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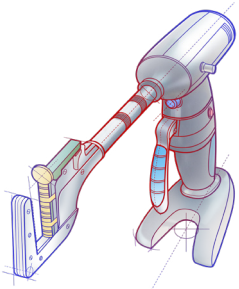
WHITE PAPER

BRUSH DC VS. BRUSHLESS DC MOTORS FOR DISPOSABLE SURGICAL POWER TOOLS

by Clémence Muron

Disposable tools are a fast-growing segment within the surgical hand tool market, driven by cost and hygiene benefits. For tool design engineers, the motor technology is often a critical choice, specifically the selection of either a Brush DC or Brushless DC motor.

Clémence Muron, Applications Engineer for Portescap, a leading supplier of motor technology to surgical OEMs, reviews the benefits of Brush DC vs. Brushless DC motors for disposable medical tools.



Surgical Stapler

Surgical power tool designers must choose whether to take a disposable or reusable design approach. Advances in component design and manufacturing techniques have made it increasingly possible to produce equipment with the capability required to perform complex surgery at a price point where disposal of the tool after a single surgery can be justified. These advances extend to motors. Design and manufacturing improvements for both Brush DC and Brushless DC (BLDC) motors have reduced price points while increasing performance – thus making it possible to achieve a sufficiently low per surgery tool cost with a disposable design. In addition, for some tools there may be an opportunity to increase safety by removing the risk of infection due to inadequate sterilization.

Motor Performance Requirements for Single-Use Tools

While motor performance requirements are similar for reusable and disposable surgical tools, the lifetime and cost requirements are vastly different. A motor specified for a reusable tool may have a lifetime requirement of hundreds or even thousands of surgeries and thus must utilise premium components and materials to achieve this remarkable feat. A motor for a disposable tool needs to provide similar performance – albeit for only a single surgery – yet must be available in high volumes and at a competitive price.

When specifying motors for disposable tools, design engineers should consider the possible advantages of conventional Brush DC motors over the more advanced BLDC technology. Due to the nature of the design and inherent reliability advantages, BLDC motors are the typical choice for use in reusable power tools. The advantages of BLDC do unfortunately increase costs vs Brush DC; thus, it is often infeasible to specify a BLDC motor for a disposable tool. Designers should work with a motor supplier well-versed in both technologies so that the performance and cost trade-offs between a Brush DC and BLDC motor technology are correctly identified.

Brush DC vs. Brushless DC Motors

If the goal of a new project is to maximize performance and reliability, a design engineer is likely to gravitate to BLDC technology. Brushless technology makes it possible to operate at high speeds (up to 100k RPM) over a long operating life. In BLDC, commutation is achieved without the use of mechanical brushes (i.e., via magnetic

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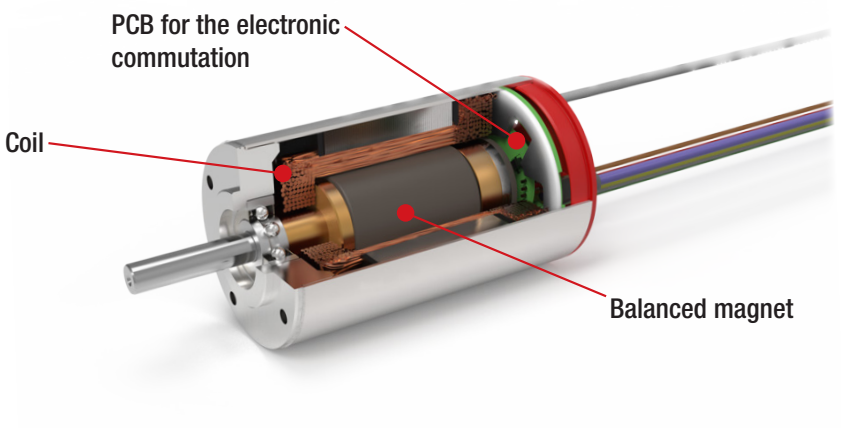
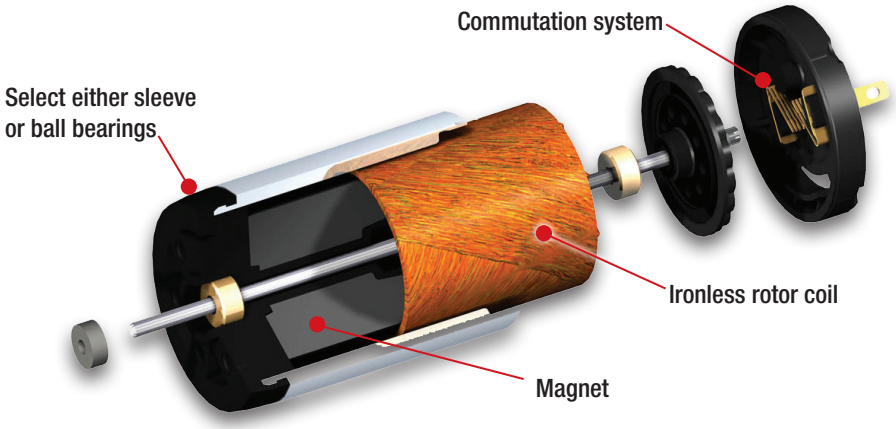
Hall sensors or sensorless drive with a brushless motor controller) – thus the contact between the rotating components and the stationary components in the motor is limited to the ball bearings. This means the lifetime of the motor is primarily related to the longevity of the bearing, and the motor can operate at high speed for an extended period.



By comparison, in a Brush DC motor, commutation is achieved through mechanical brushes (graphite or precious metal) making physical contact with the rotor to complete the electrical connection. In this case, the lifetime of the motor is primarily limited to the lifetime of the brushes, with higher speeds leading to premature wear. For a disposable tool, the higher speed may not be an issue given the short lifetime requirement – however this will depend heavily on the duty cycle and speed requirements of the application.

{ The **performance** of a Brush DC motor will vary significantly depending on the design and materials used. }

The performance of a Brush DC motor will also vary significantly depending on the design and materials used. For example, Portescap Brush DC motors are 'coreless' (most lower cost brush motors will feature an iron core), meaning that the rotor is only composed of a coil and a single shaft. The coreless design offers lower inertia which results in higher performance regarding acceleration and efficiency. It also eliminates detent torque (cogging torque), which can cause reduced smoothness of rotation at slower speeds.



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For reusable surgical tools, the lifetime and speed requirements often make BLDC the ideal solution. However, for some applications leveraging a single-use design, a Brush DC motor can provide an attractive solution.

Artery Disease Treatment Device

Cost Implications

Once the performance requirements are met, cost is often the next most important consideration. Brushless motor systems are inherently more expensive. They must include a brushless motor controller to achieve commutation, and often include embedded electronics for sensing rotor position. For some applications this cost is justifiable, though it often is not. For example, in a very high-performance application, relatively costly components may be required, such as premium bearings, dynamic shaft seals, or high-grade magnets – specification of these higher cost components can make it challenging to justify a disposable tool strategy. In contrast, in a Brush DC motor, commutation is managed directly by the brushes, and a simpler PWM circuit is used for speed control. Advances in Brush DC technology have made higher performance achievable without much impact to cost – this coupled with the short lifetime requirement for a disposable tool can mean that it is possible to meet a level of performance that is beyond what is typically considered feasible for a lower-cost Brush DC motor.

For a disposable tool, the cost incurred for a single surgery includes the full purchase price of the tool. With a reusable tool, only a small portion of the purchase price is amortized for each procedure. In addition, the surgical power tool must undergo sterilization before surgery. This process is an additional cost that should be considered when assessing the total cost of performing a surgery. As a result, the number of surgeries a surgical center can perform per tool and the cost to sterilize between surgeries are the major factors in determining whether a disposable or reusable tool is best. Naturally, a reusable tool will carry a much higher purchase price than a disposable tool. But if the center can use it for a sufficient number of procedures, then the average cost per procedure drops below that of a disposable tool *(Figure A).*

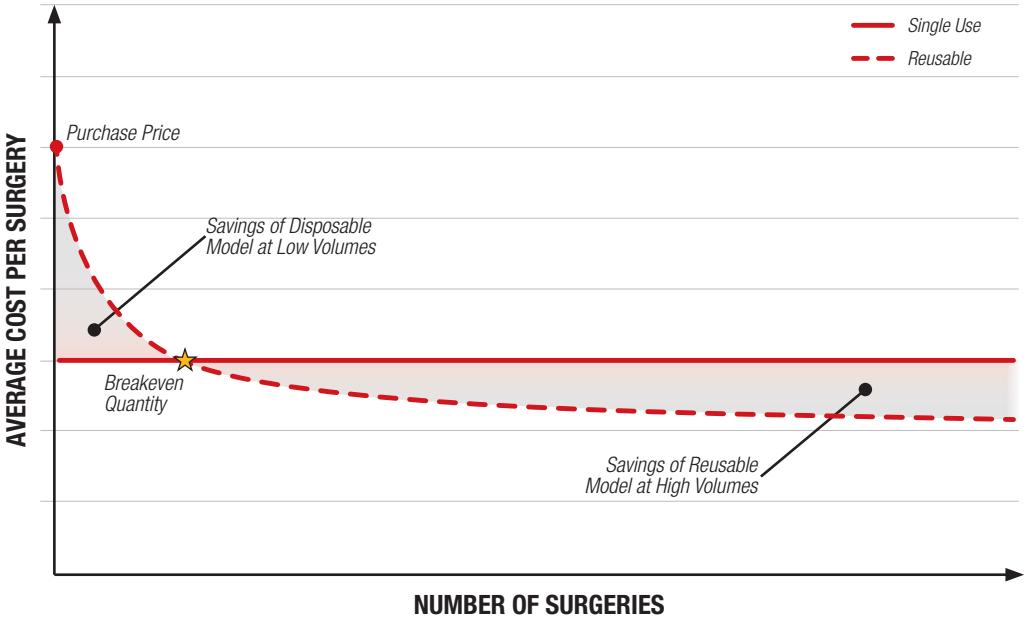

Figure A

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A higher priced reusable tool (perhaps using a higher performing BLDC motor instead of a low-cost Brush DC) will of course require more surgeries to become less expensive long-term than a disposable. Sterilization costs will also increase the number of procedures required to break-even, so much so that in some cases the disposable tool may be preferable no matter the number of surgeries *(Figure B).*

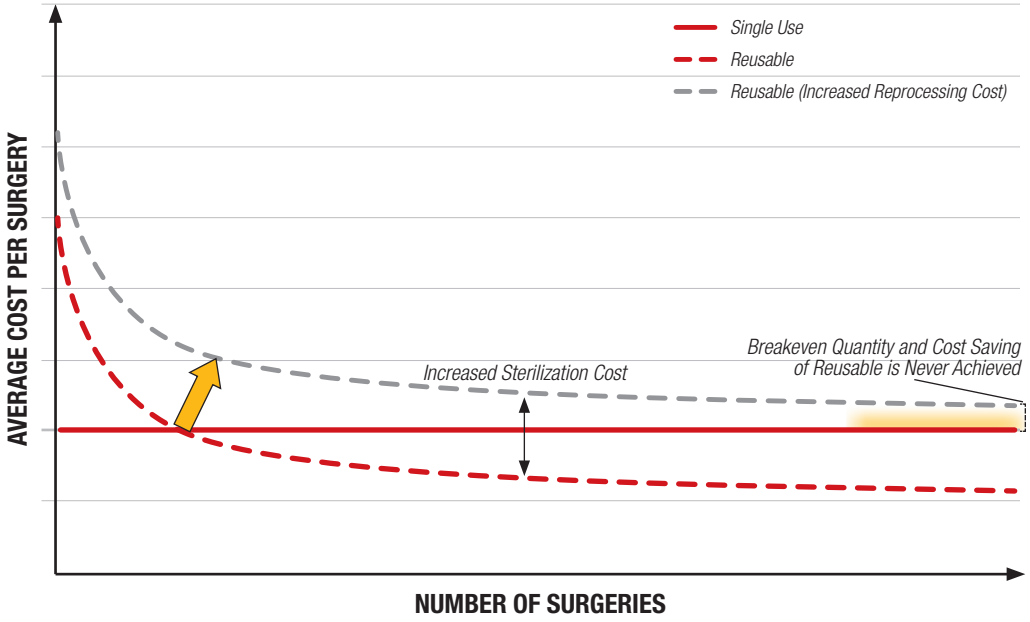
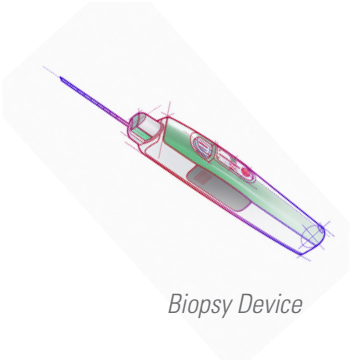


Figure B



Biopsy Device

Note that the above analysis simply compares average costs associated with the tool options and does not consider other advantages of reusable and disposable tools that should factor into the decision. For example, a high-end reusable tool will likely feature better performance and additional capabilities than any disposable tool. Even if the breakeven quantity is not reached, the value provided to surgeons and patients may still make it the right choice. Also not considered in the cost of the sterilization process is the risk of infection that a reusable tool naturally introduces. Failure to adequately sterilize the tool is dangerous for patients. This article will not go into detail regarding sterilization methods and the design of tools to facilitate sterilization. Suffice it to say any discussion of disposable vs reusable power tools would be incomplete without consideration of re-processing and patient safety. While sterilization has been proven to be safe and effective, a failure to adequately sterilize a tool between surgeries is a risk that should also be considered by surgical power tool designers. Disposable tools can be sterilized and packaged by the tool OEM, and this approach may lead to increased patient safety for some applications and hospital systems.

Example:

An R&D team at a medical device company is developing a new tool with the following specifications:

- A hand-held surgical power tool that can cause serious complications if it stops working properly during a procedure
- The motor diameter must not exceed 17mm
- The motor must run continuously at 5 mNm at 15,000 RPM

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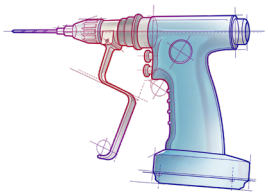

Surgical Drill

- The device is battery powered so the motor must run with minimum 80% efficiency and at voltage between 6-9 volts and a current of 1.5 amps max
- The procedure is cost sensitive so the motor must not contribute more than $20 to the cost of each surgery
- The design team prefers a disposable tool, but a reusable model is possible
- Brush DC or BLDC motor technology can be used

The engineers start by engaging with a motor supplier that offers both Brush DC and BLDC technologies and has significant experience in the surgical power tool market. The motor supplier selects a motor from each technology that is below 17mm diameter and best matches the performance and power requirements. These options are summarized in the table below:

	Brush DC	**Brushless DC**
Package	Ø 17mm, length 26mm	Ø 13mm, length 47mm
Max Continuous Torque (mNm)	5.7mNm	9mNm
Max Recommended Speed (RPM)	10,000 RPM	100,000 RPM
Controller	PWM	BLDC controller with hall sensors
Voltage Required	7 V	9 V
Current Draw	1.4 A	1.2A
Output power	9.8W	10.8W
Efficiency at working point	80%	72%
Example Price	$15	$160

Both options meet the 5 mNm torque requirement, but the maximum continuous torque rating for the DC Brush motor is only slightly higher at 5.7 mNm. This will reduce the life of the motor, but not enough to be a concern for a single procedure. The bigger problem is the speed of 15,000 rpm, which is higher than the maximum speed for the Brush DC motor. This could be okay for a single procedure, but the risk of failure during surgery is increased. The cost of the motor is low enough that it can be thrown away after each use.

The number of surgeries a surgical center can perform per tool & the cost to sterilize between surgeries are the major factors in **determining** whether a **disposable or reusable** tool is best.

The BLDC motor can easily meet the speed and torque requirements and could continue to do so for many surgeries. However, the efficiency is slightly lower than the 80% target, and the price is much higher than $20. For a BLDC motor to be viable, it would have to be used for at least 8 surgeries.

Due the performance and price demands of the application, the design engineers must choose between a Brush DC motor in a disposable model or a BLDC motor in a reusable model. A reusable Brush DC motor is not possible in this example because of the risk of failure in more than one surgery, and a disposable BLDC motor is not possible because of the cost.

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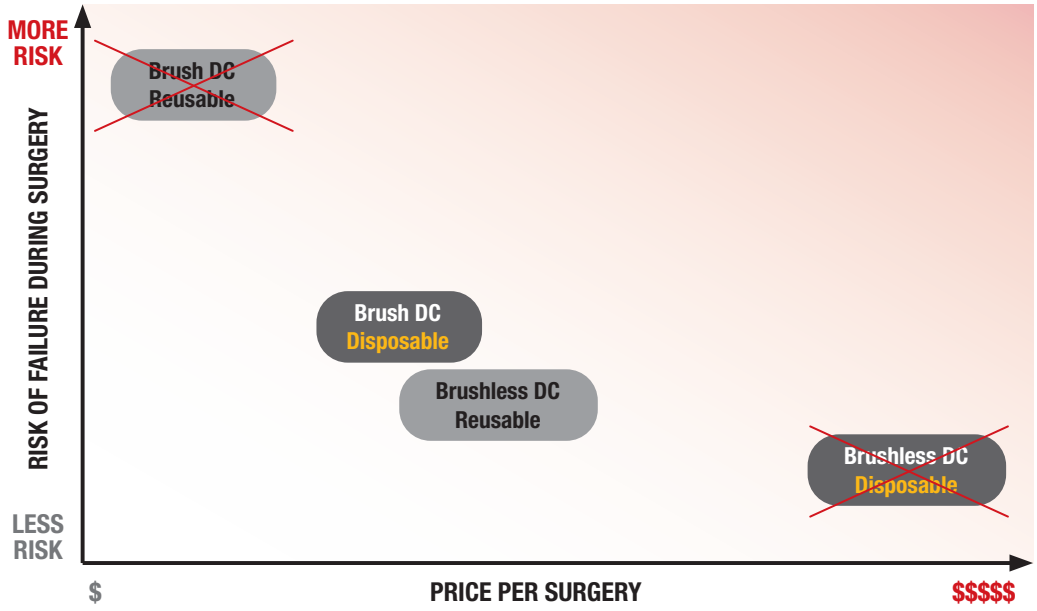

Figure C

The decision then becomes whether the risk of a Brush DC motor failing in its first surgery due to the high speed is acceptable. If not, then the engineers can reduce the speed requirement which will result in a lower performance tool. Or they can opt for the reusable model and accept the lower efficiency. They will also have to design the rest of the tool to be sterilizable and require their customers to sterilize the tool between uses. Both factors must be considered when calculating the total cost per surgery.

Conclusion

The rise in popularity of disposable surgical power tools has led to an increased demand for Brush DC motors to achieve design goals. When cost efficiency is more critical than extended motor life, BLDC technology may not be the best choice given the cost implication of the more complex solution. The choice of technology depends heavily on the application. Surgical device designers can do well by collaborating early in their design cycle with a motor supplier that has the surgical design expertise, as well as a range of both BLDC and Brush DC solutions. **P**

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