Tech Article

How to Solve Stiction and Tolerance Stack-Up in Medical Devices: A Practical Guide to Using Dry Lubricants for Friction Control

Author: Elizabeth Norwood, MicroCare Senior Chemist

Industry: Medical Device Manufacturing

Published: Medical Design Briefs

Duraglide™ Dry Lubricant

The Problem: When Good Designs Stick

Medical device engineers routinely confront a deceptively simple but persistent challenge: friction.

In theory, every part is produced at nominal dimension. In reality, parts are manufactured within allowable tolerances to control cost. When multiple components such as nested shafts, hypo tubes, sliding cartridges, triggers, pivots, are assembled, dimensional variation accumulates. This tolerance stack-up often results in:

- Elevated actuation forces
- Inconsistent device feel
- Surface galling or wear
- Difficult assembly
- "Stiction" (static friction exceeding dynamic friction)

In disposable surgical devices such as catheters, staplers, biopsy tools, and drug-delivery systems, even modest friction increases can compromise usability, or commercial viability.

While designers may try to tighten tolerances, polish surfaces, or change materials, these approaches increase cost and complexity. A more efficient solution is often found not in geometry, but in surface engineering.

The Solution: Dry Lubrication as a Design Tool

Dry lubricants, particularly those based on polytetrafluoroethylene (PTFE), offer an effective method for controlling friction without redesigning components. Unlike oils or greases, PTFE dry lubricants are dispersed in a carrier fluid and applied by dipping, spraying, or brushing. Once applied:

1. The low-viscosity carrier wets complex geometries and tight clearances.
2. The carrier evaporates rapidly.
3. A thin, uniform PTFE film stays bonded to the surface.

The result is a clean, dry, non-migrating coating that significantly reduces surface-to-surface friction.

As an example, Duraglide™ Dry Lubricant uses ultra-fine PTFE particles (1–15 μm, average ~3.7 μm) suspended in a nonflammable carrier fluid. The small particle size allows the coating to conform to surface topography, penetrate blind features, and coat intricate assemblies uniformly.

Quantifying the Impact: Why Dry Lubricants Matter

Properly applied PTFE dry lubricants can reduce the coefficient of friction to as low as 0.06, often translating into:

- 25–30% reduction in actuation force
- Smoother and more predictable device performance
- Improved tactile feedback
- Reduced wear during lifecycle testing

In many complex mechanisms, this reduction is not incremental, it is enabling.

Tech Article

Precision medical device components are manufactured within allowable tolerances, which can accumulate during assembly and increase friction between moving parts

Stiction occurs when static friction exceeds dynamic friction, causing components to resist initial movement and creating inconsistent device feel

MicroCare MEDICAL™

Making Your Devices Better

Devices that previously required force compensation or redesign can meet performance targets with minimal dimensional change.

Why Not Oils or Greases?

Traditional lubricants introduce new engineering risks in medical applications:

- Migration to packaging or sterile barriers
- Particulate attraction
- Bioburden concerns
- Residual films incompatible with cleanroom environments
- Validation complexity

Dry PTFE coatings avoid these limitations. A properly engineered dry lubricant stays fixed at the application site, leaving no oily residue and supporting cleanroom compatibility.

For example, Duraglide™ formulations use non-aqueous carrier fluids that are inimical to pyrogens and compatible with common sterilization methods, including:

- Ethylene Oxide (EtO)
- Radiation sterilization

The product is ISO 10993 tested and certified, supporting medical device validation requirements.

Addressing the PFAS Question

Because PTFE is a fluoropolymer, it is part of the broader class of per- and polyfluoroalkyl substances (PFAS). Increasing global regulatory attention to PFAS has raised important questions for medical device engineers.
It is essential to distinguish between PFAS molecules which are mobile and water soluble, such as PFOA and PFOS, and molecules that are stable and inert like PTFE.

PTFE used in medical dry lubricants is:

- A stable, high-molecular-weight polymer
- Chemically inert and non-bioavailable in its finished form
- Non-soluble in water
- Not classified as bioaccumulative

In medical device applications, PTFE is widely used in implants, catheters, vascular grafts, and surgical components due to its long-established biocompatibility profile.

However, engineers should:

- Monitor evolving regional PFAS regulations (EU, US state-level, etc.)
- Request supplier documentation on regulatory status and compliance

Reputable suppliers, Like MicroCare Medical producing Duraglide™, can provide documentation on formulation, processing, and regulatory positioning to support risk assessments and technical files.

Dry lubricants can be applied by spraying, dipping or brushing, allowing the carrier fluid to wet complex geometries and tight clearances

Dry PTFE coatings can penetrate intricate geometries and blind features, providing uniform lubrication across complex medical device assemblies

In short, PFAS scrutiny does not automatically eliminate PTFE as a viable engineering material. Instead, it reinforces the importance of supplier transparency and regulatory diligence.

Design Considerations When Selecting a Dry Lubricant

Not all dry lubricants are equal. Engineers should evaluate the following:

1. **Coating Uniformity and Viscosity**
   The carrier fluid must adequately wet and conform to complex geometries. Low viscosity promotes consistent film thickness and repeatability.
2. **Nonflammability**
   High-speed production environments often involve static discharge risks. A nonflammable carrier enhances workplace safety.
3. **Sterilization Compatibility**
   The coating must withstand EtO and radiation without degradation or migration.
4. **Materials Compatibility**
   Dry lubricants such as Duraglide™ are designed to function across metal-to-metal and metal-to-polymer interfaces common in surgical assemblies. The lubricant should be compatible with:
   - Stainless steels
   - Aluminum alloys
   - Engineered plastics
   - Ceramics and glass
5. **Process Simplicity**
   Pre-mixed, calibrated formulations reduce operator variability and simplify validation. For instance, Duraglide™ XF is supplied as a 2% PTFE solution in a nonflammable carrier, ending in-house mixing inconsistencies.

Manufacturing Benefits Beyond the Device

Dry lubricants also support production efficiency. They can be applied to:

- Injection mold cavities (as release aids)
- Assembly fixtures
- Conveyor systems
- Guides, slides, and pulleys

By reducing friction in tooling and automation systems, manufacturers can increase throughput and reduce wear-related downtime.

Fine Tuning the Solution

Different devices require different lubrication intensities. PTFE dry lubricants are available in varying concentrations (e.g., 0.5% to 10% PTFE), allowing engineers to optimize:

- Film thickness
- Friction performance
- Aesthetic finish
- Process cycle time

MicroCare MEDICAL™

Making Your Devices Better

Tech Article

Reducing the coefficient of friction can significantly lower actuation force and improve tactile feedback in surgical mechanisms

Dry lubricants support cleanroom manufacturing by leaving no oily residue and staying fixed at the application site

Dry lubricants can also improve manufacturing efficiency by reducing friction in tooling, fixtures and automation systems

MicroCare MEDICAL™

Making Your Devices Better

Duraglide™ formulations, including XF and HI variants, provide calibrated PTFE content for consistent results, with custom options available for specialized requirements.

Conclusion: Treat Friction as a Design Parameter

Friction control should not be considered a late-stage fix. It is a core mechanical design parameter.

When tolerance stack-up, stiction, and inconsistent actuation threaten performance, tightening machining tolerances is rarely the most economical solution. A carefully selected dry lubricant can:

- Lower friction coefficients to ~0.06
- Reduce actuation forces by up to 30%
- Improve assembly consistency
- Simplify validation
- Enhance manufacturing efficiency

At the same time, engineers must evaluate regulatory considerations, including evolving PFAS frameworks. High-molecular-weight PTFE-based dry lubricants, when properly formulated and documented, remain a technically robust and widely accepted solution in medical device engineering.

In many cases, the most efficient way to solve a mechanical problem is not to redesign the part, but to engineer the surface, responsibly and strategically.

About the Author:
Elizabeth Norwood is a Senior Chemist at MicroCare, LLC, which offers precision cleaning solutions. She has been in the industry for more than 25 years and holds a BS in Chemistry from the University of St. Joseph. Norwood researches, develops and tests cleaning-related products. She currently has one patent issued and two pending for her work. For more information, visit www.microcare.com.