ATTUNE™ Knee System: LOGICLOCK™ Tibial Base Central Locking Design

Mark Heldreth
Engineering Fellow | *DePuy Synthes Joint Reconstruction*

ROLES OF THE FIXED BEARING LOCKING MECHANISM IN TOTAL KNEE ARTHROPLASTY (TKA):

Proper design of modular fixed bearing tibial trays is a fundamental factor affecting the optimization of multiple design factors within the system, namely the simplicity of size interchangeability, the mechanical durability of the implant, and the potential for generation/distribution of wear debris.

IMPACT UPON SIMPLICITY AND DESIGN OPTIMIZATION:

In total knee arthroplasty, accommodation must be made for natural sizing disparity between the distal femur and the proximal tibia. However, the challenges with historical approaches for accomplishing this are numerous. First, in systems where the polyethylene insert size matches the tibial base plate size, multiple femoral sizes may be allowed to articulate upon the insert through a complex size interchangeability matrix. This may introduce compromise. For example, when the tibial insert is mated with the smallest size femoral component allowed by the interchangeability matrix, the contact pressures will be greater. These increased contact pressures may result in increased wear potential of the implant over time and results in decreased A/P conformity. Second, stability as related to the conformity ratio between the femoral component and tibial insert cannot be optimized. Higher conformity ratios result in increased stresses transferred to tibial component interfaces, and lower conformity ratios lead to decreased A/P stability. Finally, compromise is introduced to important proportionalities within the system. For example, the size of the intercondylar box on the posterior stabilized (PS) could not be fine tuned. On smaller femoral sizes this may cause a box resection slightly larger than what is needed.

The ATTUNE™ Knee System eliminates these compromises through its unique patented LOGICLOCK™ Tibial Base technology.[1] The central features of the design are common to all sizes. These features extend in a proportional manner from the center outward. As a result, the femoral and polyethylene insert sizes can always be matched. This allows for optimization and full size proportionality of the key functional parameters: tibio-femoral contact mechanics, tibio-femoral stability and PS spine/intercondylar box size. Additionally, the surgeon and OR staff are not required to remember a complex size interchangeability matrix. The Persona™ chart below (Figure 1) demonstrates this type of complex matrix. In one scenario a single insert size can work with 2 femoral sizes and 2 tibial tray sizes. In another scenario a single insert size can work with 9 different femoral sizes and 2 tibial tray sizes. This inconsistency has the potential to increase complexity during a case.

Through insert to femur matching the ATTUNE Knee System provides a simplified system, while optimizing function for each patient.

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Persona CR Femur → **Use On** → **Persona Tibia**

<table>
<tr><th colspan="2">CR</th><th colspan="12">Persona Femoral Size</th></tr>
<tr><th></th><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th></tr>
<tr><td rowspan="9">Persona Tibial Size</td><td>A</td><td colspan="2" rowspan="2">1 - 2 / A B</td><td colspan="4" rowspan="2">3 - 6 / A B</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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The resulting fit between the polyethylene insert and the tibial base plate for different combinations is shown in Figure 2. Even when the polyethylene is two sizes larger than the tray, the chamfered edges of the insert prevent overhang.

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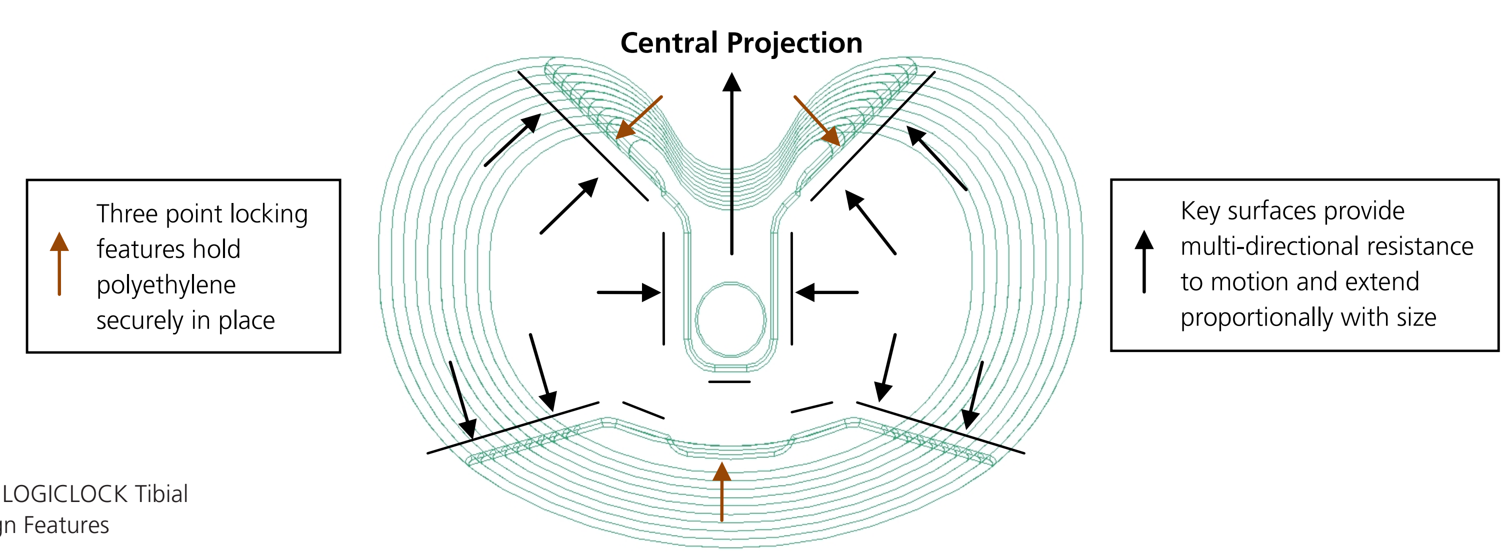

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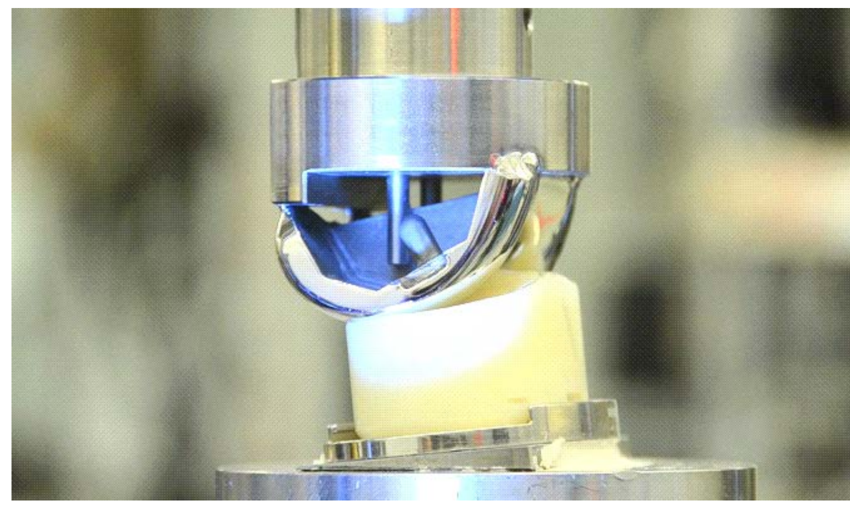
The reported incidence of mechanical failure in fixed bearing implant locking mechanisms is rare in the absence of polyethylene insert oxidation. However, significant in vitro oxidation of Ultra High Molecular Weight Polyethylene (UHMWPE) inserts has been documented in first generation gamma irradiated air packaged systems[2] and after extended in vivo implantation in second generation gamma irradiated barrier packaged systems.[3] More recent third generation polyethylene technology has focused upon increased resistance to oxidation through secondary processing, but with some commensurate reduction in mechanical properties and/or remaining residual potential for oxidation.[4,5] The ATTUNE Knee utilizes fourth generation AOX™ Antioxidant Polyethylene to provide protection against polyethylene oxidation through the active scavenging of free radicals.[6,7] This is accomplished without a reduction in mechanical properties as seen in some third generation polyethylene materials, enabling durability when combined with the LOGICLOCK Tibial Base locking mechanism.

In addition to taking extensive efforts to protect the material, the LOGICLOCK Tibial Base locking mechanism was developed with careful attention to balancing design features. Where forces are significant, broad surface areas are provided to resist them (see Figure 3). Specific locking features, such as the anterior locking tab, were evaluated against clinically successful designs using finite element analysis (FEA) and mechanical testing. Since the anterior locking tab is effectively shielded from significant forces by other load carrying design features, it acts solely to resist anterior lift off in the case of significant posterior femoral rollback. Extensive testing was conducted to determine the ability of the LOGICLOCK Tibial Base design to resist vertical separation forces that may arise due to compressive femoral loading on the posterior portions of the polyethylene insert under extreme conditions (see Figure 4).[8]

The results in Figure 5 indicate, relative to PFC® SIGMA® Fixed Bearing , the ATTUNE Knee design is capable of withstanding an equal or greater amount of femoral posterior translation under the same vertical compressive load. This is accomplished through a balance of posterior tibio-femoral conformity and anterior tab design features.



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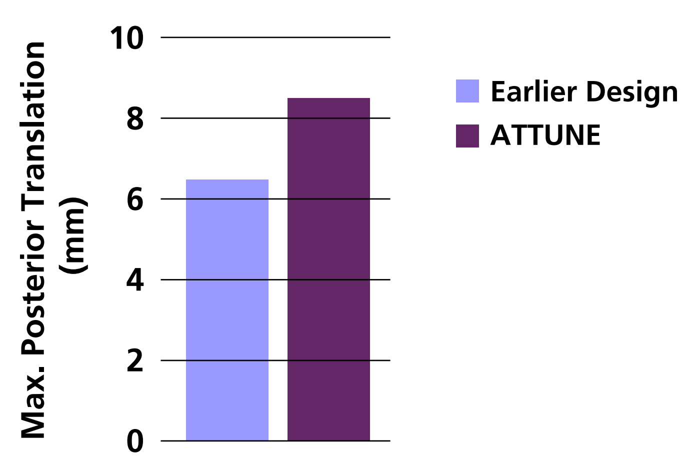

(Comparison of mid size w/ 20 mm total composite thickness)

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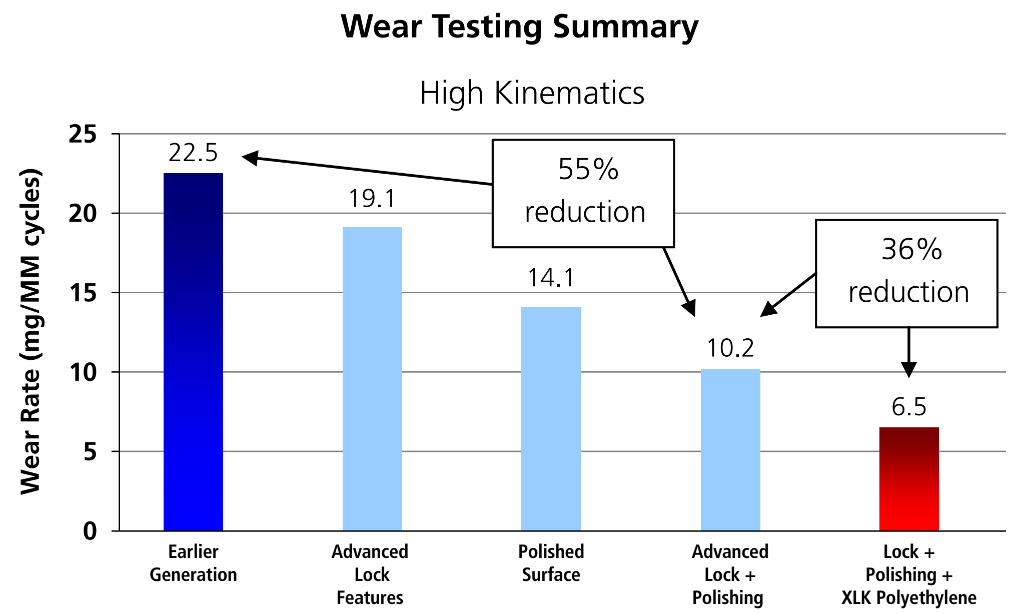
WEAR:

A major concern in the use of modular knee implants has been particle generation from the backside of the UHMWPE tibial insert. Relative motion (commonly referred to as micromotion) of the tibial insert against the proximal tibial base plate can generate microscopic particles that with time can propagate throughout the joint and lead to osteolysis, a condition that can promote bone resorption and eventually, implant loosening.[9,10,11,12]

The two main factors that contribute to the reduction in backside particle generation are the surface finish of the tibial base plate and the reduction in relative motion between the polyethylene insert and the tibial base plate through mechanical design features.[13] Prior testing has shown that improvements to both of these factors can lead to significant reductions in total wear when compared to earlier generation designs (Figure 6). The reductions in wear due to advanced base plate locking features and polished surfaces lay the foundation for realizing further improvements through crosslinked polyethylene technology. Failure to pay attention to these features can offset some of the potential wear improvement available through new polymer technology.

To establish this foundation, the tibial base plates in the ATTUNE Knee System utilize the same highly polished surface finish utilized in the clinically successful SIGMA® Knee System i2™ lock tibial base plates. In addition, the LOGICLOCK Tibial Base design provides industry leading control of micromotion (Figure 7) while simultaneously providing the previously described benefits of matched femoral/polyethylene insert articulating surfaces.



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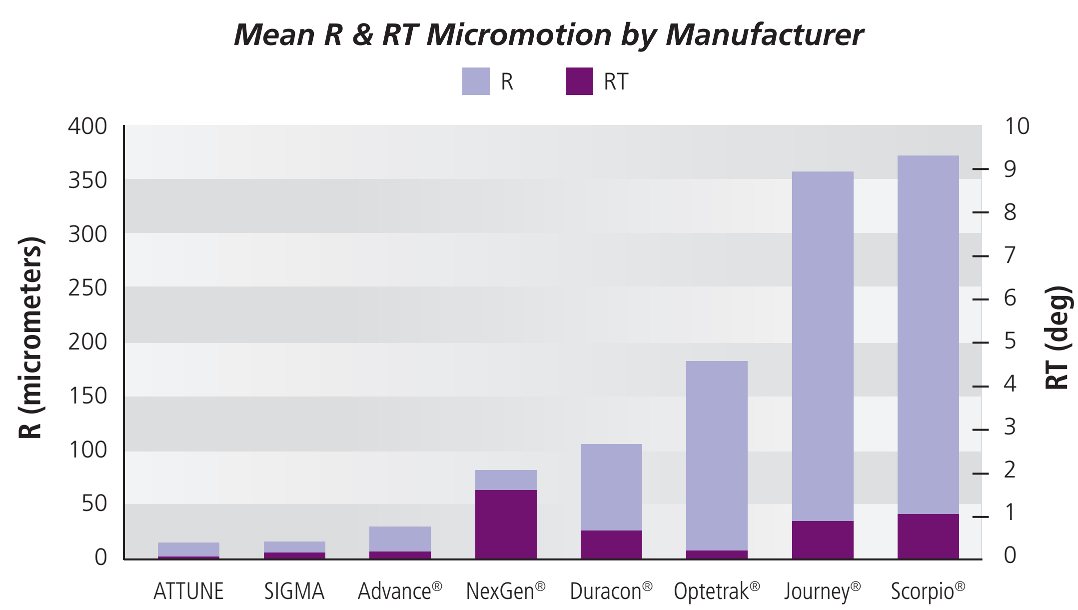

R – Vector summation of A/P & M/L micromotion, RT – Torsion micromotion due to I/E rotation

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The resistance of the LOGICLOCK Tibial Base locking mechanism to micromotion was also assessed by measuring the relative motion between the polyethylene insert and the tibial base plate after 5 million cycles of aggressive "high kinematics" wear simulator testing. The results indicated no increase in micromotion.[16]

FLUID PRESSURE MITIGATION:

Fluid pressures developed within modular locking mechanisms have previously been implicated as a factor in clinical osteolysis local to fixation screw holes.[17,18] Fluid pumping action has been hypothesized to be linked to the genesis of osteolysis through fluid pressure, fluid flow, and/or transportation of wear debris.[19] Testing was performed which replicated the types of fluid flow phenomenon previously observed clinically in a previous generation competitive base plate design (Figure 8). When mechanically tested under identical loading conditions, the LOGICLOCK Tibial Base design did not exhibit any potential for highly pressurized fluid flow that could lead to osteolysis.

Competitive tibial base plate demonstrating fluid flow exiting distal fixation screw holes

ATTUNE Knee tibial base plate under identical loading with no evidence of peripheral fluid flow

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CONCLUSION:

The patented[1] LOGICLOCK Tibial Base design is the result of extensive research and engineering to provide a solution to the following key challenges faced by all modular fixed bearing tibial base plate locking mechanisms:

1. Offering a simple system for matching femoral/insert articulations to enhance tibio-femoral contact mechanics and kinematics, while enabling proportionally sized features for the individual patient.
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References:

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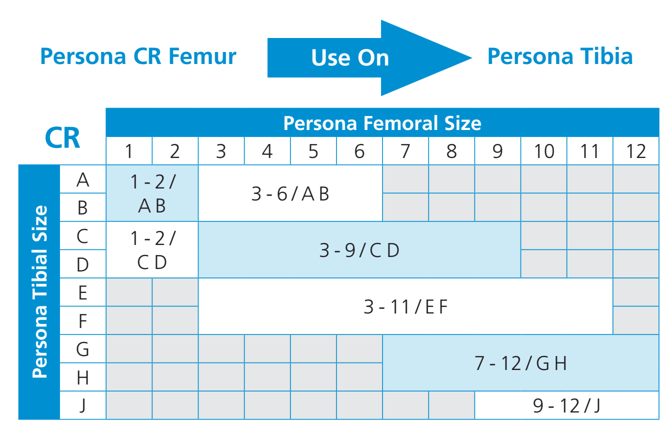

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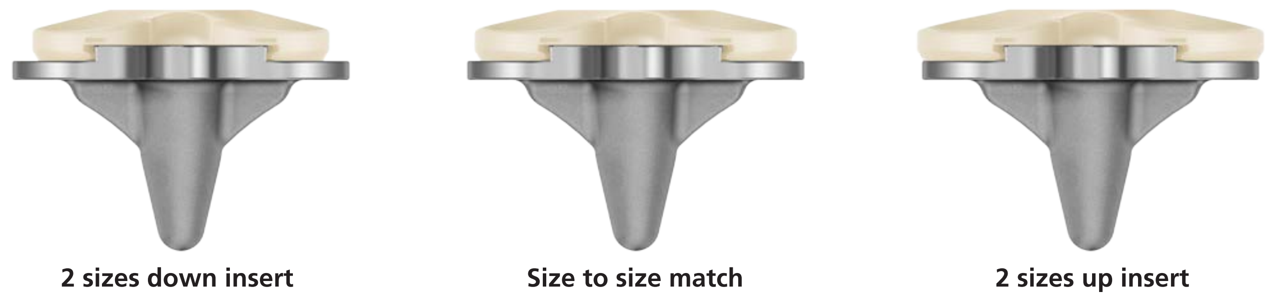

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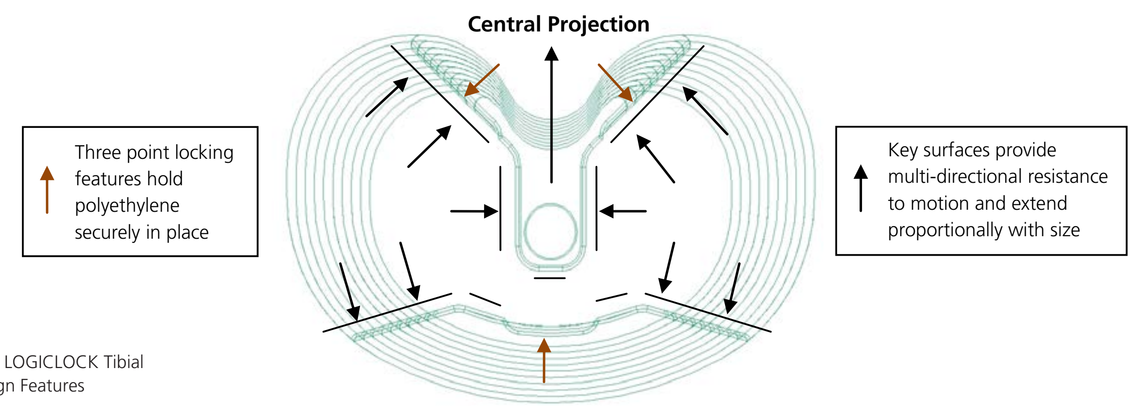

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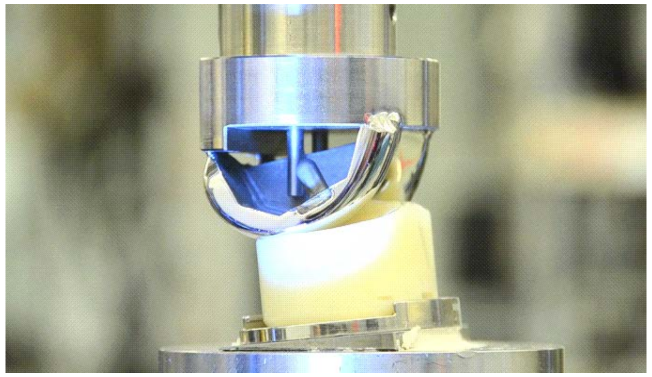

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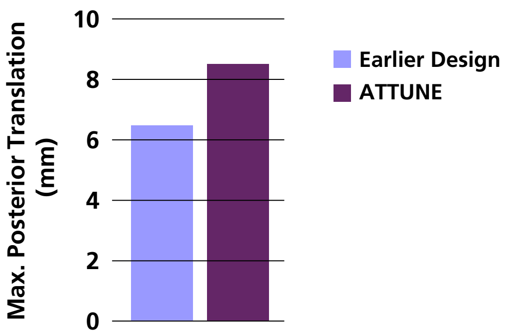

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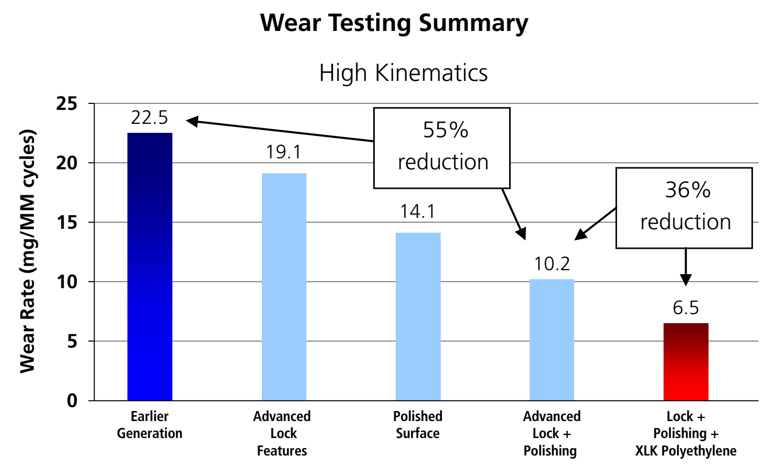

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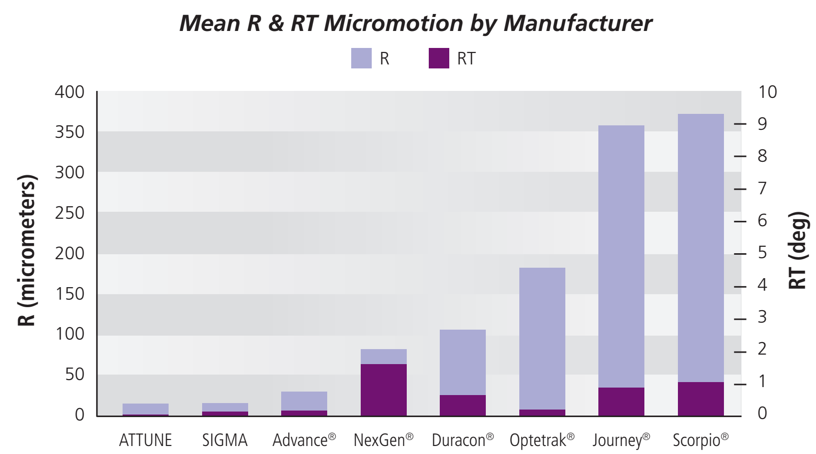

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