On the Pullout Strength of Human Nasal Hair

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Abstract

This study investigates nasal hair-to-dermis detachment in humans, quantifying the pullout force required in adult males. While many studies have investigated the behavior and function of human body hair, little is known concerning the mechanical properties of human nasal hair or the strength of the hair-to-dermis attachment. Improved understanding of nasal hair pullout in humans could aid nasal packing design, contaminant removal procedures, and even aid certain cosmetic procedures where nasal hair removal via pullout is the objective. In this study, pullout behavior of human nasal hair is investigated using sensitive force-measuring equipment and advanced scanning electron microscopy. Fifty nasal hair samples are collected from two human subjects (the study authors) representing a total of 100 pullout measurements. Results indicate that nasal hair thickness (diameter) is unrelated to required pullout force, and that the root-width-to-hair-diameter ratio appears to be a reasonable indicator of the resulting nasal hair pullout force. Larger root ratios generally correspond to larger required pullout forces. Nasal hair pullout strength from the combined 100 samples varied between 0.043N and 0.726N with mean pullout strengths of 0.430N and 0.293N for Subject 1 and Subject 2 respectively.

Keywords: *Nasal hair, pullout strength, experimental testing*

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Introduction and Background

The bristly hairs within the human nasal cavity operate to filter environmental contaminants, humidify inhaled air, and are similar in structure to external whiskers common on many mammals [1-3]. As foreign contaminants accumulate and solidify within the nasal cavity, contaminant removal may result in pullout of the nasal hair (removal of the root from the nasal dermis) which can be painful. Additionally, medical nasal packings (common following nasal surgeries) or instruments that are required to enter the nasal cavity for contaminant removal may sometimes adhere to the nasal hairs resulting in undesirable hair pullout, subsequent pain, and even folliculitis (a skin condition resulting in inflamed hair follicles). Improved understanding of nasal hair pullout in humans could help aid future nasal packing design and contaminant removal procedures where nasal hair pullout should be avoided, or even aid certain cosmetic procedures where nasal hair removal via pullout is the objective.

While many studies have investigated the mechanical behavior and function of human body hair, no studies were found to have focused on the mechanical properties of human nasal hair, or nasal hair-to-dermis detachment. One related study investigating the anchorage of human chest hair found that the pullout strength of actively growing hair is similar to that of hairs that have entered the growth rest phase [4]. Several other investigations on human hair have documented properties including the elastic, yield, and post-yield mechanical behavior, measuring fracture strains nearing 30% elongation [5-9], and documenting fracture features such as the structural separation of the hair cuticle from the cortex prior to fracture [9, 10]. However, because nasal hairs have follicles that are much larger, possess blood-filled sinus tissue, and are highly innervated [11], associating the observed properties of human body hair to nasal hair is not justified.

This study investigates the properties of nasal hair-to-dermis attachment in humans by focusing on pullout strength (the peak pullout force), aiming to quantify the force required for nasal hair removal in adult males. The paper begins by discussing the detailed experimental methods used, followed by descriptions of the human subjects and experimental results. Lastly, conclusions from the experimental testing are presented.

Methods for Nasal Hair Pullout Strength Measurement

The primary objective of the experimental program is to determine the force required to remove human nasal hair in adult males. To accomplish this goal, sensitive force measurements were taken during "plucking" of the nasal hair. The following sections detail the force-measurement procedure and describe the human subjects and nasal samples considered.

Test Setup, Instrumentation, and Loading

Figure 1 shows the apparatus developed to measure the pullout force of human nasal hairs. In Figure 1, an accuracy class 0.02 axial force transducer (type S2M produced by HBM, inc.) having 10N force capacity is mounted to a linear motion stage and connected in series to clamping tweezers using a cable. To prevent unintended tension in the cable from the weight of the hanging tweezers, a support stage was mounted at the level of the transducer, as shown in Figure 1. Additionally, to reduce any force transfer between the tweezers and support stage, a low friction polytetrafluoroethylene (PTFE) surface was provided. Following attachment of the tweezers to the nasal hair, tensile forces in the cable (created during nasal hair pullout) measured by the force transducer are recorded at 300 measurements per second using an HBM, inc., Quantum-X MX840B data acquisition system.

The nasal hair, tweezer clamp, cable, force transducer, and linear motion stage are all arranged in series (see again Figure 1), and are all subjected to the same axial force during testing.

Following attachment of the tweezer clamp to the nasal hair, the test subject is required to retract their head in a controlled manner (keeping the tweezer clamp in contact with the low-friction support stage) until detachment of the nasal hair is achieved. Because of this series arrangement, as long as the nasal hair remains unbroken during testing, the force transducer measurement will directly reflect the hair root-detachment pullout force. Figure 2 shows the equal axial force load path through the nasal hair into the nasal dermis.

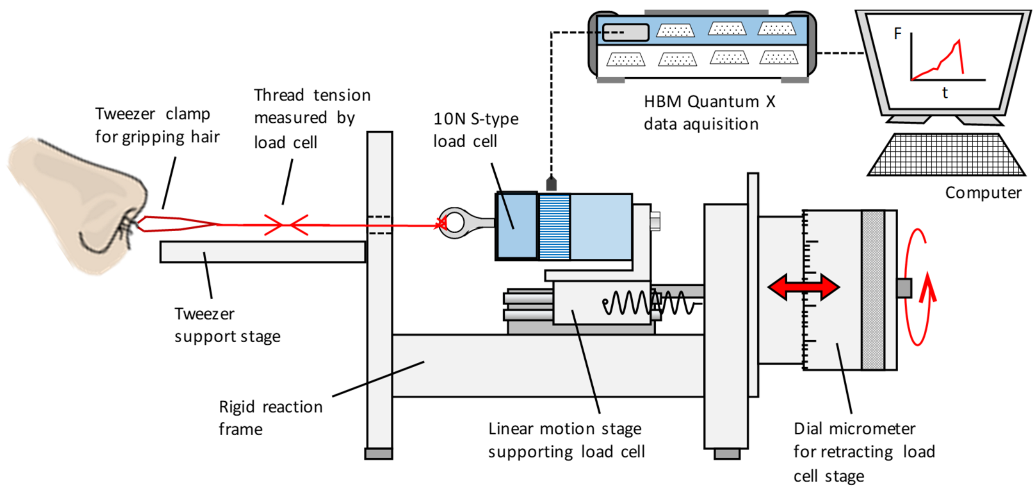

Figure 1. Testing apparatus for measuring nasal hair pullout force

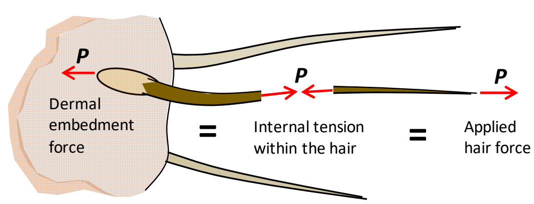

Figure 2. Load path from the applied force, through the nasal hair, into the nasal dermis

Human Subjects

The two study authors served as the human subjects for the nasal hair testing, allowing records of anecdotal evidence related to pain consistency and physiological responses to be presented along with the experimental measurements. Fifty individual nasal hairs were plucked from each of the two subjects, providing a total of 100 pullout force measurements. Given the author gender and race profiles, all pullout test data are representative of adult (ages 29 and 34) Caucasian male nasal hairs.

Hair Geometry Measurement Methods

To explore hair-root geometry factors that may affect pullout strength, four nasal hair samples from Subject 1 were investigated using a Tescan Vega 3 scanning electron microscope (SEM). SEM imaging was chosen for the investigation to allow detailed observations and measurements of plucked nasal hair microscopic features. In order to secure the hairs for imaging following the pullout tests, individual nasal hairs were attached to an adhesive carbon tape backing with careful consideration not to deform or damage the hair root during attachment. Measurement results and observations from the nasal hair SEM images are discussed in the following "Results and Discussion" section.

Results and Discussion

Nasal Hair Pullout Strength

Nasal hair pullout strength from the combined 100 samples tested varied between 0.043N and 0.726N with a mean pullout strength of 0.430N for Subject 1 and 0.293N for Subject 2. Figure 3 shows the individual strength test measurements and observed scatter from the 50 plucked hairs of Subject 1 and Subject 2. Each test measurement plotted represents a single, unbroken, nasal hair that was completely detached from the nasal dermis. From Figure 3, while the individual subject mean pullout strengths differed slightly (0.430N for Subject 1 and 0.293N for Subject 2), it is interesting to note that the strength measurement variation in each of the human subjects was similar. The standard deviations for the distributions of pullout strengths from Subject 1 and Subject 2 were 0.128N and 0.141N, respectively. Additionally, the diameter of the plucked nasal hair had little to do with the recorded pullout strength, as finer hairs had measured pullout strengths greater than those of comparatively thicker hairs as will be discussed further in the following sections.

To determine whether the strength datasets of Subject 1 and Subject 2 could be combined, a two-tailed Student's t-test (two sample t-test assuming equal variances) was considered along with a chosen level of risk equal to 5% (95% confidence). Table 1 demonstrates the statistical equivalence test between the measured nasal hair pullout strengths of Subject 1 and Subject 2 indicating significant variation between the test subject measurements (the hypothesis of equivalence should be rejected). Because of the significant variance in pullout strength between Subject 1 and Subject 2 (perhaps caused by differences in the nasal-hair root and surrounding dermis conditions), independent mean strength values should be considered (without combining into a single mean pullout strength).

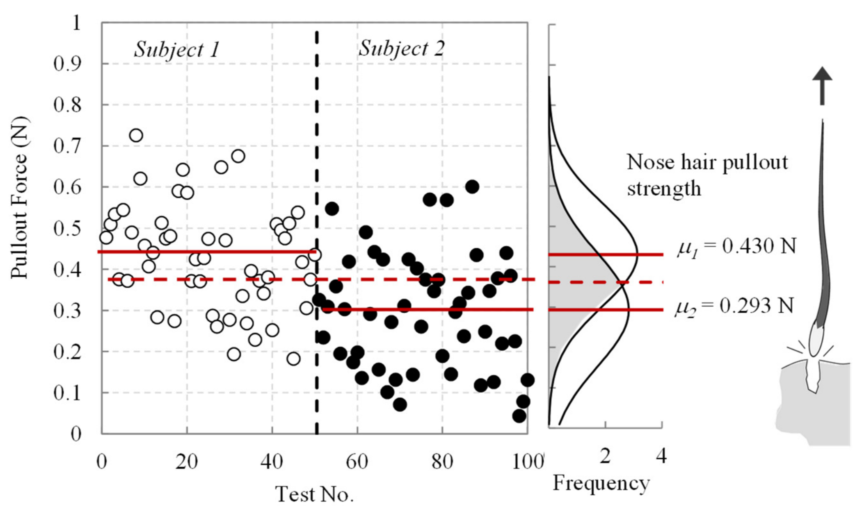

Figure 3. Nasal hair pullout force measurements and distributions for Subjects 1 and 2

Table 1. Two-sample t-test assuming equal variances

	Subject 1	Subject 2
Sample size	50	50
Mean value	0.4299	0.2931
Variance	0.0163	0.0200
Pooled Variance	0.0181	
Hypothesized Mean Difference	0	
Degrees of freedom	98	
t-Stat (T)	5.08	
t-Critical (t)	1.98	
P(T <= t) (two-tail)	1.79×10^{-6}	

t-Stat > t-Critical therefore the hypothesis of equivalence has to be rejected.

Effect of Nasal Hair Root Geometry on Pullout Strength

The ratio of maximum root width to nasal hair diameter appears correlated with the resulting hair pullout force, with larger ratios generally corresponding to larger required pullout forces as might be expected. Table 2 provides the SEM root measurements of the four representative nasal hair samples from Subject 1, along with the corresponding measured pullout strengths. Efforts were made to consider representative nasal hairs of varied root-ratios such that results could be generalized to account for natural variation within the nasal cavity. SEM images of the nasal hair roots are also provided in Figure 4, with all images taken at the same length scale for direct comparison. From the strength measurements in Table 2 and the images in Figure 4, the larger hair diameter of Specimen A was shown to have a lower pullout strength than Specimen C which had a smaller diameter but a higher root-to-hair diameter ratio. Plotting the root ratio versus pullout strength (shown in Figure 5), demonstrates that increasing the root ratio results in increased pullout resistance, with potentially diminishing returns beyond ratios of 2.5.

Table 2. Nasal hair root measurements and corresponding pullout strengths

Nasal Hair ID	Root Base, b (μm)	Root Width, w (μm)	Root Ratio (w/b)	Pullout Strength (N)
A	91.0	140.7	1.55	0.376
B	85.7	225.9	2.64	0.509
C	49.8	120.7	2.42	0.534
D	74.3	143.2	1.93	0.477

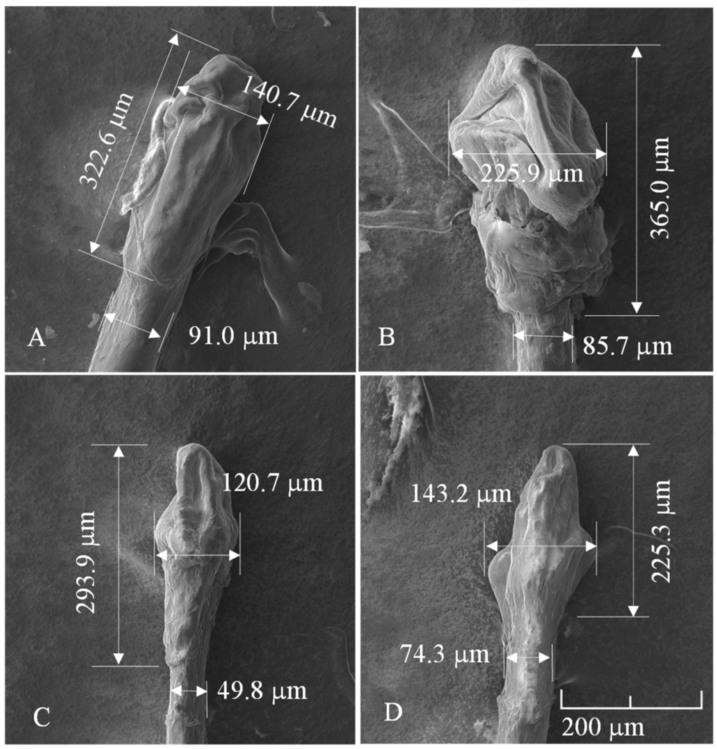

Figure 4. Scanning electron images and dimensions of nasal hair roots following pullout *(note: all images represent nasal hairs of Subject 1*)

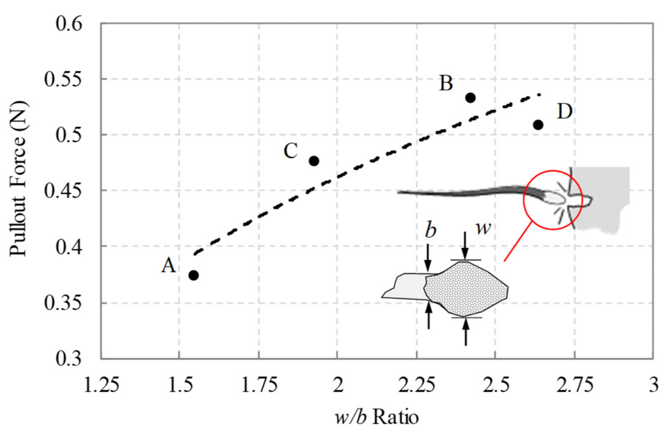

Figure 5. Nasal hair pullout force versus the hair root ratio from SEM measurements of Subject 1

Effect of Pluck Speed on Pullout Strength

Figure 6 presents the complete force time-history of the four nasal hair tests described earlier, shown to represent the typical force-time behavior observed in the pullout tests. Note in Figure 6 that a slight pull hesitation by the human subject (due to nasal pain during loading) resulted in brief dips in the force time-history plots for two of the shown hair measurements. From Figure 6, pluck velocity had little noticeable effect on the resulting force required for pullout, as sample *B* at 0.303 seconds and sample *D* at 0.830 seconds differed by less than 0.02N.

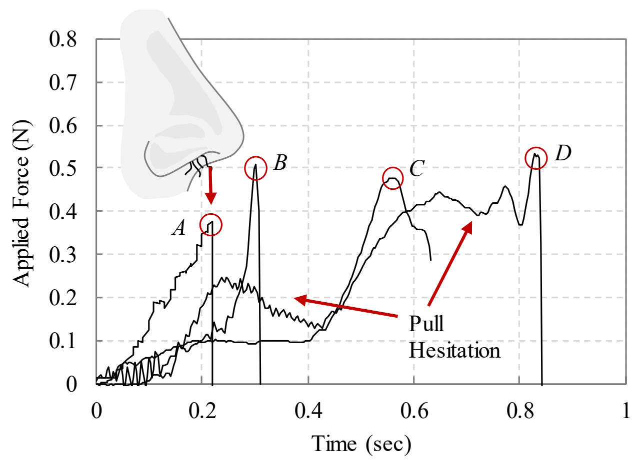

Figure 6. Force time-history plots of representative pullout tests from Subject 1

Nasal Hair Pullout and an Observed Physiological Sneeze Response

Separate from the force measurements taken, physiological sneeze responses were also documented. Initial nasal hair pullouts were almost always accompanied by a sneezing and eye-watering response; however, after two-to-three plucks, this sneezing response stopped (as if our bodies became adapted to the nasal sensations). Interestingly, given a brief break from the plucking experimentation, the sneezing response would again manifest for the first several nasal hair pullouts, before again ceasing (as if our bodies again became adapted to the sensation). This same sneeze trend was observed for both test subjects. Nasal pain associated with the experimentation also diminished following the first several specimens collected; however, the internal fear of nasal pain persisted with each test (as did the occasional pull hesitation response).

Conclusions

Pullout behavior of human nasal hair was investigated using sensitive force-measuring equipment and advanced scanning electron microscopy. Fifty nasal hair samples were collected from two human subjects (the study authors) representing a total of 100 nasal hair pullout measurements. SEM root geometry measurements were gathered from four representative hair samples taken from one test subject. The following conclusions are based on the 100 nasal hair pullout measurements and the limited SEM dimensional analyses.

1) Nasal hair pullout strengths were significantly different between the two test subjects, but pullout strength variability was relatively consistent within the nostril of each test subject. Individual mean pullout strength values for Subject 1 and Subject 2 were 0.430N and 0.293N respectively, with similar individual standard deviations of 0.128N for Subject 1 and 0.141N for Subject 2. Pullout strengths from all 100 samples tested varied between 0.043N and 0.726N.
2) Nasal hair thickness (diameter) is not correlated to required pullout force, as finer hairs occasionally had measured pullout strengths greater than those of comparatively thicker hairs.
3) The root width-to-hair-diameter ratio appears to be a reasonable indicator of the resulting nasal hair pullout force, with larger ratios generally corresponding to larger required pullout forces; however, more hairs should be evaluated to verify this trend.

4) Nasal hair pullout consistently induced a physiological sneeze and eye-watering response; however, following several consecutive nasal hair detachments, the sneeze response and eye-watering ceased.

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Declaration of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This work was funded by human curiosity alone.

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