ELDRA

Designing the Invisible

IED

Materials Technology

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In every object, there are elements we don't see.
Parts that don't define appearance – but define everything else.

Joints are the hidden architecture of furniture.
They connect, sustain, and resist.
Yet they are rarely reconsidered.

With Eldra, I explore how **Additive Manufacturing** can redesign what's invisible, turning hidden parts into optimized, intelligent structures.

Context and MOTIVATION

Traditional furniture joints are often over-engineered, bulky, and material-intensive.

They're designed for simplicity of production — not for performance, sustainability, or design freedom.

But what if we could create joints that are:

- lighter
- stronger
- customized
- and materially efficient?

What if the invisible became intelligent?

From Structure to STRATEGY

In furniture, the joint is not just a connection point – it's a **mechanical strategy**, a **material decision**, a **design philosophy**.

When rethought through Additive Manufacturing, it becomes a space where form meets performance, and where **invisible complexity becomes visible value**.

This is where Eldra begins.

Inverse
DESIGN LOGIC

In standard furniture design, the joint is often the final step, something that adapts to predefined shapes.

In this project, I reversed the process. I began with the joint as the primary actor, the starting point of the system.

By focusing first on the logic of connection, I explored how a single optimized component can inform not just structure, but also material usage, assembly logic, and even aesthetics.

It's a **bottom-up approach**,
where **the micro defines the macro**.

Key Design DRIVERS

Freedom of Design

- Lightweight structures
- Biomimetic structures
- Topology optimization
- Assembly consolidation

Lifecycle Sustainability

- Reduce material waste
- Increase product efficiency
- Design for repair

Low Volume Manufacturing

- Eliminate tooling lead times
- Service smaller market segments

WHY

The core IDEA

Eldra was born from a simple question:

“Why are we still using generic, bulky joints in an era where design can be hyper-specific?”

The idea is to apply **topology optimization and Additive Manufacturing** to joints, the invisible, structural parts of furniture, in order to make them lighter, smarter, and more sustainable.

The INTUITION

My intuition is that **the joint**, often an afterthought, **can become a space for innovation**.

Additive technologies allow us to go beyond standardized shapes and reimagine joints as performance-driven, purpose-built components.

If we design for the forces that actually act on a joint, rather than for the limitations of milling, molding, or screwing, we get a new kind of elegance.

Hidden structures'
PASSION

I've always been fascinated by what's not visible: **the bones** behind the skin, the systems that support form.

Working at the intersection of **engineering logic and design expression** is where I feel most engaged.

This project reflects my passion for structural honesty, material responsibility, and forward-thinking design methods.

The VISION

I imagine a future where furniture components are **not bought off-the-shelf**, but **generated**, **optimized**, and **printed on demand**.

A world where material is used with precision, not excess.

Where furniture is **lighter**, **more adaptable**, and aligned with circular design principles.

Eldra is a first, modest step in that direction: **designing the invisible** to make a visible difference.

Function-Enhanced Joint:

VIBRATION DAMPENING

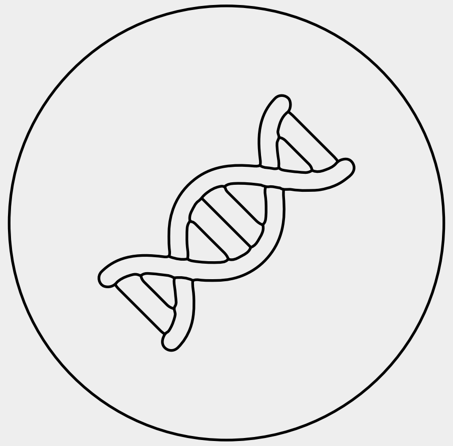
In the process of expanding the project's potential, I explored how the joint could offer **more than structural performance**.

Thinking in terms of design drivers, I chose to integrate **Embedded Functionality**, a feature that adds value without altering the joint's primary logic. The result is a **passive micro-vibration damping system**, aimed at absorbing small-scale oscillations typical in tables, modular systems, and everyday use.

This added layer of performance enhances comfort, improves durability, and aligns perfectly with the idea of **designing the invisible**.

Embedded Functionality

Design Strategy

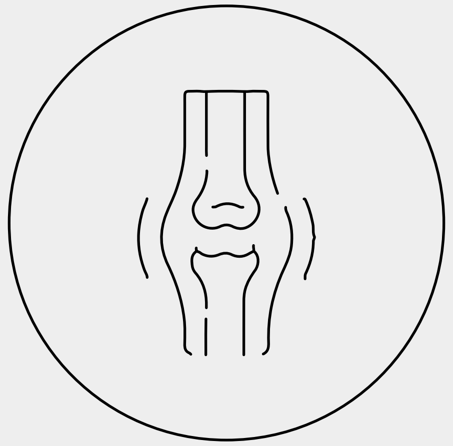


Integration of internal flex zones or thin-wall geometries designed to deform under micro-stress.
No additional parts required.

Activated Driver

Structural performance is combined with passive damping, enhancing user experience and extending system lifespan.

Narrative Bonus



Like cartilage in the human body, it absorbs invisible stress — silently improving stability, comfort, and resilience.

HOW

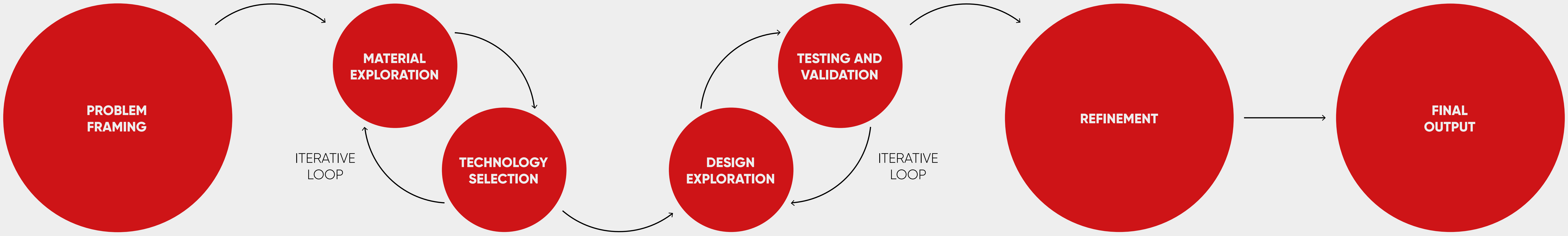
Translating a vision into reality rarely follows a linear path.

In this project, the “**how**” emerged gradually, through questions, trials, and discoveries.

The materials and technologies I started with are not the ones I ended up selecting.

Instead, I went through an **iterative loop**, constantly evaluating:

- What material behavior aligns with the forces involved?
- What technology supports that material’s potential?
- What geometry expresses both intention and efficiency?


PROBLEM FRAMING
MATERIAL EXPLORATION
TECHNOLOGY SELECTION
ITERATIVE LOOP
DESIGN EXPLORATION
TESTING AND VALIDATION
ITERATIVE LOOP
REFINEMENT
FINAL OUTPUT

Early Concept Exploration

ITERATION 1

Material

PLA

Technology

FDM

Objective

To explore initial forms and spatial logic through rapid prototyping. The aim was to test how a joint could behave geometrically without constraints from performance or cost.

Outcome

Allowed quick experimentation with shape and proportion. Enabled early design decisions and low-cost iterations in a physical format.

Limitations

Low dimensional precision, poor mechanical strength, and rough surface finish. Unsuitable for functional use or advanced structural simulation.

Functional and Structural Testing

ITERATION 2

Material

PA12
+
glass fiber

Technology

SLS

Objective

To validate geometry and topology under simulated stress conditions. Focused on achieving better structural behavior while keeping design flexibility.

Outcome

Delivered functional, lightweight prototypes with optimized structures. Good print resolution and excellent adaptability to parametric modeling.

Limitations

Plastic-like appearance and texture, insufficient visual integration with wood or other natural materials. Functional, but lacking expressive presence.

Final Design Definition
ITERATION 3

Material

AlSi10Mg

Technology

DMLS

Objective

To develop a joint ready for real-world use — mechanically strong, aesthetically compatible with wood, and suitable for final presentation and production.

Outcome

High-performance part with optimized geometry, strong mechanical properties, and a material quality coherent with the design vision. Durable, expressive, and precise.

Limitations

Higher production cost and post-processing required. Less accessible for fast iteration, but appropriate for final deployment.

The definition of the MORPHOLOGY

The morphology of the joint emerged from a hybrid workflow that combined **manual definition** and **algorithmic optimization**.

The initial mesh was modeled in **Rhinoceros**, focusing on the joint's functional boundaries and its connections with the surrounding components.

This base geometry was then exported to **nTop**, where I defined the **non-negotiable zones**:

- Areas to preserve (structural nodes)
- Interfaces for attachment with other furniture parts

The remaining volume was left open for **computational generation**, using optimization parameters aimed at reducing weight while preserving mechanical performance.

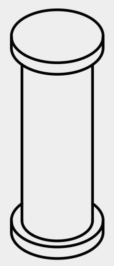
The result is a geometry that is **not entirely drawn**, but rather computed, a **balance between human intention** and **structural logic**.

WHAT

The starting point

THE JOINTS

Single-Arm Joint



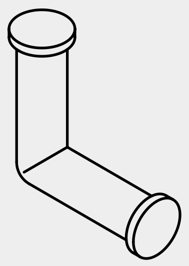
Function

Anchors a single element to a surface or base.

Use cases

Leg-to-floor, vertical mount, end support.

Double-Arm Joint



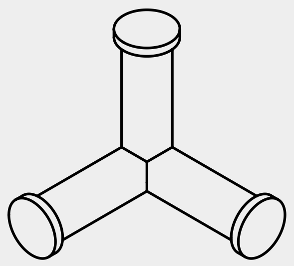
Function

Connects two elements in line or at an angle.

Use cases

Table leg to frame, beam-to-beam, edge joints.

Triple-Arm Joint



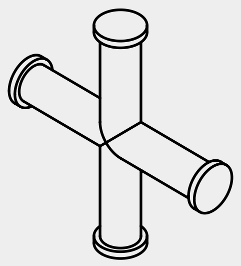
Function

Unites three elements into one node.

Use cases

Structural intersections, mid-nodes, corner reinforcements.

Four-Arm Joint



Function

Connects four elements, often in a grid or cross layout.

Use cases

Frames, shelving intersections, 3D lattice corners.

Strategic Decision
POINT

In the early stages of structural development, I found myself facing a conceptual bifurcation:
two viable paths for integrating material optimization and functional micro-vibration control within the joint.

Localized Dissipation

Internalized Optimization

Path 1 — Localized Dissipation

CONCEPT

Preserve a skeletal joint core, and apply lattice only around the attachment modules, where micro-vibrations concentrate.

PROS

- Visual contrast between solid and porous zones
- Localized control of mechanical damping
- Simpler segmentation of functions

CONS

- Risk of creating stress concentrations at the interface between lattice and solid regions
- Less integrated behavior under complex loads
- Perceived as a "patchwork" solution

Path 2 — Internalized Optimization

CONCEPT

Use topology optimization as an internal bone-like scaffold within the whole joint volume. Material is subtracted where not needed, and replaced with a gradient lattice structure, not added externally, but grown from within.

PROS

- Organic transitions between full and porous zones
- Reflects nature's logic: cortical shell + trabecular core
- Avoids stress peaks due to material discontinuity

CONS

- Requires precise control of constraints and transitions
- More complex simulation-to-manufacture workflow

CHOSEN PATH

I deliberately chose the second strategy, because it aligns not only with structural logic but with my foundational design vision: a joint that is not assembled from parts, but **grown**, **structured** and **adapted**, like an **architectural bone**.

The result is a hybrid: solid where necessary, porous where possible, and coherent as a whole.

A silent intelligence, designed from the inside out.

My nTopology

WORKFLOW

Import CAD & Implicit > Define Preserved Regions > Mesh + FEM setup

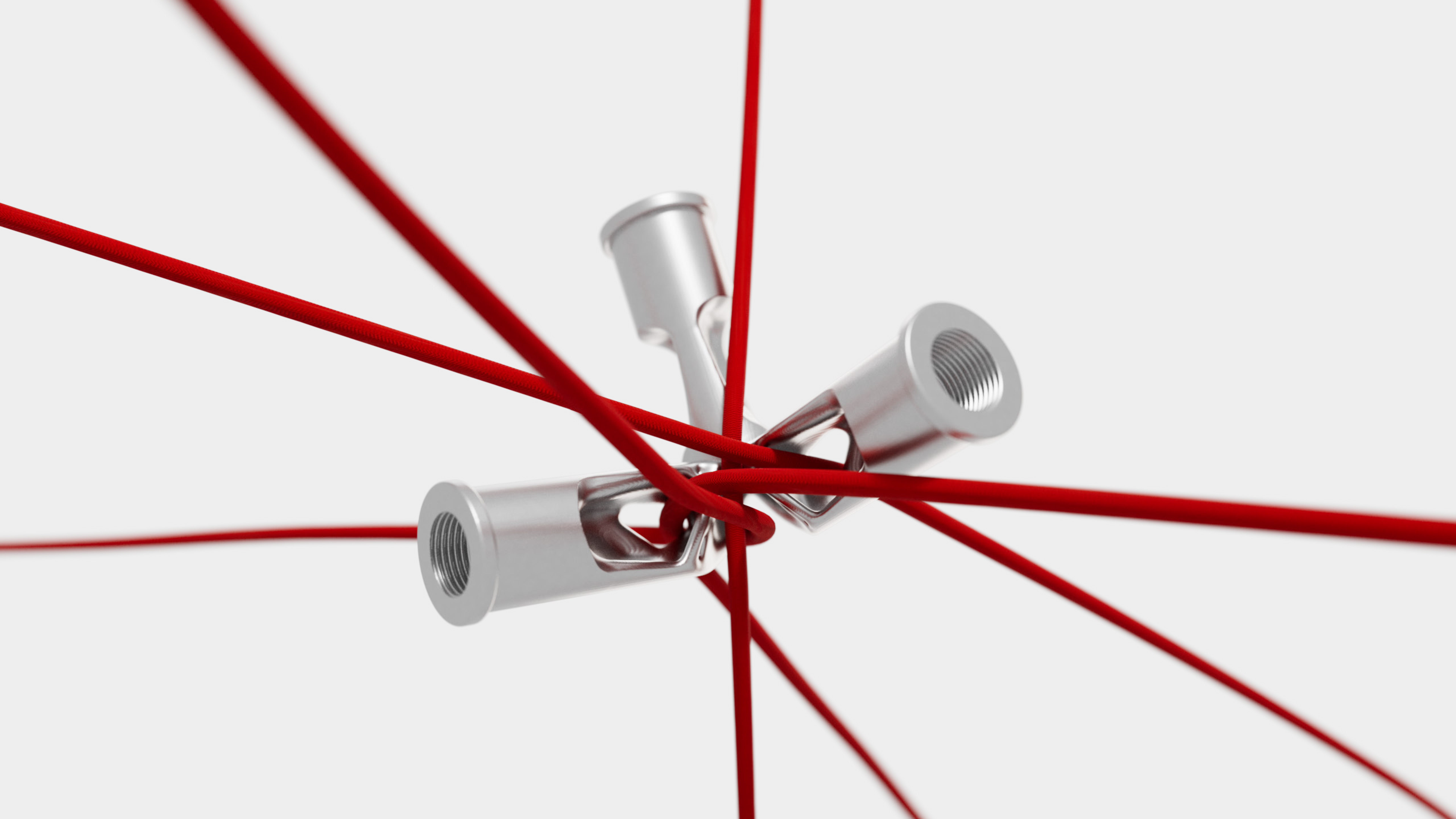
Boundary Conditions > Topology Optimization > Extract optimized geometry

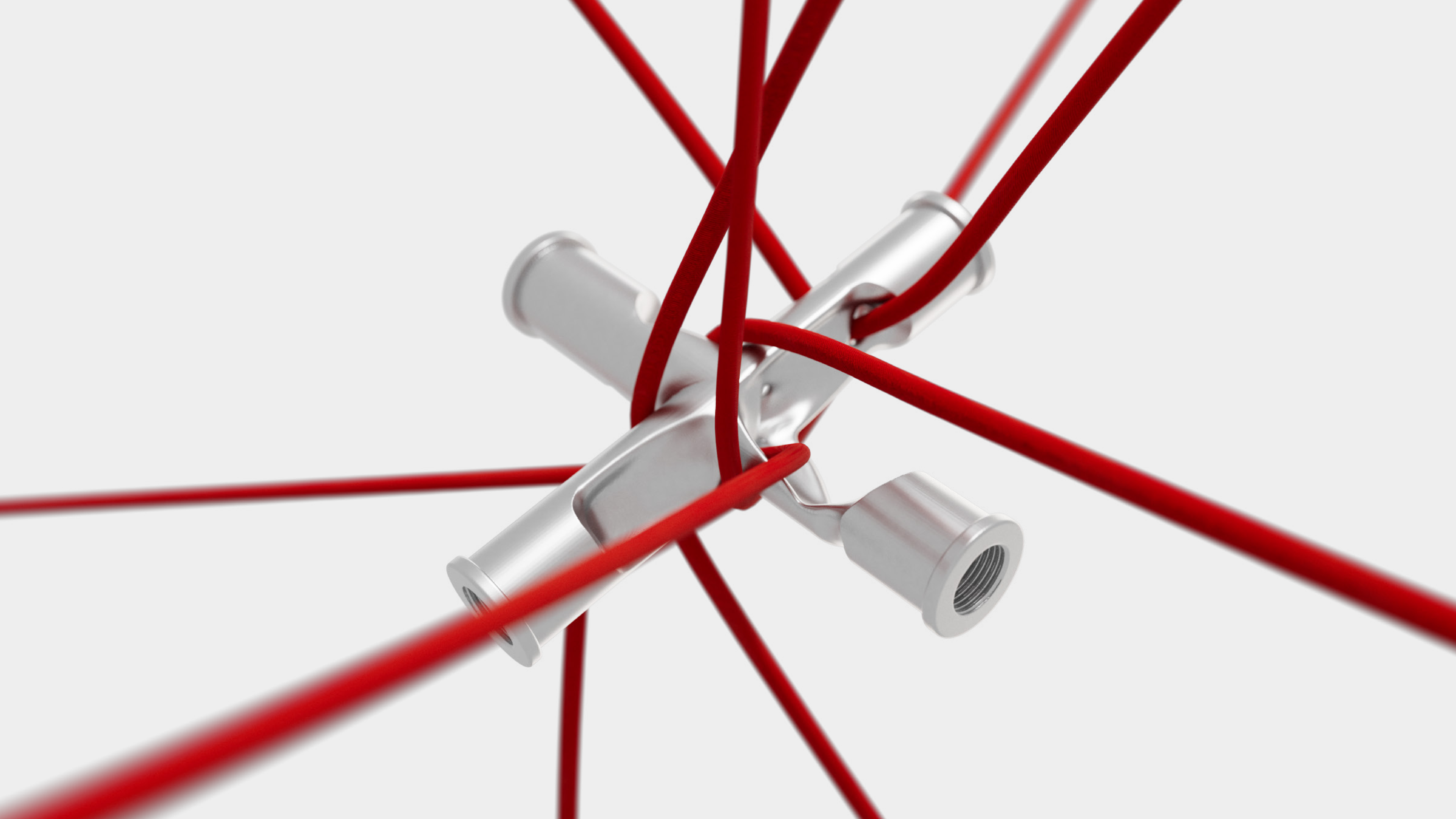
Re-attach preserved features > Fill with gyroid lattice > Export final mesh

For each joint

First step:

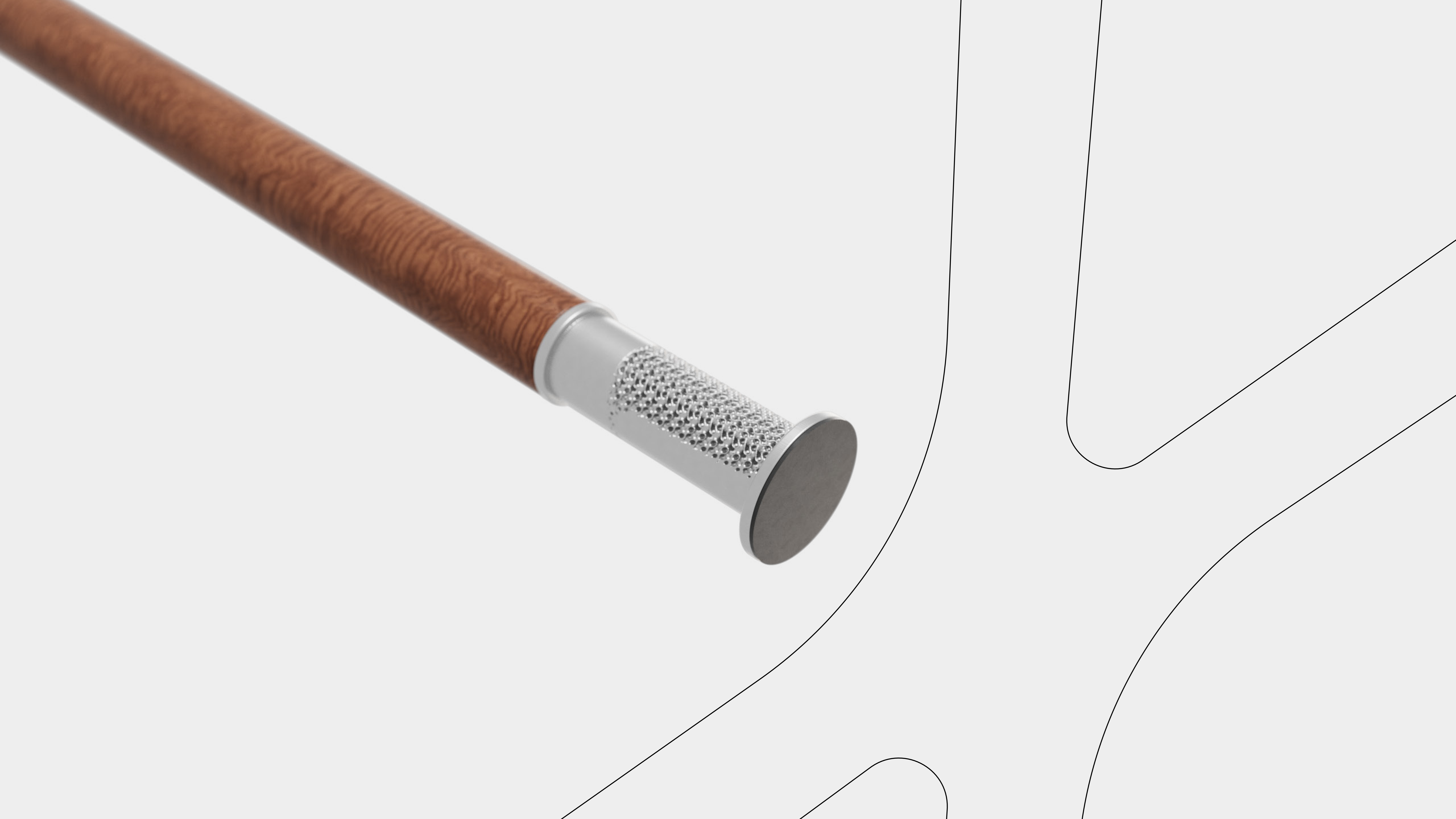
THE SKELETONS

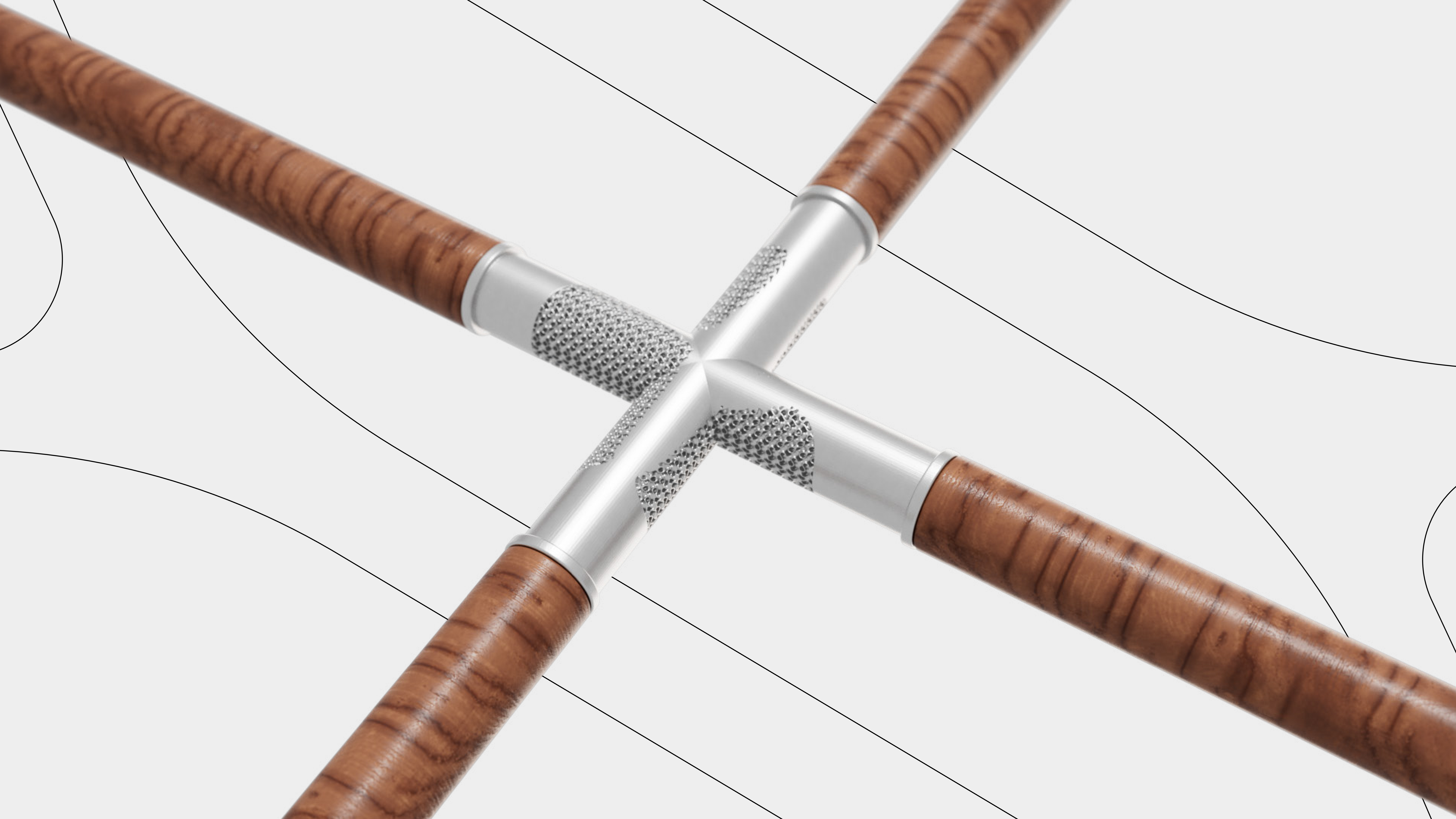




Final step:

ELDRA





Printing Logic

ARRANGEMENT

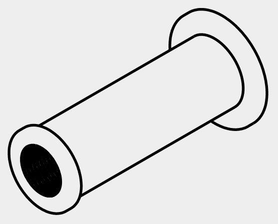
The joints are oriented in order to balance structural integrity during printing and reduce total support volume. Placement on the build plate is designed to:

- Minimize overhangs and unsupported features
- Allow for a uniform layer distribution
- Optimize powder recoating and thermal balance

Printing Logic

ARRANGEMENT

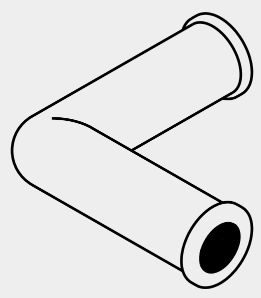
Single-Arm Joint



Position

Placed horizontally, optionally rotated 15–20° to reduce overhang length.

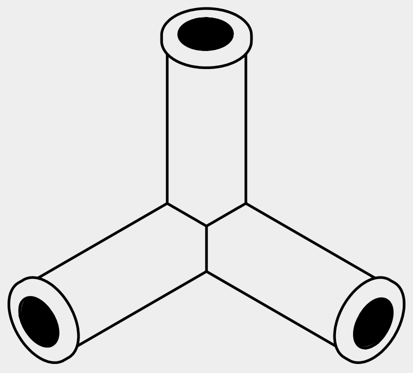
Double-Arm Joint



Position

Laid sideways, resting on both legs of the “L”. Internal corner lightly supported.

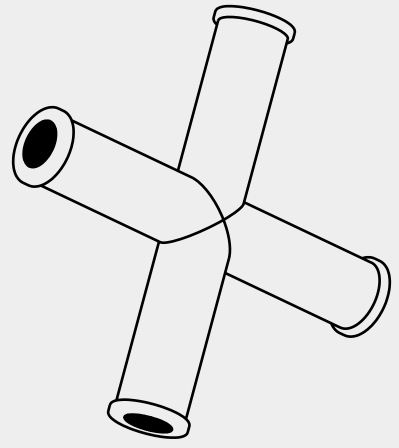
Triple-Arm Joint



Position

Laid flat on two arms, with the third pointing upward.

Four-Arm Joint



Position

Placed upright and rotated 45° on the build plate, so that all arms are slightly inclined, avoiding flat overhangs and ensuring balanced support distribution.

Printing Logic

SUPPORTS

In metal AM, supports are crucial not only for mechanical stability but also for heat dissipation and distortion control. My support logic includes:

- Minimal touch-point supports under lattice areas
- Denser supports under horizontal or flat base zones
- Orientation of the parts so that threaded modules are accessible for support removal

Special attention is given to keeping all overhangs under critical angles and ensuring that all supports are removable from the bottom or one side, avoiding internal blockages.

Printing Logic

MATERIAL AND TIME

MATERIAL AND TIME OPTIMIZATION

By optimizing nesting and part orientation:

- Multiple joint types can be printed in a single build cycle
- Powder usage and recoating time are reduced
- The lattice zones require less post-processing effort due to precise support placement

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