DUPONT

Liveo™

Impact of silicone polymers on lidocaine drug delivery and performance

Xavier Thomas, Virginie Caprasse

Introduction

Topical medicines are designed to treat various skin conditions and mainly are marketed as prescription or consumer healthcare products. Prescription market requirements include safe and effective delivery of the API (active pharmaceutical ingredient) to efficiently and effectively achieve pharmacokinetic and clinical relevance.

Formulating with silicone materials has many benefits and can play an important role in the development of medicated products by enhancing efficacy and facilitating formulation flexibility in topical applications. Silicone materials are available as excipients in a wide range of forms, including, volatile, liquid, gel and elastomeric solid. Each type benefits from the unique molecular behavior of polydimethylsiloxanes in terms of stability, permeability and interface properties.

Benefits of silicone topical excipients

Silicone topical excipients are non-irritating, non-sensitizing and safe for application on the skin. Providing a pleasant feel, breathability (flexible occlusivity), spreading ease, wash-off resistance and increased substantivity, silicone topical excipients help topical medicine to be comfortable to wear, encouraging patient compliance with prescriptions.

In addition to end-use benefits, silicone topical excipients ensure ease of formulation with API and skin penetration enhancers, processing flexibility, and reduced cost and complexity with cold processing.

More importantly, silicone topical excipients can improve the efficacy of the treatment by enhancing drug delivery to the targeted site, as demonstrated in the study reported in this paper.

Recent testing of silicone polymers for topical delivery of lidocaine

This paper summarizes recent comparison testing of three formulation matrices – water-in-oil emulsion, anhydrous gel and aqueous gel – based on three different silicone polymers. The three formulations were evaluated for their efficacy in the delivery of lidocaine and for their benefits as topical forms applied to skin. Lidocaine is a local anesthetic used in topical applications to relieve pain and numb the skin.

Study conditions

To conduct the comparison study, three different silicone materials were considered according to their polymeric structure (and, consequently, their resulting performance attributes):

- **DuPont™ Liveo™ Silicone Fluid:** A high-purity, non-occlusive, non-volatile silicone fluid that can be formulated as a skin protectant
- **DuPont™ Liveo™ Silicone Elastomer Blend:** A silicone elastomer blend made of a crosslinked silicone network swollen with a volatile silicone fluid; responsible for silky aesthetic properties, such as smooth and dry feel on the skin
- **DuPont™ Liveo™ Silicone Gum Blend:** A silicone gum blend made of a very high-molecular-weight silicone fluid dispersed in a non-volatile low-viscosity silicone fluid; responsible for substantivity and film-forming properties on skin

Each silicone material was formulated in three different types of topical formulations: water-in-oil emulsion, anhydrous gel and aqueous gel.

Methodology for drug delivery testing

When formulating for pharmaceutical applications, understanding the characteristics of the drug delivery profile is critical to assessing the efficacy of the product. The Franz-type diffusion cell method is used for skin permeation evaluation, whereby the device is equipped with a skin sample. This test method allows the quantification of the amount of drug that can diffuse outside the matrix over time, as well as the amounts that permeate through or are retained in the different skin layers.

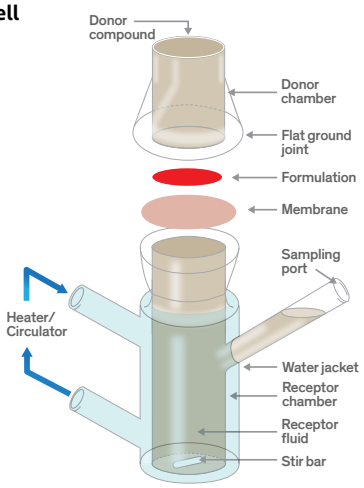
In vitro skin permeability testing

The skin permeation testing of lidocaine was performed at 32°C through dermatomed piglet skin tissues. The dermatomed piglet skin was set in Franz-type diffusion cells with 1.77 cm^2 release surface and 11 mL receptor volume filled with a receptor medium made of phosphate buffered saline (PBS) (pH = 7.4). For each formulation containing 2.5 weight% of lidocaine, a dose of 10 mg/cm^2 was homogeneously applied onto the skin. Six cells were used per formulation. The experiment was carried out for 20 hours; a 1 mL sample was collected from the receptor chamber and replaced with fresh buffer solution at specific times – 30 minutes, 1 hour, 2 hours, 4 hours, 6 hours, 8 hours, 10 hours, 12 hours, 15 hours and 20 hours – using a Logan 912 auto-sampler system. All samples were analyzed by liquid chromatography to determine lidocaine content, using a Waters ACQUITY ultrahigh-performance liquid chromatography (UPLC) system.

After 20 hours, at the end of the diffusion period, a skin compartment analysis was performed by separating the different skin layers – stratum corneum, epidermis and dermis – and recovering the lidocaine retained in each layer.

All drug samples permeated into the receptor fluid or extracted from skin layers were analyzed by UPLC.

Figure 1: Franz-type diffusion cell



Methodology for performance evaluation

Sensory evaluation

The sensory evaluation for topical products is designed to provide a sensory profile of selected formulations. Evaluated by an experienced panel, each formulation is assessed individually and rated versus one another. All sensory data are analyzed using critical response tables with significance of $\alpha<0.05$.

The formulations are applied on the forearm of each panelist to evaluate the characteristics before and after absorption.

- Before absorption: wetness, spreadability, tackiness and perception of absorption speed
- After absorption: gloss, film residue, greasiness, smoothness, tackiness and slipperiness

Occlusivity level evaluation

Moisturization of the skin is achieved through increased water content and retention in the skin. This can be accomplished by preventing the loss of water vapor from the skin through a process called occlusion. At the opposite, skin breathability requires low to no occlusivity. The occlusivity level is measured with the water vapor permeability test based on Payne cup methodology in which a collagen membrane is covered with a thin layer of the tested material. This test sample – collagen membrane and tested material – is placed on top of a stainless steel cup partially filled with water to keep a headspace between the collagen membrane and the water surface. The cup is then stored for the duration of the test in a controlled-temperature location and regularly weighed to measure the amount of water loss. All tests are carried out in triplicate.

Substantivity versus time or washes evaluations

The substantivity of silicone-based formulations on skin is evaluated versus time or washes in order to evaluate its durability, long-lasting effect or wash-off resistance. The test is performed by applying the formulations onto panelists' forearms, and the silicone remaining on skin is detected and analyzed by infrared spectroscopy using an attenuated total reflectance Fourier transform infrared spectrophotometer (ATR-FTIR) equipped with a skin analyzer device.

Study

Case Study 1: Evaluation of water-in-oil emulsion

Three water-in-oil (W/O) emulsions were prepared with the three different silicone polymers, as detailed in Table 1.

Table 1: Water-in-oil emulsion formulations

	W/O Emulsion with Silicone Fluid (% w/w)	W/O Emulsion with Silicone Elastomer (% w/w)	W/O Emulsion with Silicone Gum Blend (% w/w)
DuPont™ Liveo™ Silicone Fluid	✔	-	-
DuPont™ Liveo™ Silicone Elastomer Blend	-	✔	-
DuPont™ Liveo™ Silicone Gum Blend	-	-	✔
W/O Silicone Emulsifier	✔	✔	✔
Lidocaine	✔	✔	✔
Isopropyl Myristate	✔	✔	✔
Water	✔	✔	✔
Sodium Chloride	✔	✔	✔

Drug diffusion results

Skin permeation study of W/O Emulsion with Silicone Fluid (W/O Fluid) versus W/O Emulsion with Silicone Elastomer (W/O Elastomer)

As detailed in Table 2 and shown in Figure 2, there was no significant difference in lidocaine delivery between W/O Fluid and W/O Elastomer after 20 hours. Most of the lidocaine was recovered in the skin and the receptor chamber: 98.7% for W/O Fluid and 100% for W/O Elastomer. About 15% of lidocaine was dosed in the skin.

The equivalent lidocaine delivery between the two formulations was confirmed by the skin compartment analysis, as shown in Figure 3. More or less the same amounts of lidocaine were found in the dermis and the epidermis for both formulations.

Table 2: Skin permeation results of W/O Fluid and W/O Elastomer

	Receptor (R)		Skin (S)	R + S
	Diffusion of active (µg/cm²)	Diffusion of active (%)	Diffusion of active (%)	Average in skin and receptor (%)
W/O Fluid	159.9	84.7	14.0	98.7
W/O Elastomer	156.7	85.1	14.9	100.0

Figure 2: Permeation profiles through dermatomed piglet skin for W/O Fluid and W/O Elastomer

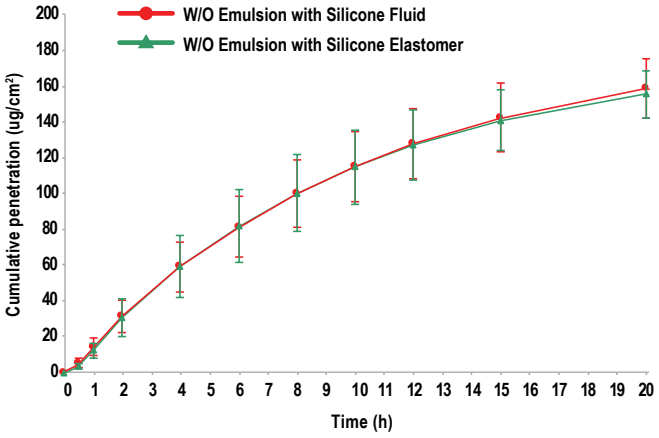
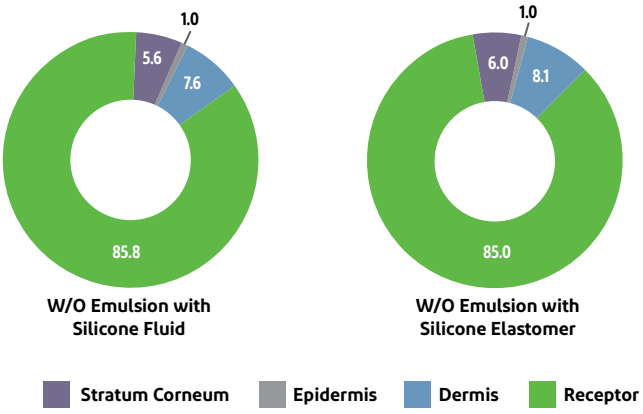


Figure 3: Skin compartment and receptor fluid analysis for W/O Fluid and W/O Elastomer



Skin permeation study of W/O Fluid versus W/O Emulsion with Silicone Gum Blend (W/O Blend)

As detailed in Table 3 and shown in Figure 4, there was no significant difference in lidocaine delivery between W/O Fluid and W/O Blend. After 20 hours, the full lidocaine content was recovered in both the skin and receptor chamber, and about 15% of lidocaine was dosed in the skin. Figure 5 shows similar repartitions of lidocaine in each skin compartment after 20 hours.

Table 3: Permeability results of W/O Fluid and W/O Blend

	Receptor (R)		Skin (S)	R + S
	Diffusion of active (µg/cm²)	Diffusion of active (%)	Diffusion of active (%)	Average in skin and receptor (%)
W/O Fluid	170.5	88.9	14.2	103.1
W/O Blend	162.5	92.7	13.7	106.4

Note: The total active recovery above 100% could be imputed to the test method uncertainties.

Figure 4: Permeation profiles through dermatomed piglet skin for W/O Fluid and W/O Blend

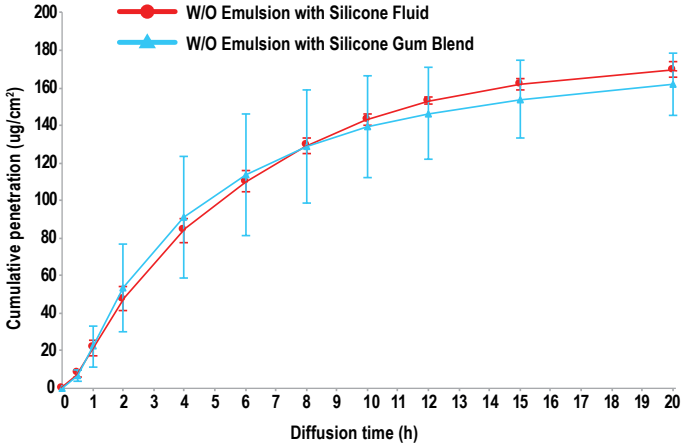
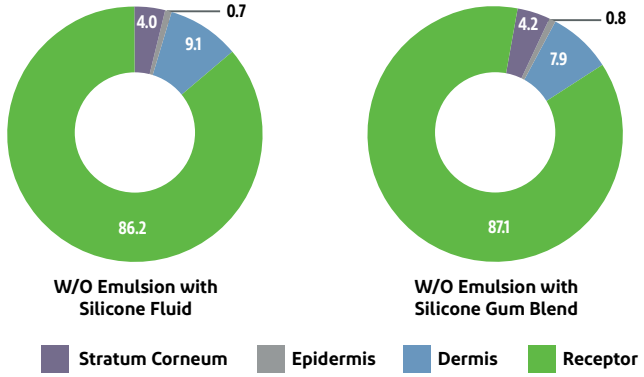


Figure 5: Skin compartment and receptor fluid analysis for W/O Fluid and W/O Blend



Performance evaluations on skin

The following performance evaluations were considered for the three W/O emulsions: occlusivity level, sensory evaluation, and substantivity versus both time and washes. Because the sensory evaluation and substantivity tests were performed as *in vivo* testing using panelists, the test samples had to be placebo, and formulations were prepared without lidocaine, as detailed in Table 4.

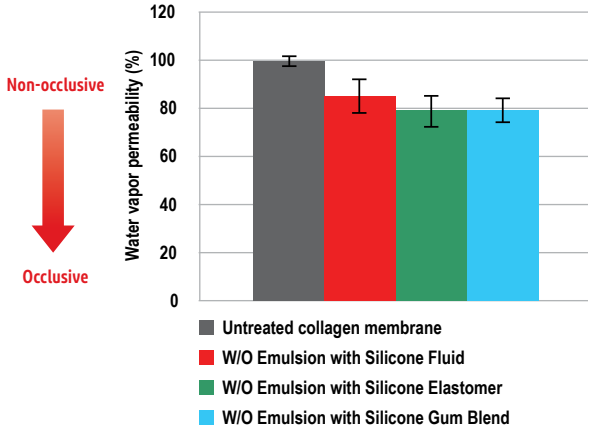
Table 4: Placebo formulations for skin evaluation

	W/O Fluid (% w/w)	W/O Elastomer (% w/w)	W/O Blend (% w/w)
DuPont™ Liveo™ Silicone Fluid	✔	-	-
DuPont™ Liveo™ Silicone Elastomer Blend	-	✔	-
DuPont™ Liveo™ Silicone Gum Blend	-	-	✔
W/O Silicone Emulsifier	✔	✔	✔
Isopropyl Myristate	✔	✔	✔
Water	✔	✔	✔
Sodium Chloride	✔	✔	✔

Occlusivity level

As shown in Figure 6, the nature of the silicone polymer used in the W/O placebo formulations did not impact the occlusivity. The three formulations would be considered non-occlusive.

Figure 6: Occlusivity level for the W/O placebo formulations



Note: Untreated non-occlusive collagen membrane is fixed at 100%.

Sensory profile

As demonstrated in the sensory evaluation summary graph (Figure 7) and the statistical analysis (Table 5), W/O Blend was greasier compared to W/O Fluid and W/O Elastomer. W/O Blend and W/O Elastomer showed a smoother feel on skin than W/O Fluid. No difference was observed between the three emulsions for the other parameters (gloss, slipperiness, tackiness and film residue).

Figure 7: Sensory evaluation summary graph for the W/O placebo formulations

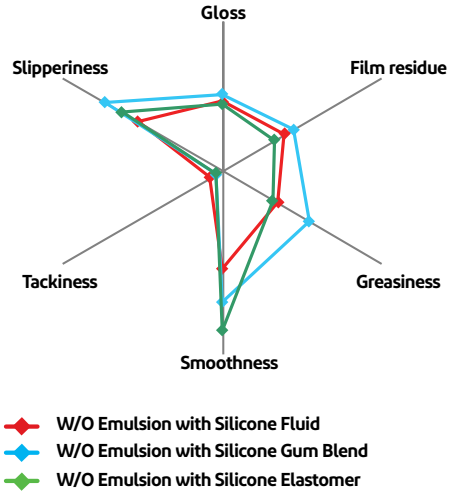


Table 5: Statistical data for sensory evaluation of the W/O placebo formulations (α<0.05)

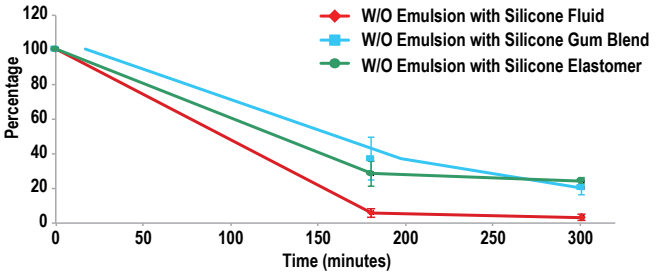
	Gloss	Film residue	Greasiness	Smoothness	Tackiness	Slipperiness
W/O Fluid	a	a	a	a	a	a
W/O Elastomer	a	a	a	b	a	a
W/O Blend	a	a	b	b	a	a

Note: For each parameter, the use of the same letter indicates the products show no significant difference (95%).

Substantivity versus time

Referring to Figure 8, the nature of the silicone polymer in the emulsion impacted the substantivity. W/O Fluid placebo had poor substantivity on skin, with less than 10% of silicone remaining on skin after 3 hours and 5 hours. W/O Blend placebo and W/O Elastomer placebo showed better substantivity: Around 35% of silicone remained on skin after 3 hours, and more than 20% remained after 5 hours.

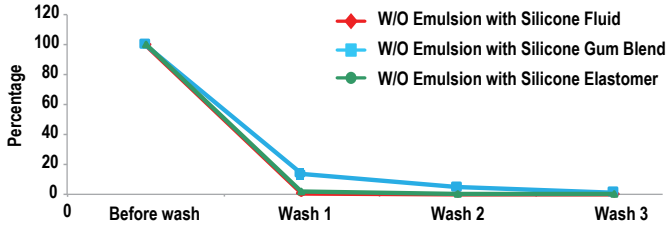
Figure 8: Substantivity versus time for the W/O placebo formulations



Substantivity versus washes

As shown in Figure 9, the nature of the silicone polymer in the emulsion impacted the wash-off resistance of the formulation. Neither the W/O Elastomer placebo nor the W/O Fluid placebo withstood the wash-off evaluation: No silicone remained on skin after the first wash. The W/O Gum Blend placebo showed a better wash-off resistance, with 20% of silicone remaining on skin after one wash but no silicone remaining after three washes.

Figure 9: Wash-off resistance for the W/O placebo formulations



Case Study 2: Evaluation of anhydrous gel

Three anhydrous gel formulations were prepared with the three different silicone polymers, as detailed in Table 6.

Table 6: Anhydrous gel formulations

	Anhydrous Gel with Silicone Fluid (% w/w)	Anhydrous Gel with Silicone Elastomer (% w/w)	Anhydrous Gel with Silicone Gum Blend (% w/w)
DuPont™ Liveo™ Silicone Fluid	✔	-	-
DuPont™ Liveo™ Silicone Elastomer Blend	-	✔	-
DuPont™ Liveo™ Silicone Gum Blend	-	-	✔
Ethylcellulose	✔	✔	✔
Octyldodecanol	✔	✔	✔
Caprylic/Capric Triglyceride	✔	✔	✔
Lidocaine	✔	✔	✔

Drug diffusion results

Skin permeation study of Anhydrous Gel with Silicone Fluid versus Anhydrous Gel with Silicone Elastomer

As detailed in Table 7 and shown in Figure 10, both anhydrous gels delivered similar total amounts of lidocaine: After 20 hours, 17.5% of lidocaine was recovered in the receptor medium and skin layers.

The total amounts of lidocaine retained in the skin were similar; however, the distribution profile in skin layers was slightly different. As shown in Figure 11, lidocaine was slightly more retained in the stratum corneum for Anhydrous Gel with Silicone Elastomer, and a slightly higher amount was found in the dermis for Anhydrous Gel with Silicone Fluid.

Table 7: Skin permeation results of Anhydrous Gel with Silicone Fluid and Anhydrous Gel with Silicone Elastomer

	Receptor (R)		Skin (S)	R + S
	Diffusion of active (µg/cm²)	Diffusion of active (%)	Diffusion of active (%)	Average in skin and receptor (%)
Anhydrous Gel with Silicone Fluid	12.7	7.9	9.8	17.5
Anhydrous Gel with Silicone Elastomer	12.8	7.9	9.8	17.5

Figure 10: Permeation profiles through dermatomed piglet skin

for Anhydrous Gel with Silicone Fluid and Anhydrous Gel with Silicone Elastomer

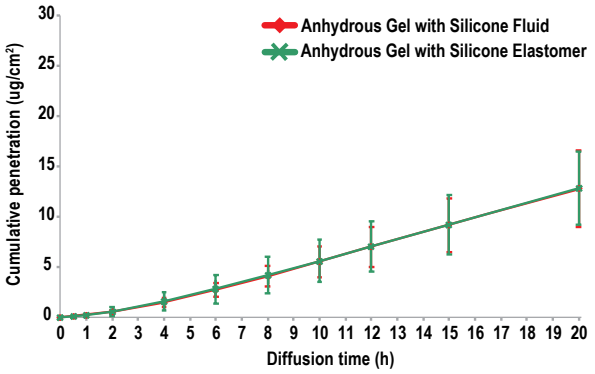
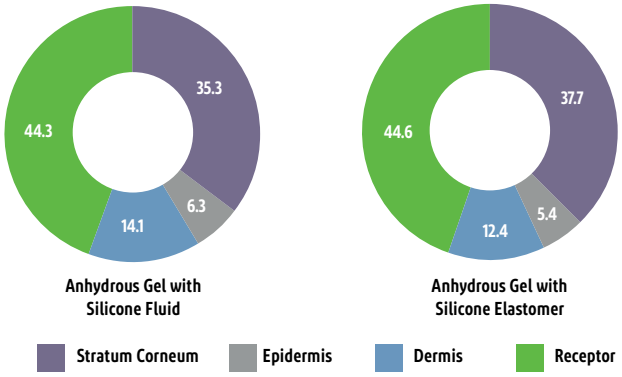


Figure 11: Skin compartment and receptor fluid analysis for Anhydrous Gel with Silicone Fluid and Anhydrous Gel with Silicone Elastomer



Skin permeation study of Anhydrous Gel with Silicone Fluid versus Anhydrous Gel with Silicone Gum Blend

As detailed in Table 8 and Figure 12, a higher diffusion rate of lidocaine after 20 hours was obtained with Anhydrous Gel with Silicone Fluid: 25.1% of lidocaine was recovered in the receptor medium (R) and skin (S) layers for Anhydrous Gel with Silicone Fluid versus 17.3% for Anhydrous Gel with Silicone Gum Blend.

The total amounts of lidocaine in the skin were similar, but with differing distribution profiles in the skin layers, as shown in Figure 13. The lidocaine concentration in the stratum corneum is higher for Anhydrous Gel with Silicone Gum Blend.

Table 8: Skin permeation results of Anhydrous Gel with Silicone Fluid and Anhydrous Gel with Silicone Gum Blend

	Receptor (R)		Skin (S)	R + S
	Diffusion of active (µg/cm²)	Diffusion of active (%)	Diffusion of active (%)	Average in skin and receptor (%)
Anhydrous Gel with Silicone Fluid	26.9	15.2	9.8	25.1
Anhydrous Gel with Silicone Gum Blend	11.7	7.2	10.0	17.3

Figure 12: Permeation profiles through dermatomed piglet skin for Anhydrous Gel with Silicone Fluid and Anhydrous Gel with Silicone Gum Blend

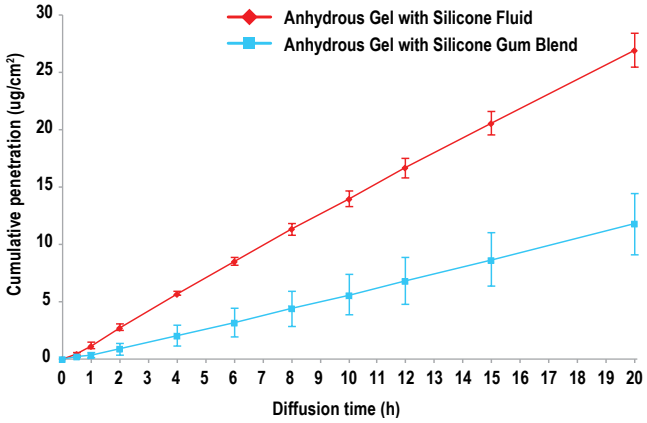
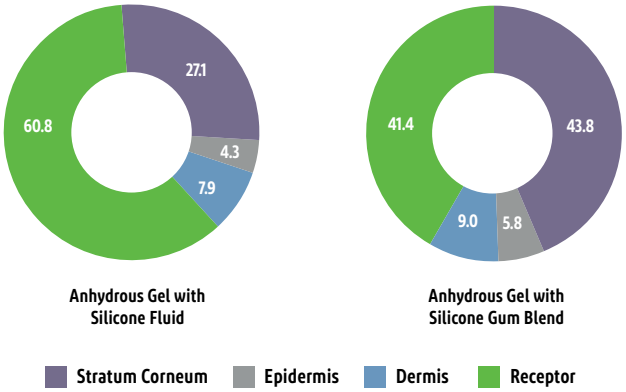


Figure 13: Skin compartment and receptor analysis for Anhydrous Gel with Silicone Fluid and Anhydrous Gel with Silicone Gum Blend



Performance evaluations on skin

The following performance evaluations were considered for the three anhydrous gel formulations: occlusivity level, sensory evaluation, and substantivity versus both time and washes. Because sensory and substantivity tests were performed as *in vivo* testing using panelists, the test samples had to be placebo, and anhydrous gel formulations were prepared without lidocaine, as detailed in Table 9.

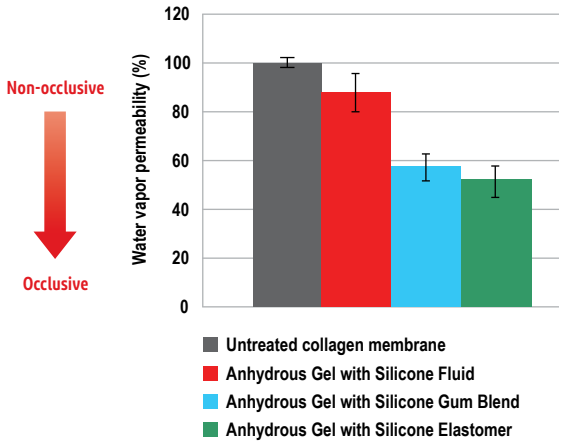
Table 9: Placebo formulations for skin evaluation

	Anhydrous Gel with Silicone Fluid (% w/w)	Anhydrous Gel with Silicone Elastomer (% w/w)	Anhydrous Gel with Silicone Gum Blend (% w/w)
DuPont™ Liveo™ Silicone Fluid	✔	-	-
DuPont™ Liveo™ Silicone Elastomer Blend	-	✔	-
DuPont™ Liveo™ Silicone Gum Blend	-	-	✔
Ethylcellulose	✔	✔	✔
Octyldodecanol	✔	✔	✔
Caprylic/Capric Triglyceride	✔	✔	✔

Occlusivity level

As shown in Figure 14, Anhydrous Gel with Silicone Fluid was non-occlusive; however, Anhydrous Gel with Silicone Gum Blend and Anhydrous Gel with Silicone Elastomer would be qualified as semi-occlusive.

Figure 14: Occlusivity level for the anhydrous gel placebo formulations



Note: Untreated non-occlusive collagen membrane is fixed at 100%.

Sensory profile

As shown in the sensory evaluation summary graph (Figure 15) and the statistical analysis (Table 10), Anhydrous Gel with Silicone Fluid resulted in a less greasy film with a less-smooth feel and lower film presence compared to Anhydrous Gel with Silicone Gum Blend or Silicone Elastomer. Anhydrous Gel with Silicone Elastomer showed the smoother and less slippery feel compared to the two other anhydrous gels.

Figure 15: Sensory evaluation summary graph for the anhydrous gel placebo formulations

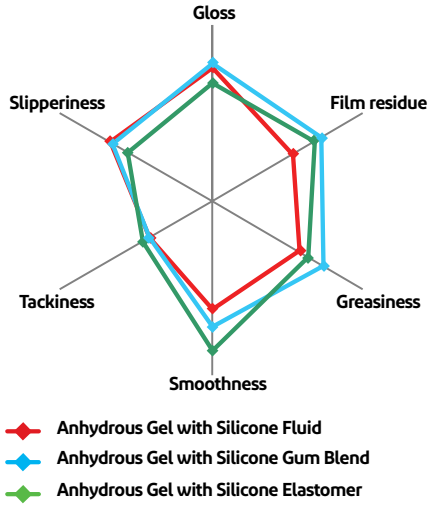


Table 10: Statistical results for sensory evaluation of the anhydrous gel placebo formulations (α<0.05)

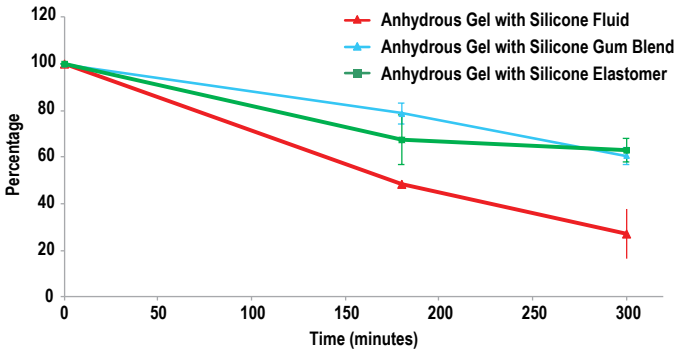
	Gloss	Film residue	Greasiness	Smoothness	Tackiness	Slipperiness
Anhydrous Gel with Silicone Fluid	a	b	a	a	a	a
Anhydrous Gel with Silicone Elastomer	a	a	ab	c	b	b
Anhydrous Gel with Silicone Gum Blend	a	a	b	b	a	a

Note: For each parameter, the use of the same letter indicates that the related test samples do not show any significant difference (95% similarity).

Substantivity versus time

With reference to Figure 16, the nature of the silicone polymer in the anhydrous gel influenced the substantivity of the placebo formulation. Anhydrous Gel with Silicone Gum Blend and Anhydrous Gel with Silicone Elastomer showed good substantivity, with 60% of silicone remaining on skin after 5 hours. Anhydrous Gel with Silicone Fluid showed a lower substantivity, with only 30% of silicone remaining on skin after 5 hours.

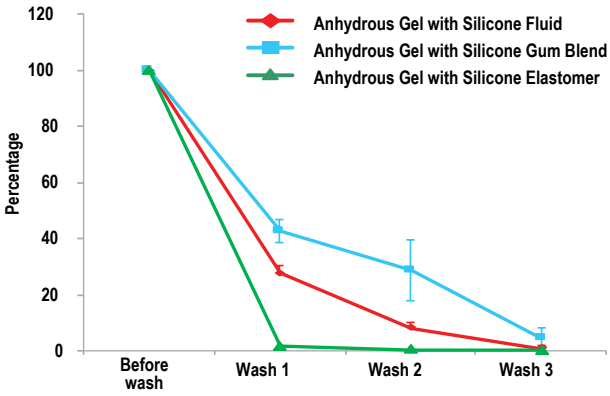
Figure 16: Substantivity versus time of the anhydrous gel placebo formulations



Substantivity versus washes

As shown in Figure 17, the nature of the silicone polymer in the anhydrous gel impacted the wash-off resistance of the placebo formulation. Anhydrous Gel with Silicone Gum Blend showed a good wash-off resistance: After one wash, 40% of silicone remained on skin, and after the second wash, 30% was still present. Anhydrous Gel with Silicone Fluid had a lower wash-off resistance with only 30% of silicone remaining on the skin after the first wash. Anhydrous Gel with Silicone Elastomer had no wash-off resistance.

Figure 17: Wash-off resistance of the anhydrous gel placebo formulations



Case Study 3: Evaluation of aqueous gel

Three aqueous gel formulations were prepared with the three different silicone polymers, as detailed in Table 11.

Table 11: Aqueous gel formulations

	Aqueous Gel with Silicone Fluid (% w/w)	Aqueous Gel with Silicone Elastomer (% w/w)	Aqueous Gel with Silicone Gum Blend (% w/w)
DuPont™ Liveo™ Silicone Fluid	✔	-	-
DuPont™ Liveo™ Silicone Elastomer Blend	-	✔	-
DuPont™ Liveo™ Silicone Gum Blend	-	-	✔
Lidocaine	✔	✔	✔
Octyldodecanol	✔	✔	✔
Water	✔	✔	✔
Methylcellulose	✔	✔	✔
Xanthan Gum	✔	✔	✔
Propylene Glycol	✔	✔	✔

Drug diffusion results

Skin permeation study of Aqueous Gel with Silicone Fluid versus Aqueous Gel with Silicone Elastomer

As detailed in Table 12 and shown in Figure 18, both aqueous gels delivered very similar amounts of lidocaine. After 20 hours, around 60% of lidocaine was found in the receptor medium and skin layers for both aqueous gels. However, the permeation of the lidocaine through the skin was slightly higher for Aqueous Gel with Silicone Elastomer compared to Aqueous Gel with Silicone Fluid: 49% versus 46.7% found in the receptor and 11.7% versus 12.8% recovered in the skin.

This observation was confirmed by the skin compartment analysis (Figure 19). For Aqueous Gel with Silicone Elastomer, the lidocaine level was higher in the stratum corneum (13.4% versus 12.3%) and lower in the dermis (5.8% versus 8.6%).

Table 12: Skin permeation results of Aqueous Gel with Silicone Fluid and Aqueous Gel with Silicone Elastomer

	Receptor (R)		Skin (S)	R + S
	Diffusion of active (µg/cm²)	Diffusion of active (%)	Diffusion of active (%)	Average in skin and receptor (%)
Aqueous Gel with Silicone Fluid	95.2	46.7	12.8	59.5
Aqueous Gel with Silicone Elastomer	88.2	49	11.7	60.7

Figure 18: Permeation profiles through dermatomed piglet skin for Aqueous Gel with Silicone Fluid and Aqueous Gel with Silicone Elastomer

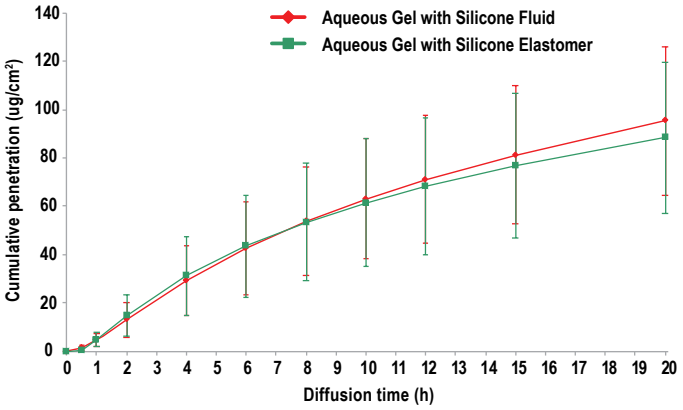
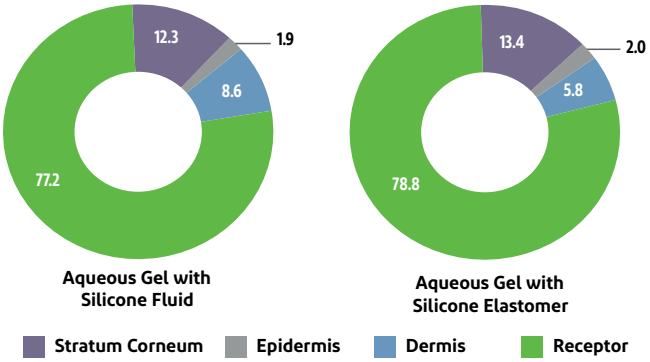


Figure 19: Skin compartment and receptor fluid analysis for Aqueous Gel with Silicone Fluid and Aqueous Gel with Silicone Elastomer



Skin permeation study of Aqueous Gel with Silicone Fluid versus Aqueous Gel with Silicone Gum Blend

As detailed in Table 13 and shown in Figure 20, Aqueous Gel with Silicone Fluid delivered a slightly higher amount of lidocaine after 20 hours than Aqueous Gel with Silicone Gum Blend: 42.8% versus 38.1% released into both the receptor and skin layers.

As shown in Figure 21, the distribution profiles in the skin layers were similar for both aqueous gel formulations, with a slightly higher amount in the dermis (11.1% versus 8.8%) for Aqueous Gel with Silicone Fluid.

Table 13: Skin permeation results of Aqueous Gel with Silicone Fluid and Aqueous Gel with Silicone Gum Blend

	Receptor (R)		Skin (S)	R + S
	Diffusion of active (µg/cm²)	Diffusion of active (%)	Diffusion of active (%)	Average in skin and receptor (%)
Aqueous Gel with Silicone Fluid	53.3	28.8	14.0	42.8
Aqueous Gel with Silicone Gum Blend	50.5	26.0	12.1	38.1

Figure 20: Permeation profiles through dermatomed piglet skin for Aqueous Gel with Silicone Fluid and Aqueous Gel with Silicone Gum Blend

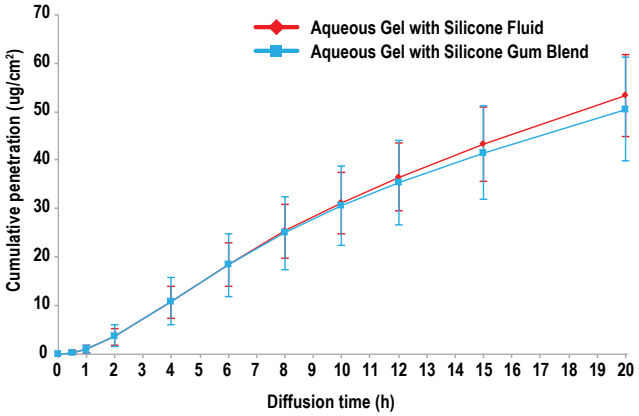
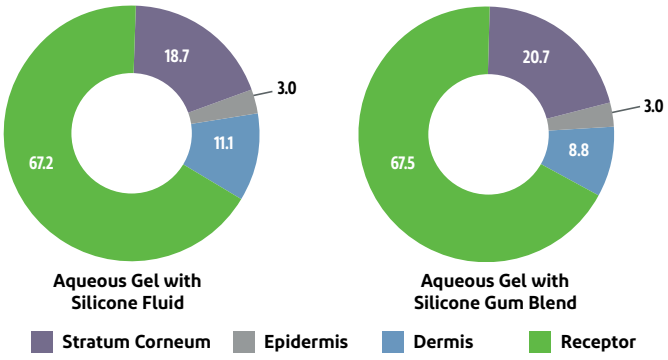


Figure 21: Skin compartment and receptor fluid analysis for Aqueous Gel with Silicone Fluid and Aqueous Gel with Silicone Gum Blend



Performance evaluations on skin

The following performance evaluations were considered for the three aqueous gel formulations: occlusivity level, sensory evaluation, and substantivity versus both time and washes. Because sensory and substantivity tests were performed as *in vivo* testing using panelists, the test samples had to be placebo, and aqueous gel formulations were prepared without lidocaine, as detailed in Table 14.

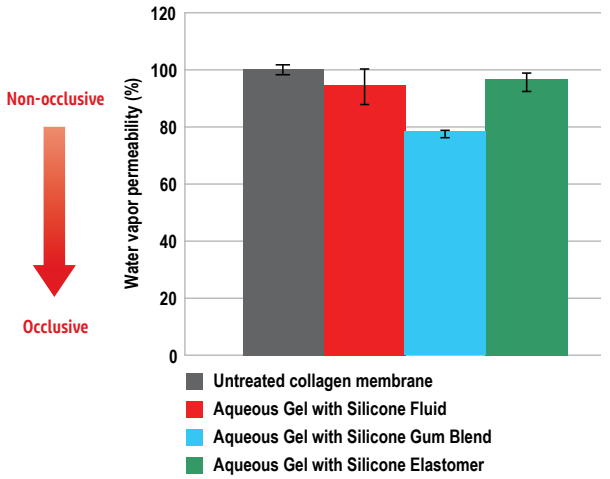
Table 14: Placebo formulations for skin evaluation

	Aqueous Gel with Silicone Fluid (% w/w)	Aqueous Gel with Silicone Elastomer (% w/w)	Aqueous Gel with Silicone Gum Blend (% w/w)
DuPont™ Liveo™ Silicone Fluid	✔	-	-
DuPont™ Liveo™ Silicone Elastomer Blend	-	✔	-
DuPont™ Liveo™ Silicone Gum Blend	-	-	✔
Octyldodecanol	✔	✔	✔
Water	✔	✔	✔
Methylcellulose	✔	✔	✔
Xanthan Gum	✔	✔	✔
Propylene Glycol	✔	✔	✔

Occlusivity level

As shown in Figure 22, all aqueous gels were non-occlusive.

Figure 22: Occlusivity level for the aqueous gel placebo formulations



Note: Untreated non-occlusive collagen membrane is fixed at 100%.

Sensory profile

As shown in the sensory evaluation summary graph (Figure 23) and the statistical analysis (Table 15), Aqueous Gel with Silicone Fluid and Aqueous Gel with Silicone Elastomer resulted in less greasiness, a smoother feel and lower film presence compared to Aqueous Gel with Silicone Gum Blend. Aqueous Gel with Silicone Gum Blend shows a higher film presence and greasiness compared to Aqueous Gel with Silicone Fluid and Aqueous Gel with Silicone Elastomer.

Figure 23: Sensory evaluation summary graph for the aqueous gel placebo formulations

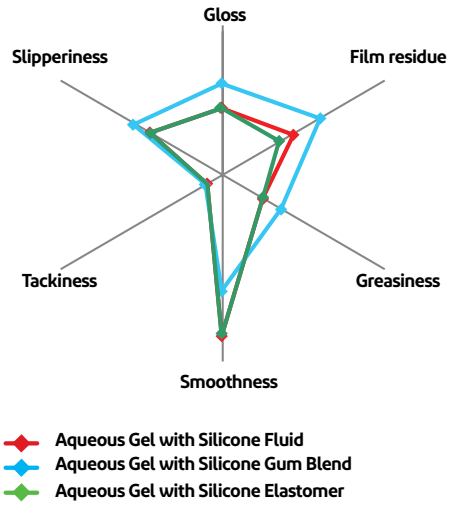


Table 15: Statistical results for sensory evaluation of the aqueous gel placebo formulations (α < 0.5)

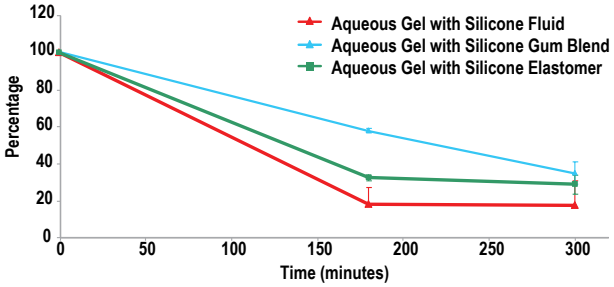
	Gloss	Film residue	Greasiness	Smoothness	Tackiness	Slipperiness
Aqueous Gel with Silicone Fluid	a	ab	a	a	a	a
Aqueous Gel with Silicone Elastomer	a	b	a	c	a	b
Aqueous Gel with Silicone Gum Blend	a	a	b	b	a	a

Note: For each parameter, the use of the same letter indicates that the related test samples do not show any significant difference (95% similarity).

Substantivity versus time

With reference to Figure 24, the nature of the silicone polymer in the aqueous gels slightly influenced the substantivity. Aqueous Gel with Silicone Gum Blend had a better substantivity, with 60% of silicone remaining on the skin after 3 hours. However, after 5 hours, the three aqueous gels behaved more or less the same.

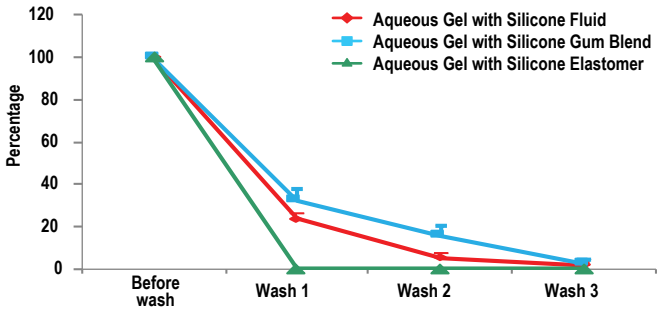
Figure 24: Substantivity versus time of the aqueous gel placebo formulations



Substantivity versus washes

As shown in Figure 25, the nature of the silicone polymer in the aqueous gels had an impact on the wash-off resistance. Aqueous Gel with Silicone Fluid and Aqueous Gel with Silicone Gum Blend showed medium wash-off resistance, with 30% of silicone remaining on the skin after the first wash. Aqueous Gel with Silicone Elastomer had no wash-off resistance.

Figure 25: Wash-off resistance of the aqueous gel placebo formulations



Conclusion

The uniqueness and versatility of silicone chemistry in terms of functionalities and characteristics offers a wide range of formulation options to load, stabilize and release various drugs for dermatological and local treatments, as demonstrated by the formulations evaluated in this paper with lidocaine as model drug.

Formulators can achieve more efficient drug delivery and more desired skin performance benefits that increase efficacy and patient compliance.

About DuPont™ Liveo™

DuPont™ Liveo™ is a globally recognized leader in technology for a broad range of innovations in medical devices, biopharmaceutical processing and pharmaceutical solutions. Our high-performance materials help create safer healthcare environments and protect the health of patients and healthcare providers worldwide. We help enable smarter healthcare and positive patient solutions.

For more information about DuPont™ Liveo™ Pharmaceutical Solutions

Visit **liveo.dupont.com** – or scan the QR code at right to be taken directly to our pharmaceutical solutions web page, where you'll find details on the full portfolio of solutions for oral, topical and transdermal drug delivery.

Form No. 04-2076-01-AGP0326 #17731M-12