3D-Printed & Bespoke Orthotic Considerations

FDM Printing, TPU Shell Design, Infill Strategy & Clinical Decision-Making

FDM (fused deposition modelling) 3D printing enables orthotic shells with clinically tailored stiffness profiles through variable infill density and pattern — something impossible to replicate with traditional thermoforming. This reference covers the key principles of FDM TPU orthotic design, infill strategy, scan-to-print workflow, quality checking, and the clinical indications where bespoke 3D-printed devices offer advantages over traditional fabrication.

1 FDM Printing Fundamentals for Orthotic Shells

Aspect	Detail
FDM process overview	Fused Deposition Modelling extrudes thermoplastic filament layer-by-layer to build a 3D object. For orthotics, TPU filament is printed to produce a shell whose mechanical properties are determined by the print parameters, not the material alone.
TPU filament grades	TPU hardness varies by shore A rating — common orthotic grades range from 87A (firm, high control) to 95A (very rigid). Shore hardness determines the maximum stiffness achievable; infill density and pattern then modulate the functional stiffness within that range.
Infill density	The percentage of the interior volume that is solid material. Low infill (15–30%) = flexible, cushioning behaviour. Medium infill (40–60%) = semi-rigid, biomechanical control. High infill (70–100%) = rigid, maximum control. Zones of different infill within a single shell allow graduated mechanical response.
Infill pattern	Gyroid and honeycomb patterns provide isotropic flexibility (equal in all directions) — best for accommodative zones. Rectilinear/grid provides directional stiffness — useful for posting zones. Gyroid is generally preferred for orthotic shells due to fatigue resistance.
Shell thickness	Wall thickness (perimeter lines) determines the structural integrity of the shell edges. Typically 2–3 perimeter lines (1.2–1.8mm wall) for orthotic shells. Thicker walls increase stiffness independently of infill.
Layer height	0.2mm is standard for orthotic shells — sufficient resolution for smooth contact surfaces. 0.1mm layer height improves surface quality but significantly increases print time without meaningful clinical benefit.

2 Infill Strategy by Clinical Indication

Zone / Indication	Recommended Infill %	Recommended Pattern	Clinical Rationale
Rearfoot control (high pronation / PTTD)	70–90%	Rectilinear	Maximise supinatory STJ moment; shell must resist calcaneal eversion under load without deforming
Rearfoot control (moderate / semi-rigid)	40–60%	Gyroid or honeycomb	Balanced control and comfort; equivalent to 3–4mm polypropylene in function
Arch fill / medial longitudinal arch	30–50%	Gyroid	Graduated support — higher at posterior arch, lower at forefoot transition; prevents arch bottoming-out
Forefoot (general cushioning)	20–35%	Gyroid	Low stiffness forefoot zone maintains comfort and toe-off mechanics; avoids forefoot rigidity
Heel zone (cushioning priority)	15–25%	Gyroid	Shock absorption at heel strike; replaces need for separate Poron heel pad in some designs
Heel zone (control priority)	60–80%	Rectilinear	Rearfoot stability for high-control prescriptions; resists heel cup deformation
Posting zones (rearfoot/forefoot wedge)	90–100% solid	Rectilinear	Posted sections must not compress under load — solid fill ensures posting angle is maintained
5th ray / lateral offloading zone	10–20%	Gyroid	Low-resistance lateral zone accommodates pes cavus or reduces lateral column loading

3 Scan-to-Print Workflow

Stage	Process	Key Considerations
1. Foot capture	3D scan (structured light, photogrammetry, or CT) in the clinically determined casting position (STJ neutral, forefoot loaded, or as per M6 — Casting Position Reference)	Casting position determines the shape built into the shell — errors here cannot be corrected in CAD. STJ neutral NWB is the most common starting position.
2. CAD design	Import scan into orthotic CAD software (e.g. Spine CAD, Delcam OrthoModel, custom parametric design). Define shell geometry, heel cup depth, arch height, shell length, and zonal infill regions	Define posting angles in the model — do not rely on post-print grinding for significant posting corrections; intrinsic posting is more accurate

Stage	Process	Key Considerations
3. Slicer settings	Import STL into slicer (PrusaSlicer, Cura, Bambu Studio). Set infill density by zone using variable infill or modifier mesh. Set layer height 0.2mm, perimeters 2–3, TPU-specific speed settings (slow — 25–35mm/s)	TPU requires slow print speeds and reduced retraction. Stringing is common with TPU — calibrate retraction carefully. Ensure build plate adhesion (PEI sheet or glue stick recommended)
4. Print quality check	Inspect printed shell for: layer delamination, stringing/artefacts, warping, correct geometry. Measure heel cup depth and shell length against design spec. Flex-test the shell manually to confirm infill zones produce expected response	Reject any shell with layer delamination — structural integrity is compromised. Minor surface artefacts are acceptable if they do not affect fit
5. Post-processing	Remove support material if used. Sand any rough edges or layer lines at contact surfaces. Heat-gun minor adjustments to heel cup if needed (TPU is heat-adjustable at ~80–100°C)	Do not overheat — TPU loses structural integrity above ~150°C. Post-print modifications should be minimal; redesign and reprint if significant geometry change is needed
6. Fitting & QA	Fit in footwear. Perform in-shoe pressure assessment if available. Confirm heel seating, no edge pressure, correct arch contact. Document fit findings	First fit with 3D-printed devices may require minor trimming — build a 1–2mm buffer at edges in the CAD design to allow adjustment

4 3D-Printed vs Traditional: When to Choose

Clinical Scenario	3D-Printed Advantage	Traditional Advantage
Complex foot geometry (severe deformity, post-surgical)	Exactly replicates scan geometry; no manual thermoforming distortion	—
Variable stiffness requirement (e.g. rigid rearfoot + flexible forefoot)	Zonal infill achieves true variable stiffness in one piece	Requires multiple material lamination; less precise
High-performance sport (weight/profile critical)	Very thin, low-profile shell possible; lightweight TPU	Carbon fibre is lighter at equivalent rigidity
Standard MSK (moderate pronation, everyday use)	Minor advantage — reproducibility, digital record	Faster fabrication; lower equipment cost; familiar to lab
Urgent / same-day fabrication	Slower — minimum 2–4 hours print time	Heat-forming in minutes; far faster for urgent cases
Paediatric (frequent replacement needed)	Digital design retained — reprint as child grows, adjusting size only	Cheaper per device if reprinting frequently
Diabetic / high-risk total contact	Precise total contact geometry; no thermoforming air gaps	Plastazote thermoforming achieves excellent total contact with simpler process

Clinical Scenario	3D-Printed Advantage	Traditional Advantage
Remote prescribing / outsourced lab	Digital file can be sent to any equipped lab globally	Requires physical cast or foam impression to be shipped

5 Quality Control Checklist

Pre-Issue QC — 3D-Printed Orthotic Shell

Check	Pass Criteria
No layer delamination visible on shell surface or edges	[ ] Pass / Fail
Heel cup depth matches prescription spec (measure with ruler)	[ ] Pass / Fail
Shell length correct for prescribed device length	[ ] Pass / Fail
All edges smooth — no sharp layer lines at plantar contact surface	[ ] Pass / Fail
Manual flex test confirms correct zonal stiffness (rearfoot firm, forefoot flexible as designed)	[ ] Pass / Fail
Device fits correctly in patient footwear — no edge pressure, heel seated	[ ] Pass / Fail
Posting zones do not compress under manual bodyweight simulation	[ ] Pass / Fail
No stringing or artefact at plantar surface contact areas	[ ] Pass / Fail

3D printing does not replace clinical reasoning — it expands the prescription toolkit. The scan is only as accurate as the casting position; the shell is only as effective as the prescription that informed its design. Understand the technology's advantages and limitations, and use it where it genuinely adds clinical value.