Materials science: Dry solution to a sticky problem

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Dry solution to a sticky problem

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Abstract

Sticking plasters revolutionized the protection of minor wounds, but they're not ideal for fragile skin. A material that mimics the adhesive properties of certain beetles' feet might provide a solution.

Adhesives that stick to skin for long periods of time, or over multiple cycles of use, are vital for medical applications. Such materials have to conform to stringent standards — for example, they must maintain robust adhesion during repeated application and removal without irritating the skin, and be non-toxic. Writing in *Advanced Materials*, Kwak *et al.*[1] report an exciting advance towards achieving these standards: an adhesive tape that uses micrometre-scale pillars on its surface to stick to skin. This innovation bypasses the need for a glue-coated surface, as is commonly used in conventional skin adhesives.

Skin adhesives are currently used billions of times a year — for example, in over-the-counter sticking plasters for the treatment of minor skin wounds, in transdermal patches for controlled drug delivery[2,3], and in tapes for affixing tubes or sensors to the skin in hospitals. Despite the remarkable success of these materials, a remaining challenge is to find adhesives suitable for use on the delicate skin of newborn infants and the elderly. Aged skin is particularly fragile, making it more susceptible to inflammation and damage[4]. Given that the number of people aged over 60 will double during the next two to three decades[5], the need for skin adhesives for the elderly is becoming increasingly pressing.

Pressure-sensitive surgical tapes first appeared in 1845, when the surgeon Horace Day applied rubber adhesive to strips of fabric[6]. For several years thereafter, minor cuts were treated with separate gauze and adhesive tape, but custom tailoring of the materials was required for domestic use. The first integrated skin-adhesive device — the Band-Aid — was invented in 1920 by Earle Dickson[7], an employee at the company Johnson & Johnson. Dickson noticed that gauze and adhesive tape did not remain attached to his wife's fingers, which she frequently injured in the kitchen. He therefore placed gauze in the centre of a strip of tape and covered the adhesive and gauze with a layer of crinoline to maintain its tack and sterility. Johnson & Johnson began mass-producing these sticking plasters shortly thereafter, and today it is estimated that more than 100 billion of Dickson's Band-Aids have been made[7].

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The adhesives currently used for sticking plasters are polymeric, pressure-sensitive adhesives based on acrylic compounds[8]. Although effective, acrylic adhesives can leave behind sticky residues, and they lose their grip after repeated use. To bypass the need for these glues, researchers have focused on adhesion mechanisms used by animals such as beetles and geckos, whose feet stick to walls without any glue. The mechanism of gecko-foot adhesion was elucidated[9] in 2000, nearly two millennia after Aristotle first reported the phenomenon: each gecko foot contains up to 500,000 hairs, each tipped with hundreds of projections known as spatulae. Similarly, the feet of beetles in the Chrysomelidae family are covered with tiny mushroom-shaped structures that help them cling to surfaces.

Gecko spatulae are roughly hundreds of nanometres in length, whereas the mushroom-shaped structures of Chrysomelidae beetles' feet are on the micrometre scale. It is possible to mimic these adhesive structures using nanometre- or micrometre-scale engineering to modify the surfaces of materials. Synthetic gecko-inspired adhesives have been made, but it has been difficult to optimize their properties for successful adhesion to wet tissues (such as those found inside the body). To solve this problem, we have previously used a hybrid approach, whereby a rubbery polymeric substrate with the surface nano-topography of gecko feet was coated with a thin layer of tissue-reactive glue[10]. The resulting material maximized adhesion to wet tissue while minimizing tissue inflammation.

Kwak *et al.*[1] have focused on achieving adhesion to dry skin in the absence of glue. They patterned the surface of a rubbery, non-toxic substrate with micrometre-scale, mushroom-shaped projections (Fig. 1) — a topology reported to be ideal for maximizing adhesion[11] — varying the dimensions of the projections until they achieved optimal adhesion to human skin in a direction perpendicular to its surface. Remarkably, the substrate maintained good adhesion through up to 30 cycles of attachment and removal, without causing significant damage to skin.

To demonstrate the functional utility of their adhesive, the authors integrated it into a wearable diagnostic device that monitors the heart using electrocardiography. When attached to a patient's chest, the device recorded several vital signals from the heart in real time over a period of two days. For commercial applications, however, Kwak and colleagues' material will probably require higher levels of adhesion — the reported system[1] achieved about 43% of the adhesion of a moderately sticky acrylic.

The authors' work is part of a growing body of research aimed at finding new materials that form interfaces with tissue. For example, another recent paper[12] describes single-use ultrathin membranes that adhere to skin using only van der Waals interactions, and which incorporate electronic components that can be used to perform electrophysiological recordings. For long-term applications, these technologies should be tested both in the presence of humidity or perspiration and to see how they cope with the shedding of dead cells. New approaches may be required to address such issues, perhaps involving surface-responsive materials[13]. Nevertheless, there is every hope that innovations such as that of Kwak *et al.*[1] will one day bring new technologies to the bedside.

References

1. Kwak MK, Jeong H-E, Suh KY. Adv. Mater. 2011 http://dx.doi.org/10.1002/adma.201101694.
2. Prausnitz MR, Mitragotri S, Langer R. Nature Rev. Drug Discov. 2004; 3:115–124. [PubMed: 15040576]
3. Prausnitz MR, Langer R. Nature Biotechnol. 2008; 26:1261–1268. [PubMed: 18997767]
4. Bianchi J, Cameron J. Br. J. Community Nurs. 2008; 13(Issue 3 suppl.):S26–S32. [PubMed: 18557571]

5. www.un.org/esa/population/publications/worldageing19502050/pdf/80chapterii.pdf
6. Smith MA, Jones NMM, Page SL, Dirda MP. J. Am. Inst. Conserv. 1984; 23:101–113.
7. http://web.mit.edu/invent/iow/dickson.html
8. Auchter, G.; Aydin, O.; Zetti, A.; Satas, D. Handbook of Pressure Sensitive Adhesive Technology. 3rd edn. Satas, D., editor. Satas & Associates; 1999. p. 444-514.
9. Autumn K, et al. Nature. 2000; 405:681–685. [PubMed: 10864324]
10. Mahdavi A, et al. Proc. Natl Acad. Sci. USA. 2008; 105:2307–2312. [PubMed: 18287082]
11. Carbone G, Pierro E, Gorb SN. Soft Matter. 2011; 7:5545–5552.
12. Kim D-H, et al. Science. 2011; 333:838–843. [PubMed: 21836009]
13. Chan EP, Karp JM, Langer RS. J. Polym. Sci. B. 2011; 49:40–44.

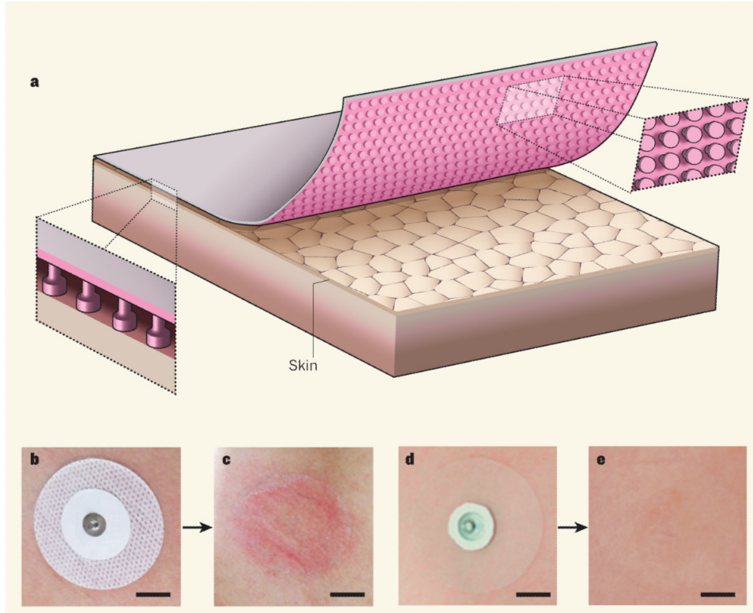

Figure 1. Glueless

a, Kwak *et al.*[1] have made a polymer material that has a surface covered in micrometre-scale, mushroom-shaped projections (upper inset). The projections mimic those found on certain beetles' feet, and allow the substrate to adhere to human skin without the use of glue (lower inset). **b**, **c**, Commonly used sticking plasters (**b**) use an acrylic adhesive to stick to skin, but can leave behind a sticky residue and cause redness (**c**). **d**, **e**, A patch made from Kwak and colleagues' material (**d**) reduces these effects (**e**). Scale bars, 1 cm. (Graphic adapted from ref. 1. Photos reproduced from ref. 1.)