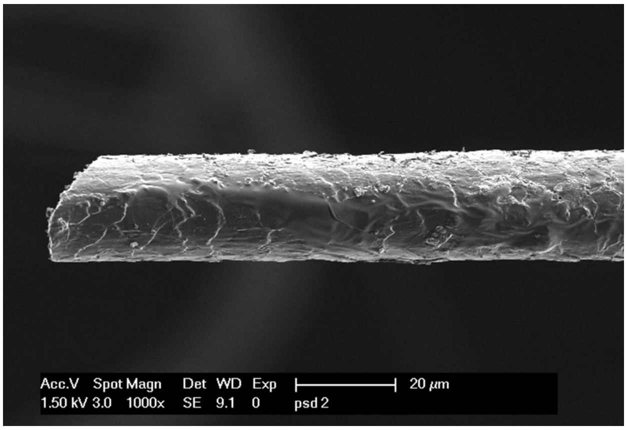

Fig. 9 Hair found in pilonidal sinus with undoubtedly cut end (scanning electron microscopy, coal dusted)

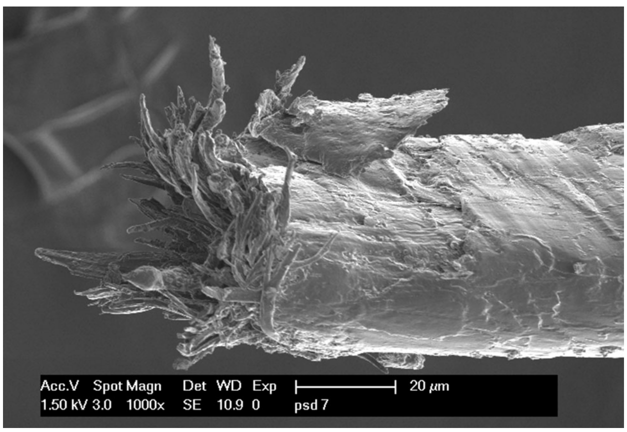

Fig. 10 Hair found in pilonidal sinus, resembling shear force with *parallel lines* on the *right side*

Even though hair is found in between 12 and 100% of pilonidal sinuses [20–25], there are few studies evaluating the role of hair as the causative factor. Harlak et al. categorized the degree of body hair in patients with pilonidal sinus and matched pairs and found a greater extent of body hair in PSD patients [26]. Karydakis described hair as a cause of the PSD, and even developed an equation containing three different factors promoting the development of a pilonidal sinus [3]. Even as hair being one of his postulated causative factors, he did not microscopically examine hair found inside the pilonidal sinus.

Shorter hair appears to be more capable of inserting into the sinus and causing further inflammation [27] in the depth, compared to longer hair, which is getting caught at the entrance of the skin sinus opening. It appears that rootless hair has a three times greater probability of entering the sinus tract than hair with its root. Alternatively, there is a more than 3× higher presence of rootless (cut hair) fragments in the dorsal sweat crest which makes exposure to these short hair fragments much more likely. Independently, this observation brings into question the hypothesis that full hair with folliculitis due to hyperkeratosis (and consecutive penetration of the hair into the subcutaneous tissues with root head on) is the source of every pilonidal sinus [28]. The massive amount of short rootless hair inside a pilonidal sinus has not been previously reported. Pilonidal sinus hair was significantly shorter than hair from three examined body regions. This may be observed if pilonidal sinus hair originates from a region not examined in this study.

Yet, two observations argue against this theory: Firstly, Zimmermann [29] and Patey and Scarff suggested that the hair causing the pilonidal sinus stems from the surrounding skin, which would be the intergluteal fold or higher up along the dorsal crest as high as the occiput [22]. Secondly, there are numerous reports of interdigital, umbilical and dorsum of feet pilonidal sinus occurring in professional barbers (in up to 13% [30]), but none of these studies have found a higher incidence of concomitant postsacral PSD in this cohort exposed to thousands of short hair fragments on a daily basis. Thus, hair seems to stay at the site of the body where it is generated. As gravity counters ascent of hair from a lower body region such as the legs from causing pilonidal sinus, sinus hair must originate from the upper dorsal crest cranial to the pilonidal sinus area. Razor depilation of the intergluteal fold and glabella sacralis/lumbar region could potentially be another source of cut hair. Postoperative razor depilation has been shown to double pilonidal recurrence rate [31]. In our small study group, none of the patients used razor depilation of intergluteal, glabella and back region.

We did not count the double cut versus single cut hair fragment before sending them to the criminal investigation department for further analysis. We approximate that one half to two-thirds of the fragments have double cut ends. All hair still growing in the skin undisturbedly was longer than 1 cm. This was also true for harvested occipital head hair which is always cut. So any fragments shorter than 1 cm are unlikely to be derived from the intergluteal fold or the lower back, because these hairs are generally not cut. So any cut hair—even single cut hair—is most likely from the head. Even a hair with root and shorter than 1 cm is likely to be head hair, as uncut telogen body hair is shorter than 1 cm (Fig. 1).

The presence of multiple short hair fragments with sharp cut ends within the pilonidal sinus implies that cutting head hair, but also razor depilation or machine cut depilation of shoulders, back and lumbar region may contribute to the occurrence of sharp fragments. Often already short hair is cut to keep it short—as in the military, a population in which the incidence of PSD is higher than in the civil population [5, 32].

Pull-epilated hair or telogen hair that falls out still has a root. This type of hair was less prevalent within the pilonidal sinus compared to double cut hair. Therefore, the process of normal aging and hair shedding and regeneration does not seem to be a major source of pilonidal sinus hair. Testing hair stiffness more than 12,000 times in a separate study [17], we never saw a single hair break. Hair needs considerable, repetitive and brute force to break through twisting. Hair never ruptures with a straight surface. Macrofibrils are torn and pulled to the outside at a length of 200 µm or more, which may also be the case in haircuts using so-called thinning shears used by barbers.

The study by Dahl and Henrichs has focused on the morphological aspects of the hair commonly found inside pilonidal sinus [12]. Although their scanning electron microscopic pictures of hair ends are similar to our pictures, they conclude hair ends were broken. However, compared to our pictures of a cut and a sheared hair, the hair ends shown in their study seem to have been cut. The evidence derived from scanning electron microscopic pictures in our study suggests that both cut and sheared hair fragments are found inside the sinus. However, a sharply cut hair is mechanically more capable of penetrating skin and thus causing a sinus [14, 16]. The sharply cut hair can translate an axial force onto a very small area of skin, thus exerting significant pressure onto a small area of skin forcing itself through the skin surface. A broken hair is not able to direct its force onto a small area of skin but divides its axial force onto a greater surface, resulting in a smaller pressure with pressure defined as $p = F/A$ where p = pressure, F = force, and A = area.

With greater hair stiffness, even more trajectorial force may be exerted through these sharp-ended fragments to promote pilonidal hair injection [17].

How do we explain that some pilonidal nests may be without hair? It seems that the hair scales allow more than one direction of hair movement. Scale effects are maximum if the tract diameter is close to the hair diameter, while in larger tracts the hair has only contact with a fraction of its circumferential scales along the fistula tract, minimizing the effects of the scales. This allows hairs with roots to move in root last if larger tracts are present. If tract diameter exceeds root diameter, then hair insertion with root first into an already patent tract is possible. The establishment of new tracts by rooted hair seems rather unlikely. It is thought that rooted hair follows into already established tracts and nests, though at a slower pace than rootless hair fragments. One can find large amounts of hair also in cases with a very fine opening, almost invisible to the eye.

40–88% of pilonidal sinus nests may not contain hair [23–25]. In a small series of pilonidal sinus histology of so-called empty nests, histological examination was performed by our consultant pathologist in 130 specimens. Findings were compared with each patient's theater notes. In 110 patients, hair was found intraoperatively and in the specimen (85%). A further 5/130 (4%) nests had hair within the cavity but not within walls, on microscopic examination. Of these empty nest specimens, in 11/130 situations there was macroscopically no hair, but microscopy showed plenty of hair.

Only in 4/130 (3%) of the patients, there was macroscopically and microscopically no hair. So in the majority (11/15; 75%) of clinically "empty nests," hair could be found embedded within the scar tissue of the nest wall. This is comparable to Franckowiak and Jackman identifying hair just microscopically in 15% of patients [24]. Thus, hair already present in the cavity may insert itself into the tissue wall surrounding the pilonidal cavity. Theoretically, hair exits from the nest to skin—as proposed by Karydakis in 1992 [10]—is possible. It is hard to understand though why hair should preferentially exit toward the skin and not impregnate the surrounding tissues at a comparable rate. The exit of hairs through patent tracts is possible if tracts are of small diameter and the hair has turned once inside the pilonidal cave. With larger pore diameters, the effect of the hair scales may be less pronounced, and hair may exit a sinus with the root end last.

The nature of the morphologic and descriptive character of microscopic hair analysis limits the generalizability of our data. Twenty consecutive hair nests chosen for analysis comprise a relatively small cohort. As we did not register type and frequency of previous haircuts, drawing a link between frequent haircuts and larger numbers of fragments in the sinus would be premature. Although large numbers of short sharp fragments can be found within the pilonidal nest, we cannot deduce which hair generates and forms the tracts and cavities, and which hair follows. Hence, larger studies need to concentrate on the military cohort analysis because of higher incidence of PSD. We analyzed only samples from a random civilian population presenting for elective surgery.

The options to prevent implantation of cut hair in the natal cleft are manyfold—reducing the amount of hair generated and falling down (less often haircuts, clippers vs. scissor cut, wet cut vs. dry cut, hair dryer (blower) after cut, shower after haircut), reducing the contact time of hair in the intergluteal fold (shower after haircut, laser depilation of intergluteal hair), reducing the rate of insertion (methods of skin protection). Strategies to identify those at risk and to prevent pilonidal sinus formation as well as recurrent disease are desperately needed for the young generation.

In conclusion, large numbers of mostly rootless hair with cut ends were found inside pilonidal sinus cavities. Usually young men's head hair is cut and shaved more frequently than body hair, making it the most likely source of the large numbers of hair within a sinus. As sharp ends penetrate the skin better than blunt ends, these might cause PSD. Additionally, cut hair fragments with sharp ends may promote hair insertion into the healthy intergluteal skin. Possibly not short hair itself, but short hair styles needing multiple haircuts may be an important part in sinus development.

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