

RESOLUTION × ACCURACY × PRECISION

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GUIDE

Designing for Precision: CAD Tips for Micro-Scale 3D Printing

How to optimize your models for ultra-high resolution and micron-level tolerances

Introduction: Why Micro-Scale Design Requires a New Approach

When working at the macro scale, most engineers can afford to be forgiving—100 μ m tolerances are good enough, and minor imperfections won't compromise function. But in micro-scale 3D printing, where features can be smaller than a strand of hair and tolerances are measured in microns, that design flexibility disappears.

Boston Micro Fabrication (BMF) offers printing systems capable of resolutions down to 2 μ m and tolerances of \pm 10 μ m. That level of precision opens the door to groundbreaking innovations in medical devices, electronics, photonics, and microfluidics—but it also demands a different way of thinking about CAD.

In this guide, we'll walk through practical tips to help you adapt your designs for micro-scale success—from setting realistic tolerances to optimizing wall thickness, supports, and channel geometry. Whether you're developing components for surgical robotics or lab-on-a-chip devices, designing with precision in mind can dramatically improve your print quality, reduce iteration cycles, and get your product to market faster.

Tolerances and Resolution—What You Need to Know

Precision in micro-3D printing starts with understanding two closely related but often confused terms: resolution and tolerance.

Resolution refers to the smallest feature size a printer can physically produce. For example, BMF's printers offer pixel sizes as small as 2 μ m, meaning you can print extremely fine details that traditional 3D printers can't resolve.

Tolerance defines how close the final printed part dimensions are to the CAD model. BMF 2 μ m systems achieve $\pm 10\mu$ m tolerances, which is critical for applications like connectors, microneedles, and microfluidic channels where dimensional accuracy affects function.

Tip 1: Don't Over-Spec Tolerances

- Over-defining tolerances can slow down your design process or introduce unnecessary challenges in manufacturing. Be strategic—tight tolerances should be reserved for critical features only.

Tip 2: Match Feature Sizes to Printer Capability

When designing features like holes, gaps, or ridges:

- **Minimum feature size should be at least 5x the pixel resolution and is dependent upon the material used.**
 - For HTL-20 used on a 10 μ m machine, the min feature size is 50 μ m.
 - For HTL-5 used on a 2 μ m machine, the min feature size is 10 μ m.
- **For HTL, a minimum recommended unsupported non bridged overhang on the 10 μ m system using HTL-20 is 300 μ m.**
 - With a 2 μ m system running HTL-5, the result is about 100 μ m — but this can vary based on the material and the specific printer used.

⚠ Common Mistake: Copy-Pasting Macro Designs

Shrinking a successful macro-scale CAD file to micro scale rarely works. Thin walls become unprintable, tolerances become unrealistic, and support structures overwhelm the part. Always start your micro-scale design with scale in mind from the beginning.

CASE STUDY

A medtech engineer approached BMF to help develop a microfluidic component with 150 μm -wide channels and ultra-thin walls for fluid control in a diagnostic device. Their original design was scaled down from a macro version, and although it printed, it suffered from:

- Collapsed internal channels
- Inconsistent wall thickness
- Resin trapped in sharp interior corners

After a design review with BMF's applications team, they made several key changes:

- Rounded internal transitions to reduce stress points
- Increased channel diameter to 200 μm with optimized aspect ratios
- Added vent holes for proper resin drainage

The final result? A production-ready prototype with functional internal flow, improved surface finish, and dimensional accuracy within $\pm 10 \mu\text{m}$ —ready for in-vitro validation.



Prototype of an electronic connector printed on a BMF 3D printer

Wall Thickness and Structural Integrity

One of the most common reasons micro-scale prints fail is due to walls that are too thin or geometries that collapse during printing or post-processing. At the micro level, every micron matters—and what looks printable in CAD may not survive real-world conditions.

Tip 1: Follow Minimum Wall Guidelines

BMF recommends the following minimum wall thicknesses for common materials:

Material Minimum Wall Thickness

HTL ~50-75 μ m

BIO ~75-100 μ m

Note: These values are dependent on part geometry and orientation. For unsupported walls or large structures, thicker dimensions may be needed.

Tip 2: Use Ribs and Fillets to Add Strength

If your part has very thin walls or long unsupported spans, consider:

- Adding ribs or micro-pillars for reinforcement
- Using fillets or chamfers at corners to reduce stress concentrations and reduce unsupported overhangs

⚠ Common Mistake: Designing Hollow Parts with No Drainage

When printing hollow micro-parts, ensure there are proper escape channels for uncured resin. Trapped resin can lead to part failure or deformation during post-cure. When in doubt, consult your printer's support guidelines—or run a quick benchmark print to test your assumptions.

Tip 3: Orient for Strength

Part orientation affects not just printability, but mechanical performance. Walls aligned with the build axis may be weaker than those oriented across layers. When structural integrity is key, experiment with orientations and validate performance through testing.

Undercuts, Overhangs, and Supports

In traditional additive manufacturing, supports are often a necessary evil. But at the micro scale, supports can quickly become liabilities—adding complexity, increasing cleanup difficulty, and even compromising delicate features if not handled properly.

Because of this, smart geometry planning and orientation choices are essential to minimize or eliminate the need for supports altogether.

Tip 1: Avoid Unnecessary Overhangs

While BMF's printers can handle moderate overhangs, it's best to:

- Limit overhang angles to $\leq 30^\circ$ where possible
- Add slight drafts or chamfers to unsupported edges
- Use self-supporting geometries like arches or fillets

If a feature must overhang, make sure it's thick enough (typically $>100 \mu\text{m}$) to survive unsupported without sagging or deformation.

Tip 2: Design Supports That Are Easy to Remove

For features that do require supports:

- Keep them minimal and localized
- Avoid placing supports inside channels or enclosed spaces
- Design them with breakaway tabs or snap points to simplify removal
- Connect supports to a raft so that the entire group of supports can be removed at once instead of having to remove them individually

Some geometries may require custom internal supports—in which case it's often worth adjusting the design to eliminate the need altogether.

Tip 3: Let Orientation Do the Work

Proper part orientation can eliminate the need for supports in many cases:

- Rotate the part so critical features face upward, avoiding overhangs underneath
- Use the flattest surface as the base to ensure stability during printing
- Orient hollow parts with drain paths down to help with resin flow and cleaning
- Connect supports to a raft so that the entire group of supports can be removed at once instead of having to remove them individually.

Microfluidic and Channel Design Considerations

Designing microfluidic components comes with its own set of challenges—even more so when you're working at the 3D-printed micro scale. Whether you're developing a diagnostic cartridge, a drug delivery device, or a micro-mixer, even the smallest design oversight can compromise fluid flow, functionality, or post-processing success.

Tip 1: Optimize Channel Size and Aspect Ratios

- While BMF printers can produce channels as small as $30 \mu\text{m}$ ($2 \mu\text{m}$ system printing in HTL), for ease of clearing out we recommend:
- Minimum enclosed channel diameter: $\geq 120 \mu\text{m}$

- Aspect ratio (height:width): Keep close to 1:1 for consistent accuracy
- A max length:diameter ratio of 100:1
- Avoid sharp corners or extremely long, narrow paths

Tip 2: Design for Cleanability

- Resin can easily become trapped in tight or enclosed features. To reduce the risk of contamination or incomplete curing:
 - Include flush ports or vent holes at the ends of channels
 - Model in a luer lock connector or something similar to easily connect a syringe or other device to help clear out channels
 - Avoid dead-ends or sharp turns where resin might pool
 - If necessary, keep channels open-faced during design and bond them later with a flat cover
 - For prototypes and test devices, post-processing strategy should be part of your initial design thinking—not an afterthought.

Tip 3: Consider Function + Flow Early

- Microfluidic performance depends not just on geometry, but surface finish, feature fidelity, and channel consistency. When designing:
 - Test prototypes at full scale, using the actual printer and material you plan to use
 - Simulate fluid flow when possible (via CFD or analog methods)
 - Leave space for connectors, inlets, and outlets that will interface with tubing or sensors
 - A beautifully printed chip won't be useful if it can't connect cleanly to the rest of your system.
 - Model in a luer lock connector or something similar to easily connect a syringe or other device to help clear out channels.

⚠ Common Mistake: Assuming Transparency = Easy Inspection

While some BMF materials offer optical clarity, 3D-printed surfaces may still contain micro-roughness or internal refractions that obscure inspection. If precise visualization is required (e.g., for bubble tracking or droplet manipulation), discuss surface finish requirements or post-processing options with BMF's applications team.



Prototype of an microfluidic chip with a luer lock printed on a BMF 3D printer

Material Selection and CAD Settings

Choosing the right material is just as important as designing the right geometry—especially when you’re working at the micro scale. Each resin used in BMF’s micro-precision printers has different mechanical, thermal, and optical properties that impact how your part performs in the real world.

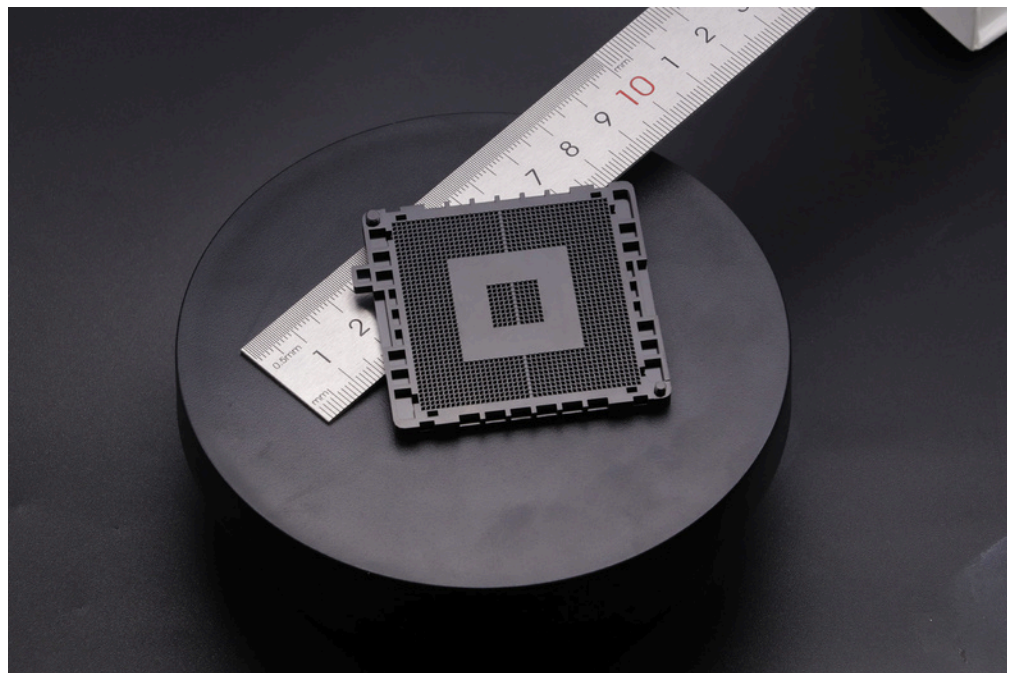
At this level of precision, even small differences in shrinkage, post-cure behavior, or layer adhesion can impact fit, function, and dimensional accuracy. Smart material selection—and properly configured CAD exports—can save time, reduce failed prints, and improve overall product reliability.

Tip 1: Match Material to Application

- Here’s a quick guide to how BMF’s most popular materials align with common engineering goals:

Material	Key Properties	Ideal For
HTL	high strength, rigidity, and heat resistance	Micro injection mold tooling, connectors
BIO	Biocompatible, ISO 10993 certified	Medical devices, microneedles, surgical tools
TOUGH	Rigid, robust, combination of strength and elongation	Snap-fit parts, housings, clips

Before locking in your design, it’s important to verify how your chosen material will cure, shrink, and handle mechanical stress—especially if your part has fine features or must fit with off-the-shelf components.



Tip 2: Export Smart CAD Files for Printing

- Your beautiful CAD design won't print well if it's exported incorrectly. Keep these tips in mind:
- Use STL or 3MF formats with high-resolution tessellation
- Avoid overly "chunky" mesh exports—this introduces faceting errors
- Set angular tolerance to $\leq 1^\circ$ and chord height to $\leq 5\mu\text{m}$ for best results
- Keep files under control: extremely dense meshes slow down slicers and increase print time without added benefit
- If you're unsure, ask your print team or applications engineer to review your file before printing.

Common Mistake: Ignoring Material-Specific Design Limits

Each material has unique limits on things like:

- Minimum feature size
- Minimum wall thickness
- Minimal hole diameter
- Support requirements

Review BMF's material datasheets or speak with an expert before finalizing parts—especially for mission-critical prototypes or validation builds.

Conclusion

Designing for micro-scale 3D printing isn't just about shrinking things down—it's about re-thinking your approach to tolerances, geometry, and materials at an entirely new level of precision.

With pixel sizes as small as $2\mu\text{m}$ and tolerances down to $\pm 10\mu\text{m}$, BMF's micro-precision 3D printers open up design freedom that traditional methods just can't offer. But to unlock that potential, you need to start with CAD models that are built for success.

By applying the tips in this guide—from wall thickness and orientation to channel design and material choice—you'll reduce failed prints, accelerate iteration cycles, and move your part from concept to prototype faster and more reliably.

Want to See What's Possible?

If you'd like feedback on a design—or want to see how your part performs on a BMF printer—we'd be happy to print a free benchmark part so you can evaluate the quality firsthand.

 [Request a free benchmark part](#)

Or, reach out to our applications team to discuss your next micro-scale project.