BJD
British Journal of Dermatology

Insights into shaving and its impact on skin

K. Cowley and K. Vanoosthuyze

Gillette Reading Innovation Centre, Reading, U.K.
460 Basingstoke Road, Reading, Berkshire RG2 0QE, U.K.

Correspondence
Kevin Cowley.
E-mail: cowley.k@pg.com

Accepted for publication
17 November 2011

Funding sources
This work was fully funded by Procter & Gamble. Financial support for publication of this supplement was provided by Procter & Gamble.

Conflicts of interest
The authors are employees of Procter & Gamble.

DOI 10.1111/j.1365-2133.2011.10783.x

Summary

Male grooming has its roots in antiquity. Control and styling of facial hair has invariably required the development and use of metal instrumentation. Once crude and unreliable, it has latterly become sophisticated and subject to intense research and development at the highest scientific level. This paper describes how male grooming is being impacted by improvements in fundamental understanding of male skin. Skin issues associated with poor hair removal approaches are common, but are often overlooked or their aetiology misunderstood by patients and physicians. By incorporating advanced scientific measurement and imaging technology into clinical testing, insights are being gained into both the common concerns which men express and optimal solutions for these concerns. Specific aspects such as the study of nicks and cuts and the identification and release of trapped hairs are discussed. Finally, details are presented on how the individual elements of technologically advanced razors play a role in managing the skin and hair, highlighting further the complexity of the shaving process.

The process of shaving represents a complex compromise, in balancing robust removal of hair against minimizing impact to the sensitive skin substrate. Men typically articulate their ideal shave as one which maximizes the closeness of the shave, but does not compromise on comfort or skin irritation. Close examination of the physiology of the male beard reveals that it can be likened to tough fibres embedded in a soft jelly-like matrix (Fig. 1). This discrepancy in the relative properties of skin and hair results in a significant challenge when attempting to manipulate hairs for optimal, safe removal during shaving.

The shaving challenge

The elastic modulus of dry beard hair has been measured to be around 3–4 GPa, which decreases to around 1–2 GPa when the hair is fully hydrated.[1,2] The deformation of skin, in comparison, is highly nonlinear and viscoelastic, with skin approximated to have an initial modulus of the order of 1 MPa.[3,4] This results in a relative ratio of around 1000 for the stiffness of hair/skin, resulting in hairs being relatively loosely supported in facial tissue. As a blade engages and cuts a hair, the hair can be seen to be translated in the plane of the skin due to the lack of support, resulting in a sensation of tug and pull.[5] Similarly, application of hair cutting forces along the axial direction of the hair shaft has been shown to result in hair extension from the hair follicle, due to distortion of the soft material between the hair root and the skin surface layers.[6]

The cross-sectional size and profile of each individual hair are known to vary between individuals and across the facial sites of a single individual.[2] Beard hairs are typically larger and more elliptical than scalp hairs[7] and consequently are observed frequently to rotate in their follicles to present the major axis of the hair to the advancing blade edge.

Thus, it can be seen that hairs are highly mobile within the skin in both rotational and axial directions. These effects confound efforts to engage and cut the hairs close to the skin surface. However, hair mobility can be exploited to provide a measurable improvement in closeness and this has formed the basis for multiblade razor strategies for many years.[6]

The manner in which people shave will also vary tremendously across individuals, perhaps as a consequence of the relatively private nature of the shaving process. Many individuals will be self-taught, adapting their technique to meet the individual needs of their physiology and attitudinal preferences. Differences are observed in all aspects of shaving behaviour, including the regimen deployed prior to and after the shave and the number, direction, speed and force of shaving strokes used.

Various instrumental methods are available to study the behaviour of individuals, although many require bespoke development to be applied to the shaving process. These include filming techniques, often using ultra-high speed digital cameras, motion capture systems to record biomechanical movements and instrumented razors to measure the applied forces associated with the shave.

Fig 1. Topography of the neck, illustrating stiff hairs held within soft, undulating skin.

Table 1 Shaving behaviour data indicating the range of behaviour seen across a range of subjects

	No. of strokes	Shaving load, (N)	Preparation time, (s)	Shave time, (s)
High	700	4	100	1000
Low	30	0·5	10	30

Typical high and low values for each parameter are shown.

Example data gathered in this way are shown in Table 1, highlighting a typical high level for each shaving parameter and a typical low level. It can be seen that the differences between individuals are frequently greater than an order of magnitude. Consequently, commercial razors are required to contend with a huge variety of shaving behaviours in the hands of consumers, in addition to the physiological challenges mentioned previously.

The neck as a specific problem area

The physiology of the face varies significantly between adjacent areas, even within an individual. Comparison of the properties of cheek and neck, for example, shows large differences in many of the key variables that will impact the quality of the shave. Hair elevation angles have been shown to be significantly lower on the neck than on the cheek, (Gillette, Unpublished data) a factor which can make it more difficult for the blade to engage into the hairs when stroking with the hair growth direction. Skin properties also exacerbate the problem with, for example, greater skin roughness on the neck than on the cheek, as shown in Figures 2 and 3. In some cases, localized mounding of the skin on the neck can impede the beard hair from protruding freely from the follicular opening (Fig. 4), described as a 'trapped hair'.

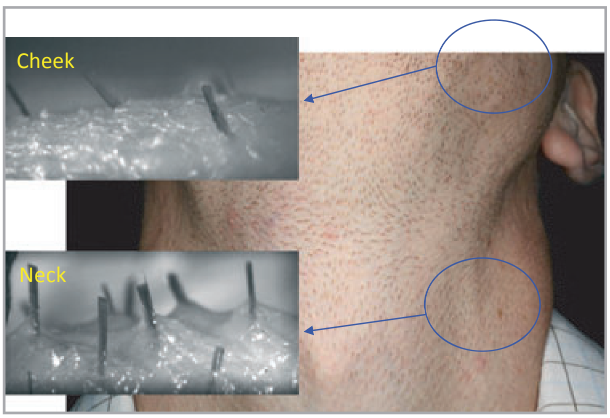

Fig 2. The difference in skin roughness observed for cheek and neck regions on a single individual.

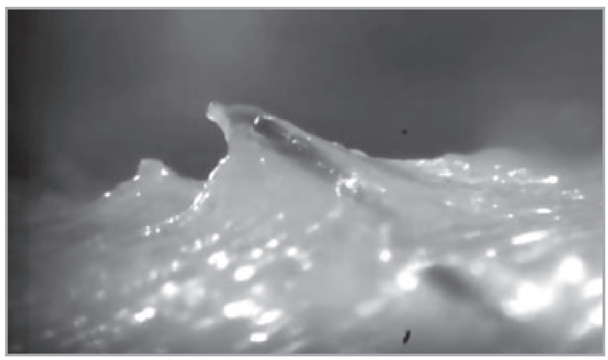

Fig 4. A trapped hair, characterized by localized mounding of the skin on the neck, 48 h after shaving.

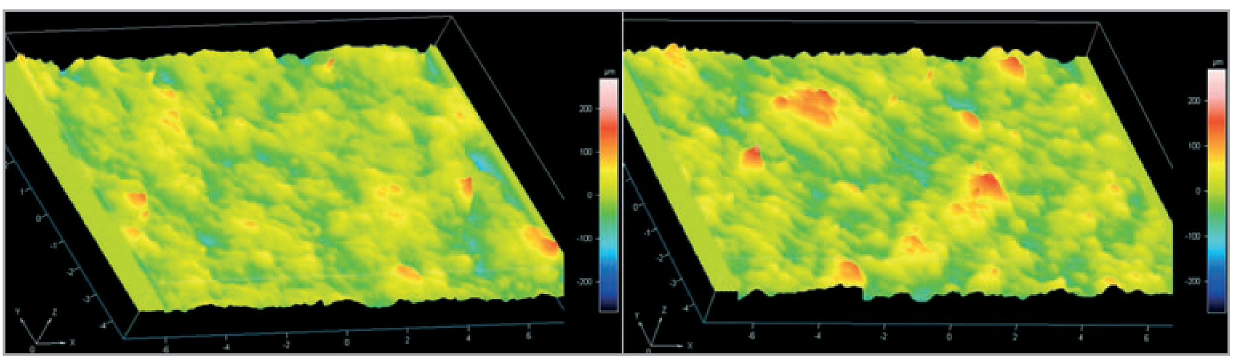

Fig 3. Skin roughness measured for cheek (left) and neck (right) using the PRIMOS system. Mean ± SD roughness measurements (Ra) across 12 male panellists were 17·5 ± 4·4 μm for cheek and 25·3 ± 5·2 μm for neck, measured 24 h post-shave.

The majority of men report the neck as the area where they are most likely to experience soreness and irritation. Signs of shave-induced irritation include redness, nicks and cuts, burning, stinging, tightness, dryness and itching. Among men who shave with a razor, 'Does not nick or cut' is the number one priority in their blade shaving product needs (Gillette, Unpublished data). Detailed understanding of the quantity and location of nicks and cuts is therefore a key element in understanding during-shave and post-shave comfort.

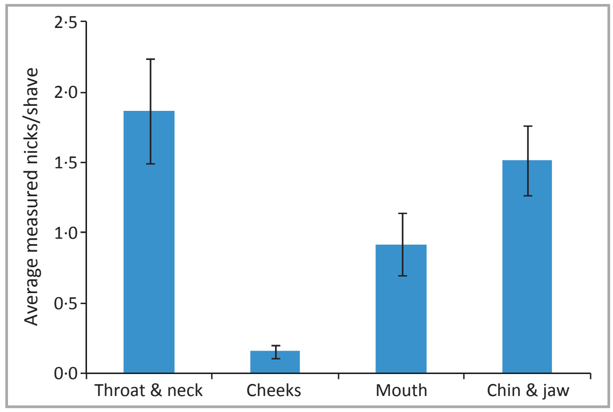

Fig 6. Shaving nicks shown as a function of facial area. The data are taken from an independent clinical study involving 32 men, shaving daily over a 3-week period with a three-bladed system razor and commercially available shave gel.

Objective measurement of nicks and cuts

Traditionally, studies of the impact of shaving upon skin have relied upon consumer self-assessment, conducted immediately after the shave. This form of assessment is contingent on the diligence and eyesight of subjects, and ambiguity exists in the classification of an individual nick. In addition, many of the nicks may be small in size and can be occluded from the line of sight of the subject. Micronicks may therefore be linked to, and perceived as, other consumer endpoints, such as shaving soreness and irritation.

In the development of safe shaving products, there is a need to quantify facial nicks reliably and accurately to evaluate product performance. To this end, a new imaging and analysis methodology has been developed, enabling the capture of repeatable high-resolution digital images of the face. The system comprises three automatically controlled 15 megapixel cameras, with accurate repositioning of the subject's head. Images are taken before and immediately after shaving, to allow assessment of shave-induced nicks (Fig. 5). Thereafter, software enables rapid processing of images, alongside the subject's metadata. An automatic facial segmentation algorithm identifies different facial regions and nicks are identified through operator assessment. Importantly, the system allows a permanent record to be stored, for full data traceability.

The system has been deployed in independent clinical testing and has enabled the measured nicks to be evaluated as a function of facial area. Thirty-two men, shaving with three-bladed system razors with commercially available shave gel, were measured twice weekly over a 3-week period to assess the quantity of nicks obtained. The results are shown in Figure 6 and illustrate that the greatest propensity to nick is on the throat and neck. This is consistent with the challenging physiology of the neck noted previously and with consumers reporting the neck as a problem area.

The results enable exploration of the correlations between objectively measured nicks and the different attributes of self-assessed irritation. Measured nicks were shown to correlate significantly with self-assessed rash/redness on the neck (Fig. 7). In the pursuit of detailed understanding of the fundamental interactions occurring during shaving, these data indicate the need to deploy measures with the greatest levels of sensitivity. Above all, the data highlight the need for the razor to manage the skin effectively, to minimize shave-induced nicks which can contribute to perceived irritation.

Identification and release of trapped hairs

Years of extensive research in the area of male hair removal have identified several key issues that men continually experience in the hair removal process. One particular issue stems from the phenomenon of trapped hair. Although less

Fig 5. Example images of a subject obtained using the system for quantification of shaving nicks.

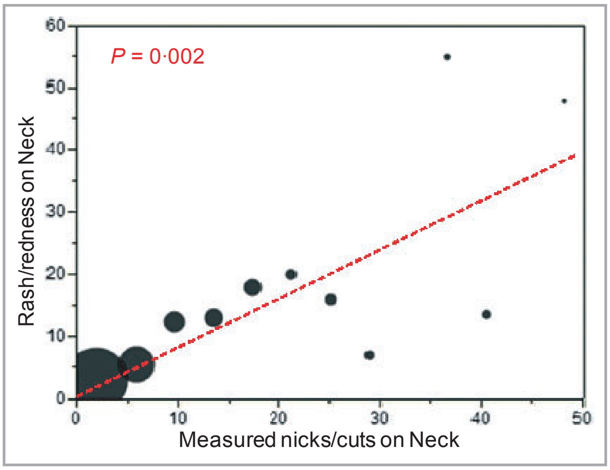

Fig 7. The relationship between measured nicks and self-assessed rash/redness on the neck, indicating a significant correlation at >95% confidence. The data have been grouped to provide a weighted correlation, with the size of each bubble relating to the number of datapoints represented.

severe than clinical conditions such as pseudofolliculitis barbae,[8] trapped hairs are thought to affect a much wider population and can have a negative impact on the success of a man's wet shaving routine, often leading to irritation in prone areas, such as the neck. As such, the ability to characterize trapped hairs and develop remedial treatments to address the issue is of relevance to male consumers. The neck is particularly prone to trapped hairs due to the unique physiological characteristics of the skin and hair, particularly loose, rough skin and high incidence of low-lying hairs. There is evidence to suggest that shaving irritation involves the removal of irregular elevations of the skin by the razor blade, particularly around follicular openings.[9] Incorrect management of trapped hairs can therefore result in inefficient hair removal and potential skin irritation during shaving, which in turn can exacerbate the problem, leading to a cycle of repeated skin insult and repair.

To date, standard two-dimensional (2D) imaging of facial areas prone to trapped hair has proved to be limited. Often the ambiguity associated with 2D images has prevented the observer from determining if a hair is trapped and if so, to what extent. This has been a challenging barrier in the development of novel approaches to help relieve the issue of trapped hairs.

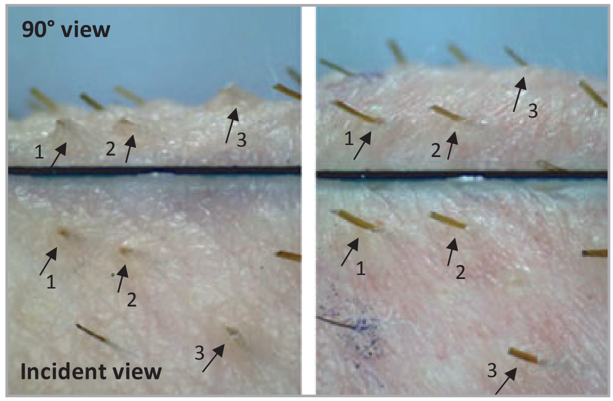

Fig 9. Example images from the stereo viewing system, showing simultaneous incident view and 90 ° view of the same hairs before (left) and after (right) treatment with a preshave scrub, illustrating release of trapped hairs (as indicated by the arrows).

Recent advances in high-resolution three-dimensional (3D) imaging, coupled with specific research efforts, have led to the development of novel methods for the identification and characterization of trapped hairs. The first of these methods utilizes a commercially available microscope (Veho VMS-001 USB microscope; Veho, Eastleigh, U.K.) modified to include a proprietary stereo viewing adaptor (Fig. 8). This system enables imaging of trapped hairs and associated skin topography from both incident and 90° views simultaneously. Example images from the system are presented in Figure 9, showing hairs before and after treatment with a preshave scrub, illustrating trapped hair release. The precise field of view limits this system, however, to qualitative analysis. A second system enables a quantitative approach, through deployment of stereo photography. A single lens reflex camera with a stereo lens attachment is used to generate stereo pairs within a single image. The image is then cropped into separate left and right images, which are overlaid for 3D viewing on a stereoscopic monitor (Fig. 10). Characterization of trapped hairs is conducted by an operator via inspection and quantification of the 3D images.

A product comparison test was conducted to quantify the impact of commercially available scrub and brush products on trapped hair release, against a water splash control. Trapped hairs were quantified on six selected sites on the necks of 12 male subjects before and after each treatment, 48 h after shaving. It was shown that incidence of trapped hairs was higher than anticipated, with 100% of test participants exhibiting

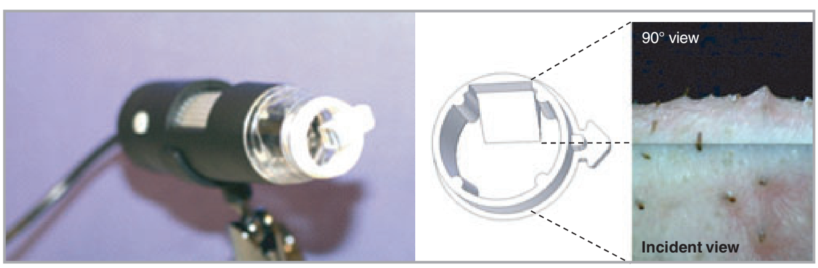

Fig 8. Commercially available microscope modified to include a proprietary stereo viewing adaptor. This allows images to be obtained simultaneously from both incident and 90 ° angles, facilitating the characterization of trapped hairs.

Fig 10. Single lens reflex camera with a stereo lens attachment used to generate stereo pairs within a single image. The image is then viewed using a stereoscopic monitor.

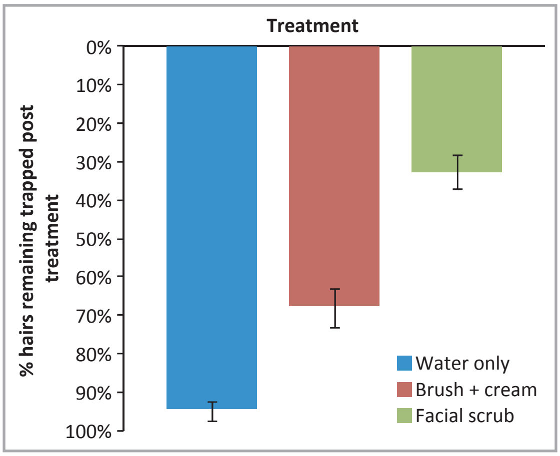

Fig 11. The impact of treatment on the number of hairs remaining trapped on the neck. Six sites were tested on 12 male subjects before and after each treatment, 48 h after shaving. The facial scrub was found to be the most effective treatment in releasing hairs that were trapped prior to the shave. The error bars represent 95% confidence intervals for the data.

trapped hairs on the neck area. On average, almost 20% of beard hairs in tested male neck sites were trapped before treatment, with some study participants experiencing greater than 35%. After treatment, use of either the scrub or brush treatments yielded a significant trapped hair release benefit compared with a water-only control (Fig. 11). Furthermore, use of such preshave products has proven beneficial in improving men's shaving experience.[10]

The razor's anatomy

Modern razors comprise multiple highly advanced technological features that act to manage the skin and the hair during the shaving process. These ensure that the optimum compromise of closeness and comfort is attained, by presenting the hairs in the most favourable manner for removal, while controlling and supporting the surrounding skin. From the invention of the safety razor in the late 18th century, razors have included a leading guard element at the front of the cartridge to protect the skin from the blades. In recent years, the guard has often incorporated soft, flexible microfins. These aim to stretch the skin ahead of the first blade, thus presenting a smoother surface to be shaved and helping to present the hairs in a position to be cut more efficiently.[11] Figure 12 shows scanning electron microscopy images of skin replica positives taken with and without stretch from a microfin guard, to illustrate the change in local topography achieved.

At the heart of the cartridge lies the advanced blade technology. Blades are typically machined to be around 0·075 mm thick, giving them a thickness of less than a human hair. The radius of the sharpened ultimate blade tip is around 25 nm, which represents just a few hundred atoms in size. As discussed previously, the process of the blade cutting through the hair is one which translates and pulls the hair due to the forces involved. This can lead to the sensation of pull and tug experienced by consumers. By employing a finer cutting edge, lower forces are required to progress the blade through the

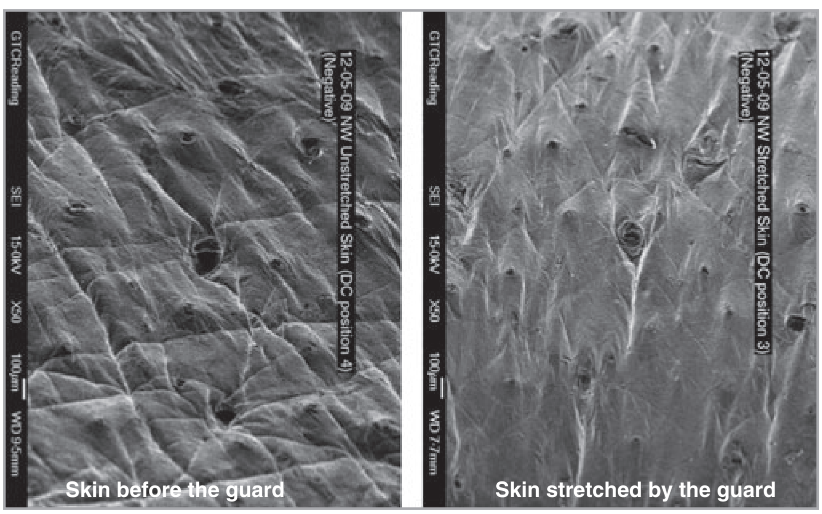

Fig 12. Scanning electron microscopy images of skin, showing the impact of the guard in applying localized stretch to the skin surface. Static silicone dental rubber replicas were made of untreated skin and the skin immediately behind the guard of modified Gillette Fusion cartridges. Images were obtained using epoxy resin positives taken from the silicone replicas.

hair and consequently this leads to an improvement in shaving comfort.

The idea of utilizing multiple blades within a cartridge has existed for many years, with the first patent for a five-bladed razor granted in 1929 (US 1920711). Historically, razors with many blades have been characterized by very high skin drag and hence have offered minimal consumer benefit. The key to multiple blade technology is not just the number of blades, but also the spacing of the blades. The pressure exerted on the skin by the blades causes the skin to bulge between the blades. By spacing the blades closer together, the skin bulge is reduced and a more uniform stress is placed on the skin, resulting in a safer, more comfortable shave.[12]

The ultimate arbiter of any technology development in shaving will be the in-market consumer. Technologies are required to perform successfully across a huge range of physiologies and behaviours, hence the importance of large-scale consumer validation. New razor developments typically involve testing on more than 10 000 men, often consisting of panels of 250 newly recruited men, shaving for several weeks. Performance is evaluated through in-depth questionnaires, designed to explore the many different attributes of shaving comfort, irritation and closeness. The intention for technology development is always significantly to out-perform previous systems across a range of key shaving attributes.

Conclusions

While many different methods of facial hair removal are available to today's male consumer, men continue to choose wet shaving as their primary method of hair removal.[13] Modern blades and razors are the product of extensive research and technologically advanced manufacturing procedures; these combine to provide the consumer with an optimum shaving experience.

Fundamental understanding of male shaving is particularly confounded by significant variability in both the physiology of different individuals and the shaving behaviour adopted by those individuals. Razors are required to operate within this variability and aim to provide consumers with optimal performance across the broadest range of conditions. Each element of the modern razor has an important role, not just in assisting in removal of hairs, but in carefully managing the skin to allow the blades to pass with minimal impact.

Objective measures of the shaving process are invaluable in providing supporting data for fundamental understanding of the interactions occurring. New instrumentation and measures focused on the response of skin are being developed continually. These allow quantification of the shaving process and correlation with subjective attributes of comfort and irritation.

In conclusion, shaving represents a highly complex series of mechanical and chemical interactions occurring at the surface of the stratum corneum. In attempting to meet consumer demands for both great closeness and optimal comfort, successful management of the skin is paramount.

What's already known about this topic?

- The process of shaving has been the subject of intense research to facilitate commercial development of new razor technologies.
- Research in the development of new techniques to explore and quantify the shaving process has remained largely unpublished and hence unavailable to dermatologists.

What does this study add?

- Insights in inherent challenges associated with the shaving process, due to physiological and behavioral aspects.
- Insights in new scientific measurement and imaging technologies used in clinical testing to study the impact of shaving on skin and the quantification of trapped beard hairs.
- Insights in razor features which play a role in the process of managing the skin and hair to ensure effective, safe hair removal.

Acknowledgments

The authors thank Hannah Roberts and Dan Coe (both Gillette Reading Innovation Centre, Reading, U.K.) for providing clinical data on nicks and cuts, Nigel Weston and Jamie Weeks (both Gillette Reading Innovation Centre, Reading, U.K.) for trapped hair release data and Jonathan Crowther (P&G, London Innovation Centre, Egham, U.K.) for PRIMOS images and roughness data comparing cheek and neck.

References

1 Wickett R. Measurement of the mechanical strength of hair. In: *Handbook of Non-Invasive Methods and the Skin* (Serup J, Jemec GBE, eds). Boca Raton, FL: CRC Press Inc, 1995; 535–41.
2 Thozhur S, Crocombe AD, Smith PA *et al.* Structural characteristics and mechanical behaviour of beard hair. *J Mater Sci* 2006; **41**:1109–21.
3 Manschot JFM, Brakkee AJM. The measurement and modelling of the mechanical properties of human skin *in vivo* – II. The model. *J Biomech* 1986; **19**:517–21.
4 Hendriks FM, Brokken D, van Eemeren JTWM *et al.* A numerical-experimental method to characterize the non-linear behaviour of human skin. *Skin Res Technol* 2003; **9**:274–83.
5 Ertel K, McFeat G. Blade shaving. In: *Cosmetic Dermatology: Products and Procedures* (Draelos ZD, ed). Oxford: Blackwell Publishing, 2010; 156–64.
6 Terry J. Materials and design in Gillette razors. *Mater Des* 1991; **12**:277–81.
7 Tolgyesi E, Coble DW, Fang FS, Kairinen EO. A comparative study of beard and scalp hair. *J Soc Cosmet Chem* 1983; **34**:361–82.
8 Shander D, Ahluwalia GS. Treatment of pseudofolliculitis barbae. In: *Cosmetic Applications of Laser and Light-Based Systems* (Ahluwalia GS, ed). Norwich, NY: William Andrew Inc, 2009; 353–67.
9 Bhaktaviziam C, Mescon H, Matoltsy AG. Shaving. I Study of skin and shavings. *Arch Dermatol* 1963; **88**:874–9.

10 McDermott A, Westbrook A, Warnke D *et al*. The use of a shaving regimen for male facial shaving improves overall skin condition. *J Am Acad Dermatol* 2010; **62** (Suppl. 1):AB38.
11 Hollander J, Casselman EJ. Factors involved in satisfactory shaving. *JAMA* 1937; **109**:95–101.
12 Procter & Gamble. *Gillette Advances in Shaving Technology*. 2009. Available at: http://www.pgdermatology.com/downloads/documents/Gillette_WhitePaper.pdf (last accessed 5 December 2011).
13 Draelos Z. Cosmetics: an overview. *Curr Probl Dermatol* 1995; **7**:43–64.