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TECHNICAL NOTE

ODONTOLOGY

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Bite Marks: Physical Properties of Ring Adhesion to Skin—Phase 1*

ABSTRACT: Unsupported excised skin may shrink by as much as 50% or more. In 1981, a method was developed for ring adhesion to skin with the goal of minimizing tissue distortion upon excision. Five modified versions of the technique bearing the author's name followed (Dorion types I, II, III, IV, and V). The scientific literature reveals little supporting empirical evidence for the preferential use of one adhesive/suturing technique over another. This study compares the use of various bonding materials (Loctite Super Glue gel®, Dermabond™, Vetbond™), cleaning agents (ethanol, dishwashing liquid, and shaving cream), and depilatory (Veet®) on the effects of ring adhesion to skin. The conclusions indicate that surface wetness is the most influential factor affecting ring adhesion to skin, followed by the type of bonding material, its "freshness," and by the cleaning agent used to prepare the skin. The use of a depilatory or shaving cream is to be avoided.

KEYWORDS: forensic science, bite mark, bite mark research, bitemark, bitemark research, ring adhesion to skin, skin excision, TriggerScan™

A recent article suggests that 87.5% of Diplomates of the American Board of Forensic Odontology excise the bite site on cadavers (1). Unsupported excised skin may shrink by as much as 50% or more (2). In 1981, a method was developed for ring adhesion to skin prior to excision with the goal of minimizing tissue distortion (3–5). This was the first of five modified versions of the technique bearing the author's name (Dorion types I, II, III, IV, and V) and reported over the years at various forensic conferences/meetings (Dorion RBJ, personal communication, February 12, 1985; Dorion RBJ, personal communication, April 14, 1993; Dorion RBJ, personal communication, May 16, 1997; Dorion RBJ, personal communication, September 11, 1998; Dorion RBJ, personal communication, March 26, 1999; Dorion RBJ, personal communication, May 21, 1999; Dorion RBJ, personal communication, June 8, 1999; Dorion RBJ, personal communication, February 28, 2002; Dorion RBJ, personal communication, February 5, 2007) (6–12). A search of the literature reveals only one article (13), one thesis (14), and one alternate method (15) peripherally dealing with this topic.

Ring detachment has been attributed to many factors including corpse and climatic temperature variations, ventilation, humidity, body wetness, as well as the cyanoacrylate's physical properties not to mention other chemicals (2). The scientific literature reveals little supporting empirical evidence for the preferential use of one adhesive/suturing technique over another for bite mark excision as clinical experience prevailed. This study compares various bonding materials (Loctite Super Glue gel® (Henkel Corporation, Westlake, OH); Dermabond™, (Ethicon [Johnson and Johnson Company] San Angelo, TX); Vetbond™ [3M Corporate Headquarters, St.-Paul, MN]), cleaning agents (ethanol, dishwashing liquid, and shaving cream), and depilatory (Veet® [Reckitt Benckiser Group, Slough Berkshire, England and Wales]) on the effects of ring adhesion to skin.

The TriggerScan™ (Dvorak Instruments Inc., Tulsa, OK) was developed to measure tension or compression characteristics of firearms. In essence, the instrument measures force versus displacement. It can also be used, according to the manufacturer, with other items, such as switches, push buttons, keyboards, etc., as long as they fit within the instrument's operating range. The device was modified for use in the present research. There is no financial relationship with the authors and any commercial entities mentioned herein.

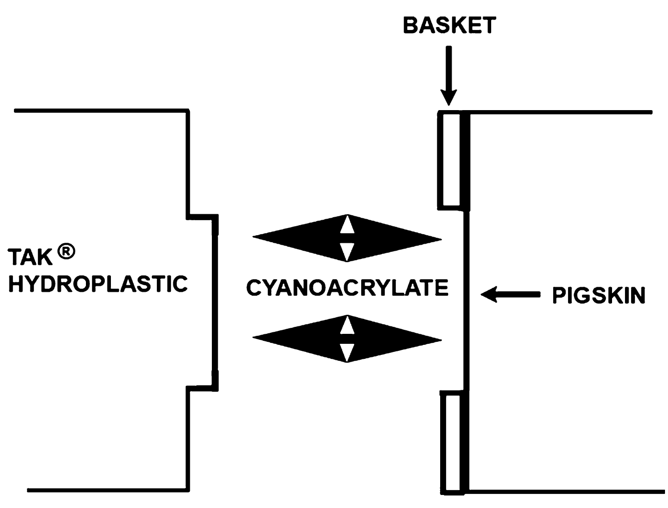

FIG. 1—*Illustration of the relationship between Tak® Hydroplastic, the cyanoacrylate, and the pigskin.*

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The first phase of this multi-level research studied the amount of tensile stress needed to rupture the bond between the TAK® Hydroplastic excision ring (Pearson Dental Supply Co., Sylmar, CA), the cyanoacrylate glue/gel, and pigskin (Fig. 1). The pigskin varied from untreated/hairy to shaved. The skin was treated with various materials including dishwashing detergent, shaving cream, ethanol, Veet®, etc. The room temperature and humidity was controlled, the skin condensation/wetness removed, and various commercial "fresh" cyanoacrylate glues and gels utilized. The physical properties of the various materials used were assessed in regard to skin adhesion.

Materials and Methods

Pigskin was used as test material for its similarity in physical properties to human skin (Fig. 2).

The TriggerScan™ 2.0 is a precise instrument used in ballistics to measure the amount of force needed to pull a firearm trigger. It was modified for use in this study to incorporate TAK® Hydroplastic, a histology basket (male component), and a tightening ring SS type F (Figs 3 and 4).

FIG. 2—*Pigskin specimens.*

Additional instrumentation and materials included the following: a digital thermometer to record pigskin and room temperatures, a battery-operated razor, disposable razors, a nail file, a spatula, a scalpel, a chemical depilatory (Veet®), and the Leica® stereomicroscope (Leica Microsystems Inc., Ontario, Canada).

Dishwashing detergent (Palmolive® Original scent dishwashing liquid [Colgate-Palmolive Company, Toronto, ON, Canada]), shaving cream (Personnelle™ [The Jean-Coutu Group Inc., Quebec, Canada]), and 98.9% ethanol, a solvent that can dissolve/dilute numerous fatty and aromatic substances were individually evaluated for cleaning/treating the pigskin.

Cyanoacrylates are acrylic resins with general formula $C_5H_5NO_2$. As this material polymerizes, it adheres to skin creating a chemical bond. Three different types of cyanoacrylates were used: Methyl-2 Loctite Super Glue gel®, N-butyl Vetbond™, and 2-octyl Dermabond™.

The controlled conditions integrated the following: temperature variations from 21 to 25°C; the room humidity varied from 20% in winter to a maximum of 60% in summer; ventilation was <0.15 m/sec at 21°C and <0.25 m/sec at 25°C; CO_2 was inferior to 1000 parts per million.

The pigskins were treated in different ways under varying conditions to include the following variables:

1. Untreated hairy pigskin.
2. Mechanical shaving at the abattoir.
3. Mechanical shaving at the abattoir and dishwashing detergent.
4. Mechanical shaving at the abattoir, dishwashing detergent, and 98.9% ethanol.
5. Shaving with a battery-operated razor and ethanol.
6. Shaving cream, razor, and dishwashing detergent.
7. Shaving cream, razor, dishwashing detergent, and ethanol 98.9%.
8. Depilatory (Veet®).
9. Veet®, dishwashing detergent, and ethanol.
10. Fresh versus old Loctite Super Glue gel®, MS, S, E (see table footnotes).
11. Methyl-2, N-butyl and 2-octyl cyanoacrylates comparing (MS, S, E):
    a. Methyl-2 cyanoacrylate: Loctite Super Glue gel®.
    b. N-butyl cyanoacrylate: Vetbond™.
    c. 2-octyl cyanoacrylate: Dermabond™.
12. Tensile strength at different temperatures and humidity.

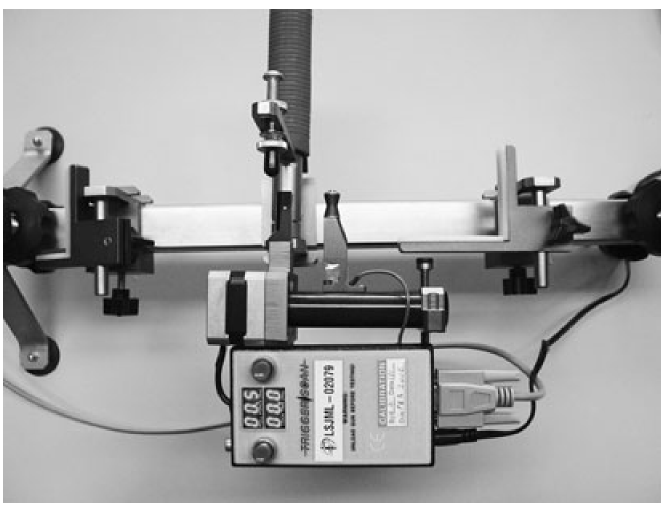

FIG. 3—*The TriggerScan™ instrument.*

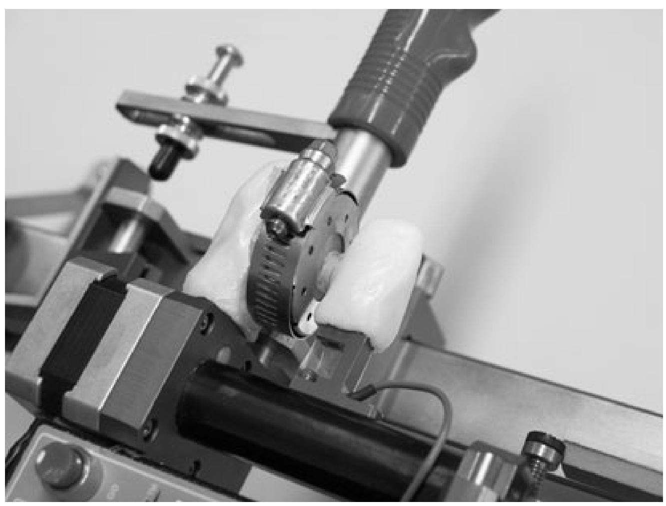

FIG. 4—*The TriggerScan™ prototype showing the relationship described in Fig. 1.*

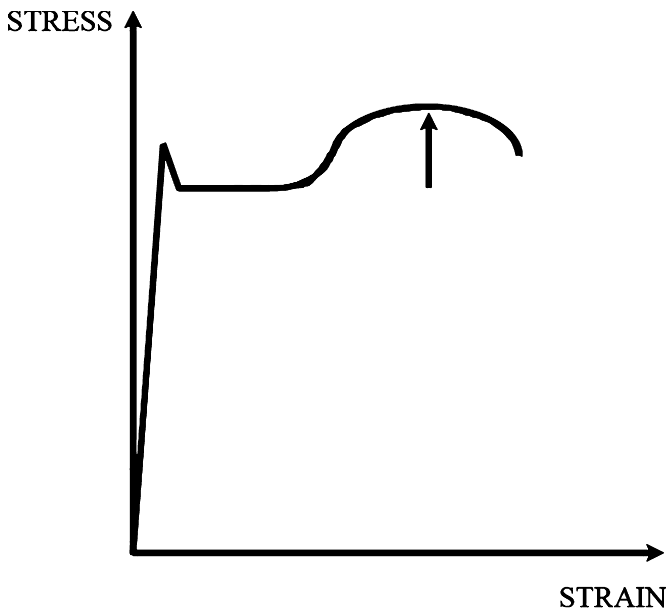

FIG. 5—*The effect of substrate stiffness on the stress/strain curve.*

TABLE 1—*TriggerScan™ tests and results with different variables.*

Material	Cleaning Method	Results PSI	Results KPa	Number of Tests Performed
Loctite Super Glue gel® (1)	MS	3.1–5.7	30.34	4
Loctite Super Glue gel® (2)	MS, D	14.3–19.7	117.21	3
Loctite Super Glue gel® (3)	MS, S	9.9–23.3	114.45	7
Loctite Super Glue gel® (4)	MS, S, E	15.5–16.9	111.69	3
Loctite Super Glue gel® (8)	R, E	4.1–9.9	48.26	14
Loctite Super Glue gel® (9)	SC, R, S	4.9–6.5	39.30	3
Loctite Super Glue gel® (10)	SC, R, S, E	4.1–8.7	44.19	6
Loctite Super Glue gel® (11)	V	3.7–4.1	26.89	2
Loctite Super Glue gel® (12)	V, S, E	3.7–5.5	31.72	5
Old Loctite Super Glue gel® (6)	MS, S, E, D	36.7–67.0	357.49	5
Fresh Loctite Super Glue gel® (7)	MS, S, E, D	46.8–67.2	393.14	4
Vetbond™ (5)	MS, S, E	22.2–37.6	206.15	5
Dermabond™ (13)	MS, S, E	29.1–33.7	216.43	5

D, dehydrated specimen; E, ethanol; MS, mechanical shaving at the abattoir; R, shaving with disposable razor; S, dishwashing detergent; SC, shaving cream; V, Veet®.

Tensile stress is that type of stress in which two sections of material on either side of a stress plane tend to pull apart or elongate. At its limit, the material breaks or permanently deforms. For example, Fig. 5 illustrates the typical tensile stress curve of a metal; the arrow located at the top of the curve refers to the maximum stress a metal can withstand when subjected to tension without breaking. In relationship with this, the tensile stress curve encountered with pigskin is similar; the present research measured the maximum stress on pigskin when subjected to tension of bonded TAK® Hydroplastic material to cyanoacrylate.

Following the stress tests on the TriggerScan™, the pigskin specimens were fixed in formalin 10%, histology slides prepared, and colored with two dyes: Pure Safran Gatinais for fat and Crystal Violet for the cyanoacrylate. Photographs of sectioned specimens were taken using a Nikon D200 camera (Nikon Canada, Mississauga, Ontario, Canada) mounted on a Leica stereomicroscope MZ75.

TABLE 2—*TriggerScan™ tests with different materials and the same cleaning/treating method at different temperatures.*

Material	Cleaning Method	Temperature (°C)	Results PSI	Results KPa
Old Loctite Super Glue gel®	MS, S, E	20.7	24.6	169.61
		21.2	57.5	396.45
		16.4	66.6	459.19
Fresh Loctite Super Glue gel®	MS, S, E	21.5	46.0	317.16
		13.0	48.5	334.40
		18.6	60.0	413.68
Dermabond™	MS, S, E	16.9	32.9	226.84
		17.6	26.3	181.33
		19.4	32.0	220.63
		20.2	32.9	226.84
		16.6	32.9	226.84
Vetbond™	MS, S, E	19.1	24.6	169.61
		21.2	22.2	153.06
		20.9	33.7	232.35
		21.1	28.8	198.57
		15.8	40.3	277.86

E, ethanol; MS, mechanical shaving at the abattoir; S, dishwashing detergent.

Tables 1 and 2 illustrate test results utilizing various combinations of bonding materials (Loctite Super Glue gel®, Dermabond™, Vetbond™), cleaning agents (ethanol, dishwashing liquid, and shaving cream), and depilatory (Veet®) under varying conditions.

Results

Figure 6 and Table 1 illustrate the resulting tensile forces (calculated as a mean) obtained with and without the use of different cleaning agents on pigskin. In Fig. 6 column #1, 4.4 PSI (30.34 KPa) refers to a mechanically shaved pigskin (MS) utilizing Loctite Super Glue gel®. Column #2 records the effect of dehydration on pigskin with a corresponding increase in adhesion to 17.0 PSI (117.21 KPa). Column #3, 16.6 PSI (114.45 KPa) refers to the mechanically shaved and cleaned pigskin (dishwashing detergent) with Loctite Super Glue gel®. Column #4, 16.2 PSI (111.69 KPa) (example of a curve obtained on the TriggerScan™ in Fig. 7) adds ethanol as a cleaner with little difference in result from column #3. Columns #8, 9, and 10 have a common factor of shaved pigskin by disposable razor (R). Column #8, 7.0 PSI (48.26 KPa) was cleaned with ethanol and Loctite served as bonding agent. It shows an increase in adhesion compared to the baseline column #1 (48.26/30.34). Columns #9 through 12 show the lowest tensile force results on the pigskin. Column #9, 5.7 PSI (39.30 KPa) used shaving cream and dishwashing detergent. Column #10, 6.4 PSI (44.19 KPa) used shaving cream, dishwashing detergent, and ethanol. Column #11, 3.9 PSI (26.89 KPa) used Veet®. Column #12, 4.6 PSI (31.72 KPa) used Veet® with dishwashing detergent and ethanol (example of a curve obtained on the TriggerScan™ in Fig. 8). Columns #5, 6, 7, and 13 show the best results. Column #5, 29.9 PSI (206.15 KPa) refers to a mechanically shaved pigskin cleaned with dishwashing detergent, ethanol, and Vetbond™ as adherent. Column #6, 51.8 PSI (357.49 KPa) has the same as the previous condition, but the specimen was dehydrated and 3-month-old (opened) Loctite Super Glue gel® was used. Column #7, 57.0 PSI (393.14 KPa) has the same as the last condition but with fresh Loctite Super Glue gel®. Last, column #13, 31.4 PSI (216.43 KPa) represents a nondehydrated specimen, mechanically shaved, cleaned with dishwashing detergent and ethanol, and bonded with Dermabond™.

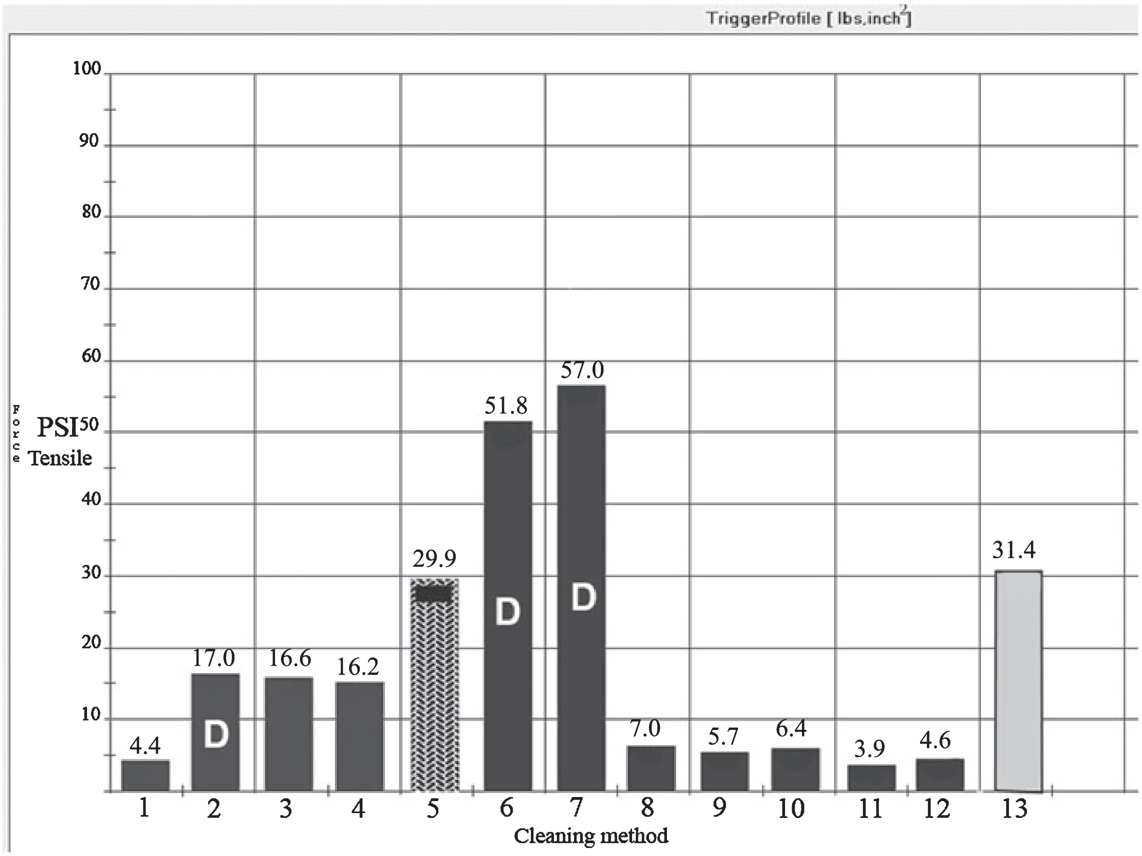

FIG. 6—*Graphic illustration of the use of various cleaning agents versus tensile stress.*

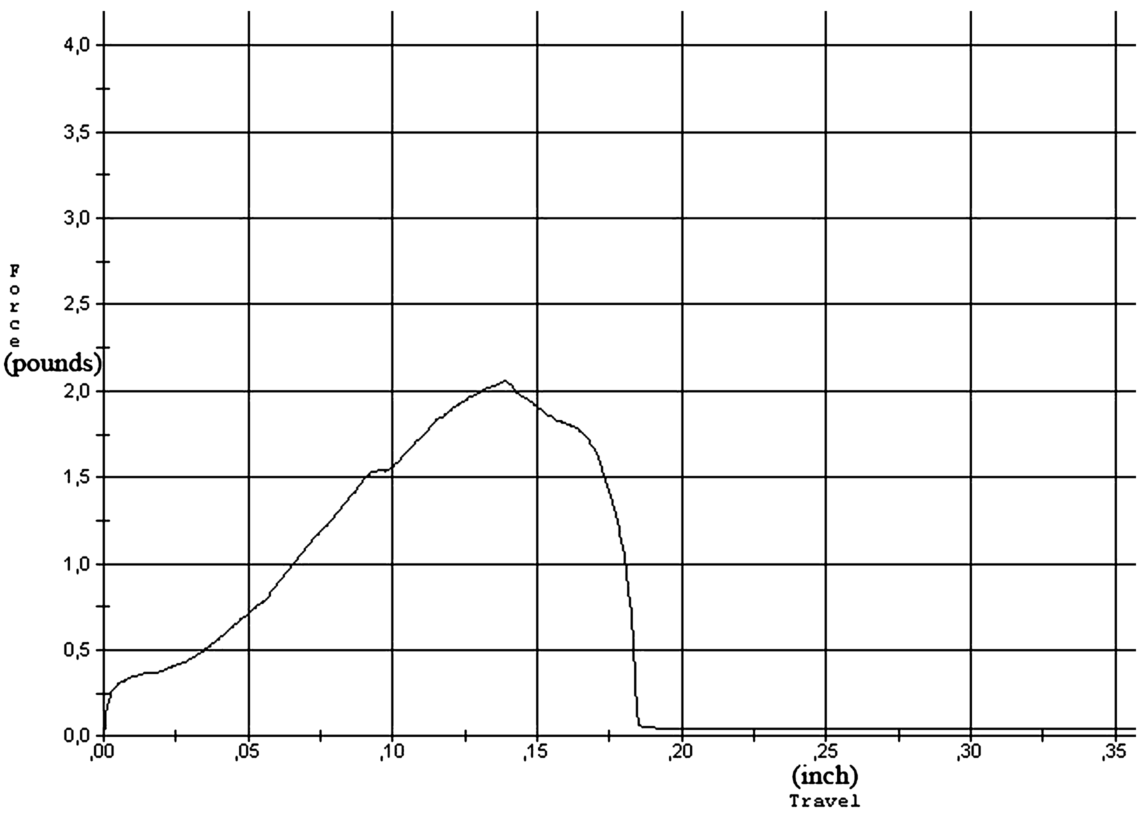

FIG. 7—*Graphic illustration of the effects of shaving and cleaning (dishwashing detergent and ethanol) on the tensile stress with Loctite Super Glue gel® corresponding to column #4 in Fig. 6.*

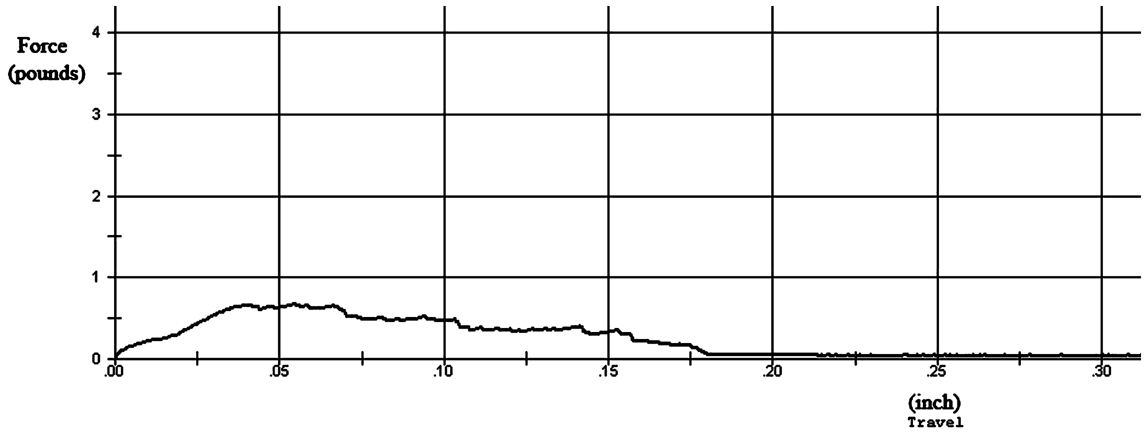

FIG. 8—*Graphic illustration of the effects of shaving, cleaning (dishwashing detergent and ethanol), and the use of Veet® on the tensile stress with Loctite Super Glue gel® corresponding to column #12 in Fig. 6.*

Discussion

Effects of Ethanol

The tensile stress tests indicate that razor-shaved pigskin cleaned with 98.9% ethanol alone (column #8) results in an increase in adhesion to mechanically shaved pigskin by 59.1% (column #1). When pigskin was cleaned with dishwashing detergent and ethanol, the result was quite similar to dishwashing detergent cleaning only (a decrease in adhesion of *c.* 2.4%). When the pigskin was razor shaved with shaving cream, cleaned with dishwashing detergent and ethanol, there was a resultant increase of 12.3% adhesion compared to the nonuse of ethanol (columns #9 and 10).

Effects of Freshness of the Cyanoacrylate

Considering the freshness of cyanoacrylate (unopened), Loctite Super Glue gel® showed a 10.0% increase in adhesion compared with 3-month-old (opened) material (columns #6 and 7).

Effects of Different Forms of Cyanoacrylate

The use of different glues under the same cleaning conditions (shaved and cleaned with dishwashing detergent and ethanol) gave different results of adhesion to pigskin. Vetbond™ gave an 84.6% increase in adhesion when compared to Loctite Super Glue gel®, and Dermabond™ a 93.8% increase in adhesion (columns #4, 5, and 13).

Effects of Different Cleaning Methods

The best cleaning method for increased adhesion appears to be mechanical shaving with dishwashing detergent and ethanol.

Effects of Body Wetness

The results from mechanical shaving (column #2), having previously exposed the pigskin to room temperature and ventilation for *c.* 5 h (dehydration), resulted in an increase in adhesion of 286.4% compared to the baseline (column #1). Also, the dehydrated specimens (*c.* 3 h) shaved and cleaned with dishwashing detergent and ethanol before bonding with "old" Loctite Super Glue gel® (column #6) gave an increased adhesion of 219.8%, while "fresh" (column #7) increased adhesion by 251.9% when compared to shaving and cleaning with dishwashing detergent and ethanol (column #4).

Effects of Temperature

Tests were performed using old (opened) and fresh (unopened) Loctite Super Glue gel®, Dermabond™, and Vetbond™ glue and the following cleaning methods: mechanical shaving, dishwashing detergent, and ethanol at different temperatures (Table 2). In each of the four cases, despite a significant pigskin decrease in temperature, the tensile force increased significantly. For example, when the skin temperature was decreased from 21.2 to 16.4°C, the tensile force increased from 396.45 to 459.19 KPa when using old Loctite Super Glue gel®. At this juncture, it is uncertain whether other factors are contributory to this increase.

Effects of Veet®

When Veet® was used alone (column #11) or with dishwashing detergent and ethanol (column #12), there was a massive reduction in adhesion.

Considering these results, certain recommendations for ring adhesion to skin are appropriate:

- The use of fresh (unopened) cyanoacrylate.
- Razor shaving the skin and cleaning it with dishwashing detergent and 98.9% ethanol for degreasing and surface dehydration.
- Skin surface wetness should be eliminated.
- Dermabond™ adheres more than any other cyanoacrylate. However, it is not cost efficient, has too short a working time, and a very liquid consistency.
- The use of Loctite Super Glue gel® and Vetbond™ as cyanoacrylates of choice for price and ease of use. But the latter has a very liquid consistency.
- Shaving cream and Veet® (or other chemical depilatory) should be avoided.

Conclusion

The first phase of this multi-level research clearly demonstrates that surface wetness was by far the most influential factor affecting ring adhesion to skin. Second, but to a lesser extent, ring detachment is influenced by the type of cyanoacrylate used, the freshness of the cyanoacrylate and by the materials used to clean or prepare the skin. Third, chemical depilatories and shaving creams should be avoided in the area of ring adhesion. Last, skin temperature variations should be avoided as further research is required for this variant.

Conflict of interest: The authors have no relevant conflicts of interest to declare.

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