AN EXPLORATION ON
BAMBOO JOINERY

DESIGN EXPLORATION SEMINAR

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DECLARATION FORM

I declare that this written report represents my own idea in my own words, and where others, ideas or words have been included, I have mentioned the original source. I also declare that I have adhered to all principles of academic honesty and integrity and have not falsified, misinterpreted or fabricated any idea, data, facts or source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also penal action from the source from which proper permission has not been taken, or improperly cited.

Name – Naiga Catherine
Roll No - 216130005
Date - 15-03-2023

APPROVAL SHEET

The project titled as "AN EXPLORATION ON BAMBOO JOINERY" by Naiga Catherine is approved in partial fulfilment of the requirement for the degree of "Master of Design" in Industrial Design.

Guide: Prof. Avinash Shende

Chairman:

Internal Examiner: Not Required.

External Examiner:

ACKNOWLEDGMENT

To start with, I would like to sincerely thank my project guide **Prof. Avinash Shende** for his invaluable guidance at every stage of this project. .
I am also grateful to all the workshop staff and students of Industrial Design Centre (IDC) for their kind help and useful suggestions.

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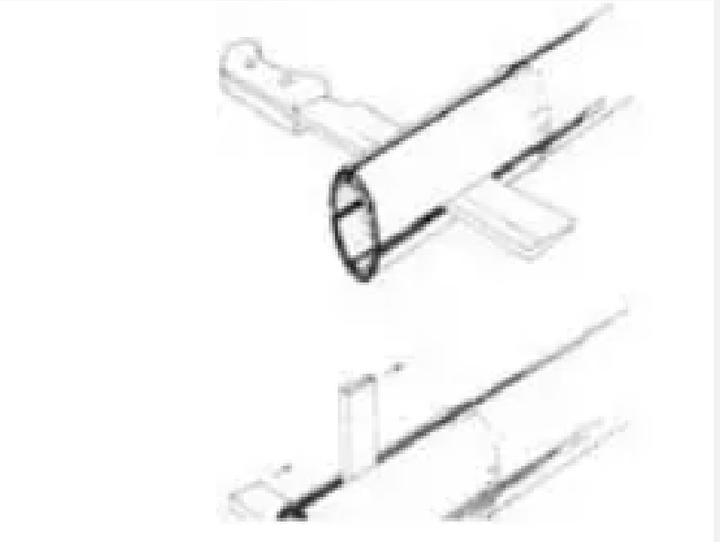
Bamboo construction

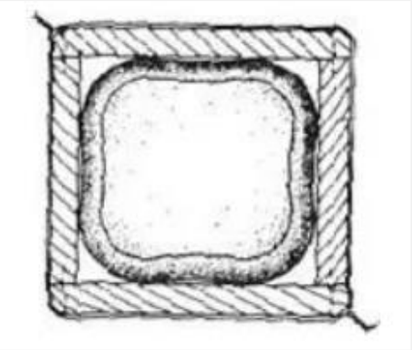
- Bamboo as a **building material** has **high compressive strength and low weight** has been one of the most used building material as support for concrete, especially in those locations where it is found in abundance.
- Bamboo as a building material is used for the construction of **scaffolding, bridges and structures, houses**.
- Due to a distinctive rhizome-dependent system, bamboos are one of the fastest-growing plants in the world and their growth is **three times faster than most other species of plants**.
- They are renewable and extremely versatile resource with multi-purpose usage. Among many uses of bamboo, **Housing** is one of the major areas applications especially in the wake of residential shortages around the globe.
- Bamboo as a building material is conventionally associated with the region **of Southeast Asia and South America** where climate is best suitable for its cultivation.
- In many of the nations, bamboo is used to hold up suspension bridges or simply make places of dwelling.



Methods of Working on Bamboo

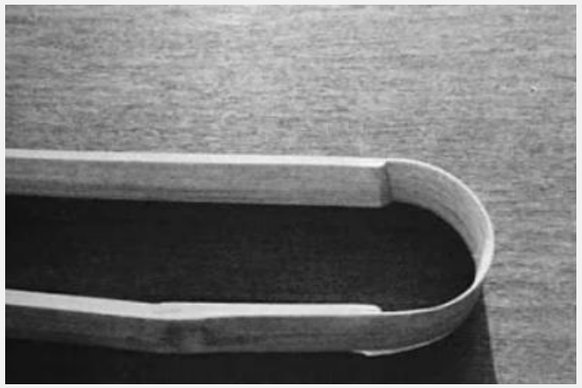
For a bamboo to be used as a building material, it must be worked on to create desired shape, bend and length to be used for structural or other purposes. **Following are the different works involved with use of bamboo:**

1.Splitting
2.Shaping
3.Bending



Splitting of Bamboo

The bamboo canes are split into **halves or quarter** sections using a knife ideal for the job and setting them apart by a wedge. About **four or eight** segments can be acquired which are used as canes, strips or battens. Canes can be peeled to make strings and ropes up to the age of 18 months.



Shaping of Bamboo

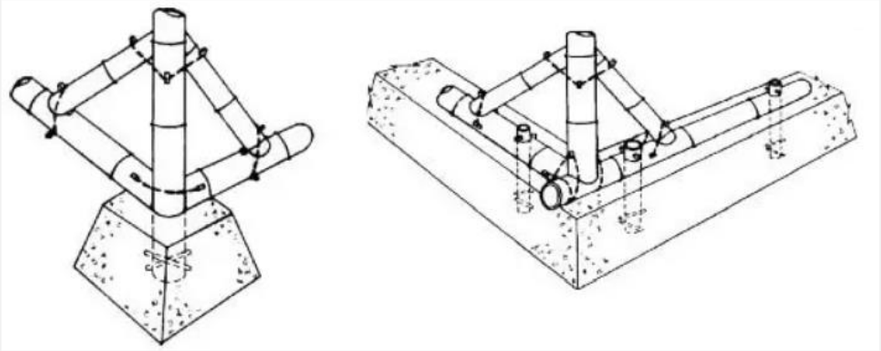
Even though bamboos are naturally circular in form but if they are grown in a **box of square** shape they acquire a shape as desired.

Bending of Bamboo

Bamboos can be bent while they are freshly cut by **heating them above the temperature of 150° C.** Bamboo will retain this shape even after cooling and drying off.

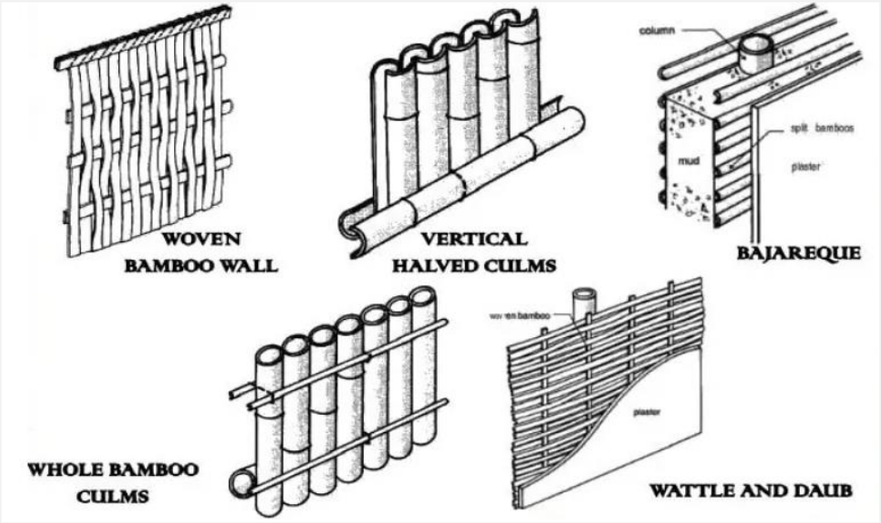
- **Bamboo for Foundations**

There is very **limited use** of bamboo as foundation material because when in contact with moisture laden surface they **decay fast**. However, this issue can be tackled to quite an extent though proper treatment using appropriate chemicals. The various types of foundations constructed with bamboo are: a) Bamboo which is in direct contact with ground surface. b) Bamboo fixed to rock or preformed concrete footings c) Composite bamboo or concrete columns d) Bamboo piles



- **Walls Construction with Bamboo as a Building Material**

Bamboo is extensively used for construction of **walls and partitions**. Posts and beams are the main elements normally constructed with bamboo provide structural framework for walls. They positioned in a way to be able to withstand forces of nature. An infill is used between framing elements to add strength and stability to the walls.



- **Roofing with Bamboo as a Building Material**

Bamboo is one of the best roofing materials and provides **ample sturdiness to the structure**. The bamboo roofs encompass **purlins, rafters and trusses.**

- **Scaffolding with Bamboo as a Building Material**

Due to advantageous properties of **bearing heavy load** bamboos are considered as one of the highly-endorsed materials for scaffolding even for tall structures. For the construction of scaffolding, cane extensions are obtained by lashing cane ends using **several ropes**. The ties are positioned in such a way that forces acting vertically downwards lodge the nodes in the lashing. This technique has immense significance since the joints can be re-aligned in the right degree.

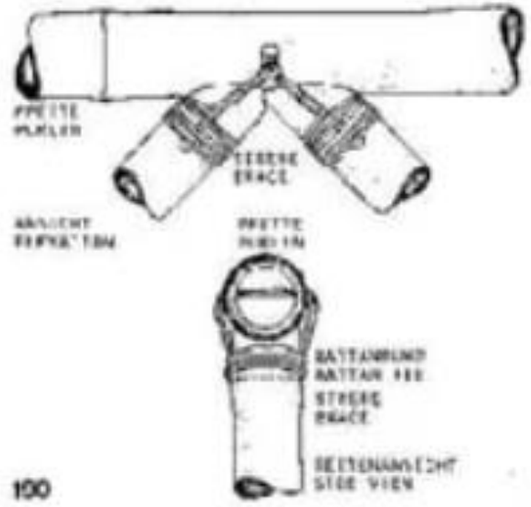
Types of structural connectors used with bamboo

FRICTION –TIGHT ROPE CONNECTIONS
For tight connections **green bamboo strip** are used, the **fibers are watered** before tying around the bamboo. While drying the fibers **shorten and connection becomes stronger**.
Materials used traditionally:
- Coco/sago palm fiber
- Bast
- Strips of bamboo
- Rattan

Materials used nowadays:
- Iron wires (zinc coated)
- Plastic tapes/ ropes

Lashing ties

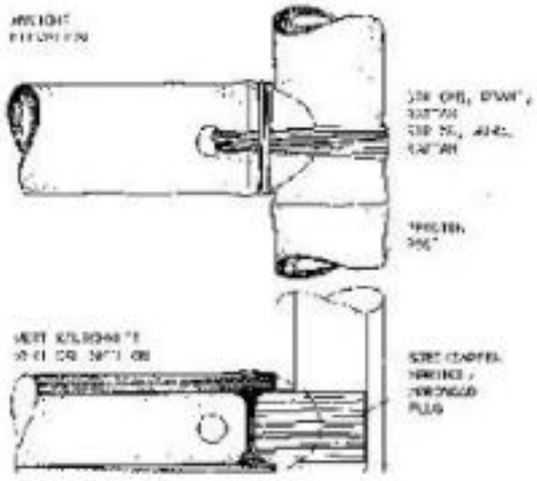
The common type of **connection at a joint** is lashing. The ties are also of organic material and therefore provide optimal compatibility between the elements of the construction system.
Cords and ropes are made of bamboo bark, bast, coconut or sogopalmfibres.
Nowadays also plastic cords are used. Bamboo ropes of twisted bamboo fibres are produced in lengths up to 350m. They are more wear resistant than standard ropes. With a tensile strength of 720 kp/cm3 a rope of an arms thickness can bear up to 14 tons.
Binding wire is an industrial product.
Zinc coated wire has the same lifetime as bamboo.
Plait strips
Usual plait materials are rind strips of bamboo rattan or lianas. Soaked before use they are more pliable. When drying, the fibers shrink and the connection tightens



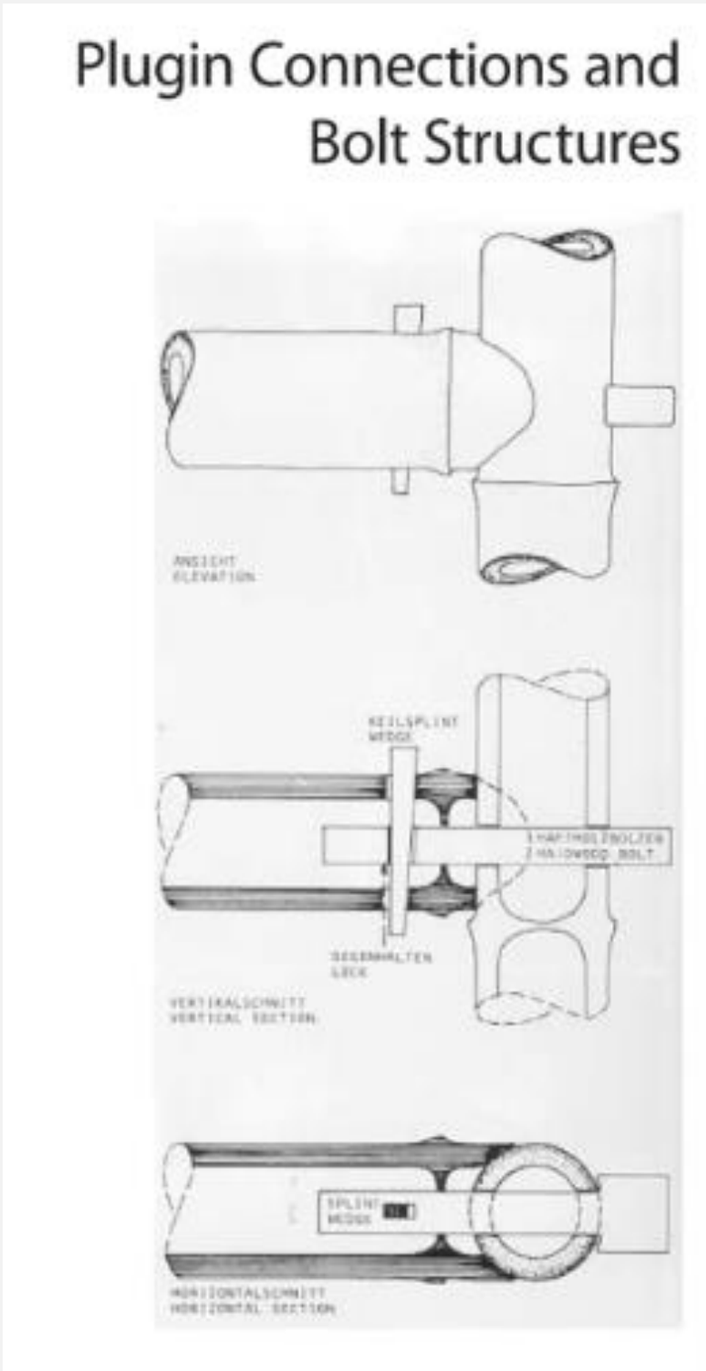
Lashing ties - connection of a purlin and two braces with three drill-holes.

PLUGIN/ BOLT CONNECTIONS

Constructions with **secondary interlocking elements** often used in context with rope connections. In this case **the bolts must transfer tractive and compressive forces**. In wooden connections, this is done by different types of profiles
The **metal nail** is a performing element. If the bamboo is not fresh at all, the bamboo is often spitted by the wedge shapes nail. There are 2 exceptional cases, the gusdua angustifolia and chusquea bamboo from central and northern America.

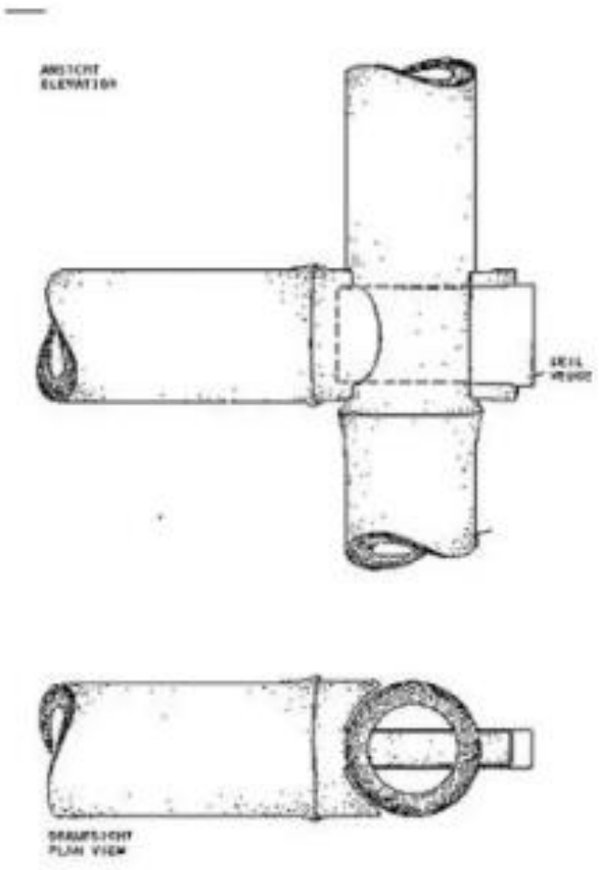


Connection with inner plug and a horizontal drill hole to fix the connection with a lashing tie. If the lashing is tight and the plug fits quite good into the opening, both plug and lashing can do the power transition. But even if not, this connecting method can be very durable at less force. The inner plug prevents the beam from slipping down the post and the lashing is against unplugging.

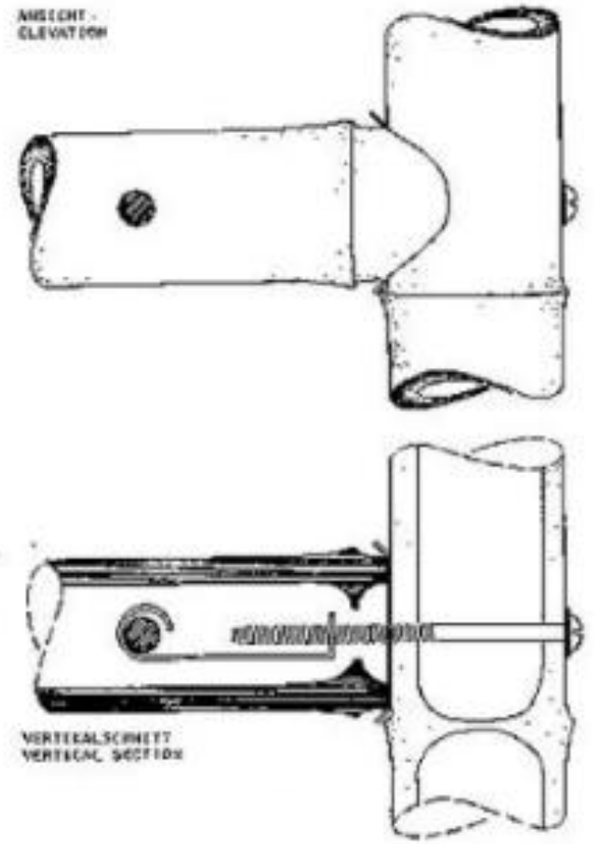


bracket interlocking stud

Interlocking connection with a wedge. With the wedge driven into the opening, the strips of the horizontal beam are pressed into the hole and fix the beam. If the wedge shrinks, the beam can be easily pulled out of the opening. So additional arrangements like lashing or bolts are necessary for a save connection



Connection with a steel tension clamp. Leaving the low-tech sector, with the use of steel elements a lot more connections become possible. Avoid connections which produce great forces vertical to the cane axis. They can destroy the bamboo cane.



Modern connection by Shoei Yoh in 1989

For his bamboo roofs in Fufuoka, Shoei Yoh used a steel tube put into the bamboo and which is connected to the cane with bolts. The steel tube is strong enough to withstand the pressure of tightened bolts. In addition there are 2 bolts in vertical direction. For the connection to the knot, a steel bar is welded into the tube and again it is screwed to the knot. Because of the numerous bolts the connection is also suitable for greater loads. The result is a very technical but strangely over styled looking connection

Modern connection by Renzo Piano building workshop in 1997. the canes are connected to a specially designed steel element via binging wire. Instead of a bolt driven through bar and cane, a wire is tied through the holes and tied around the bamboo. A fine artwork but because of the fine wire seemingly only for small forces.

POSITIVE FITTING CONNECTIONS

Wooden connections with slit and tenons like they are traditionally used for carpenter like construction.
They are rare because,

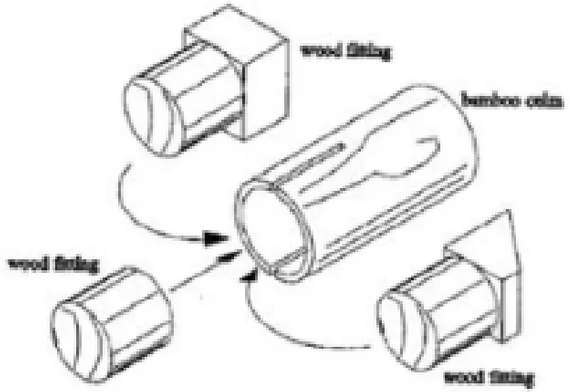
- Bamboo is round
- Bamboo is hollow
- Bamboo splits

But although there are these problems, positive fitting connections are used in traditional bamboo buildings. Different types of holes are cut into the bamboo and make it possible to connect the round bamboo rods.

positive fitting bamboo connections

WOODCORE CONNECTIONS

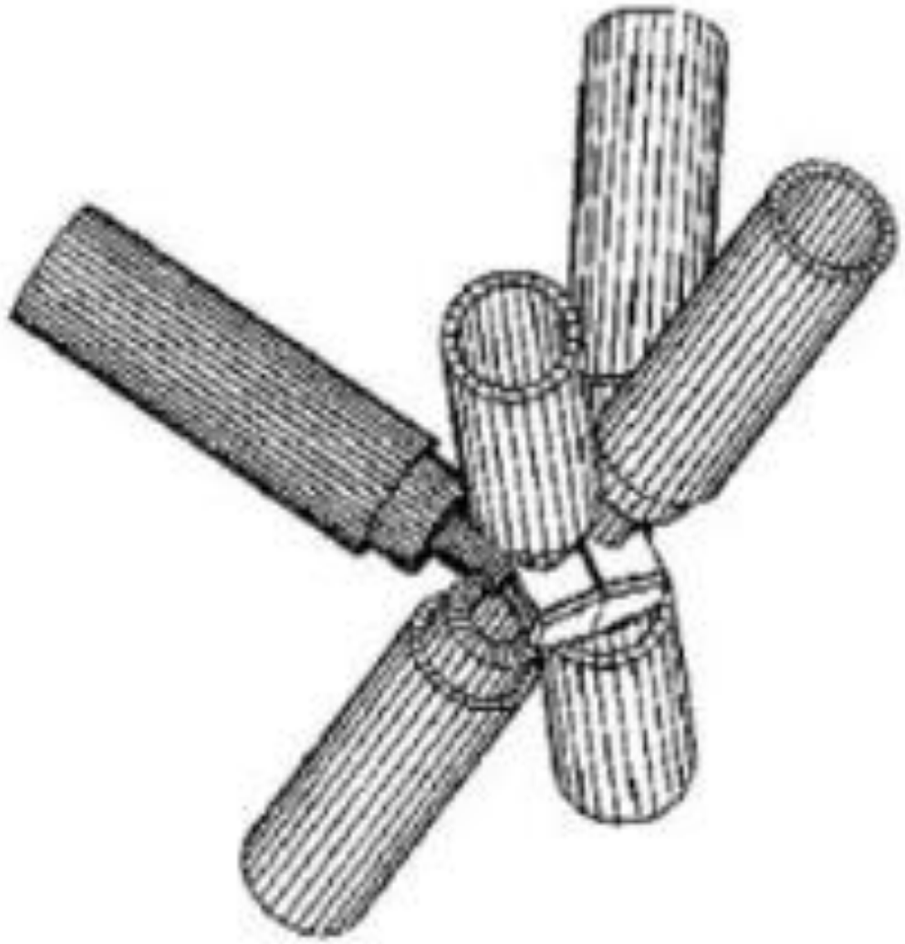
A piece of wood can be used and glue can be employed to stick it to the inner surface of bamboo. Any normal glue provides a capacity far larger than that of bamboo in the tangential direction. Two slots are needed in the bamboo cane to control cracking during the insertion of wooden cylinder. The wood fitting can be extended outside the culm to meet the outcoming piece of wood from other elements, them normal wood construction method can be used for connection connecting system wood core connection. The steel plate c is introduced in the slot of wooden cylinder and glued to it with a mixture of epoxy resin and Portland cement. The plate is projected, so that its outer extreme can be adapted for different applications
Its low priced and parts are easily available too.



Types of structural connectors used with bamboo

INTERLOCKING CONNECTIONS

Pan knot
This works on bamboo with diameter smaller than 80mm. These threaded bolts can transfer about 50 percent of the tractive force



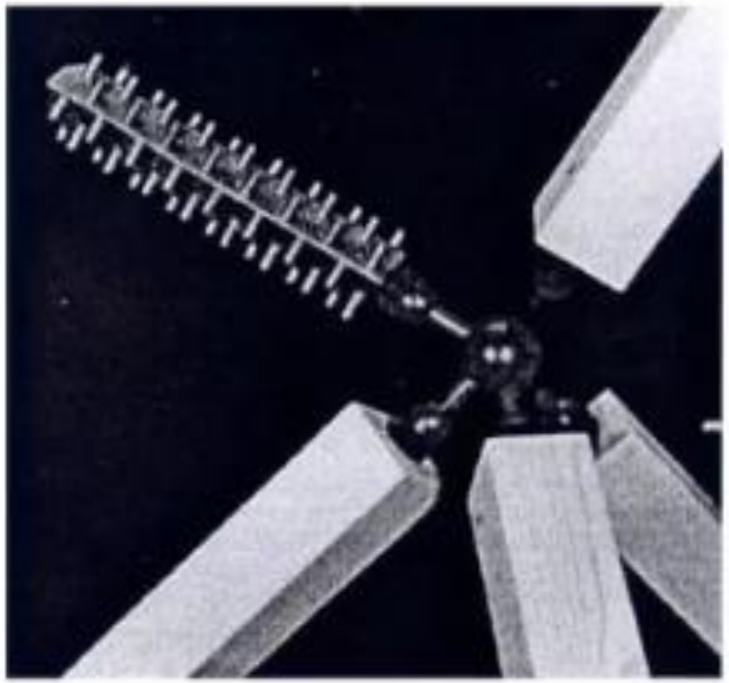
In plane or space trusses, the plates from two or more incoming elements can be pre welded to each other and then the rest of the connection can be assembled. The figure shows aa connection in which a small box is made up of steel plates, so that the faces are perpendicular to the axis of the incoming elements. The steel tips are then welded directly to those surfaces. Welding is thought of here because it is heaper than machining of the tips, but in some cases this can be achieved as well.

PAN – KNOT SPACETRUSS

Small bamboo canes (diameter upto 80 mm) can transfer ca.50% of the maximal tensile force if threaded bars are glued or sheded into the cane ends. For compressive forces the maximum force is where the cane breaks if connected with a headplate. If overhead working is necessary tests by an officially recognized material testing institution and special permission of the building department are required.

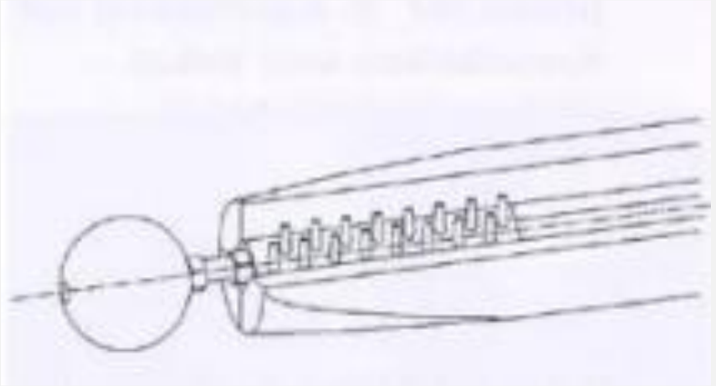
Pan knot space truss consist of two elements only – the pan ball knot and cane with sheded thread rod. That means more economic statics, drawings and production. Furthermore they can be dismantled and reused.

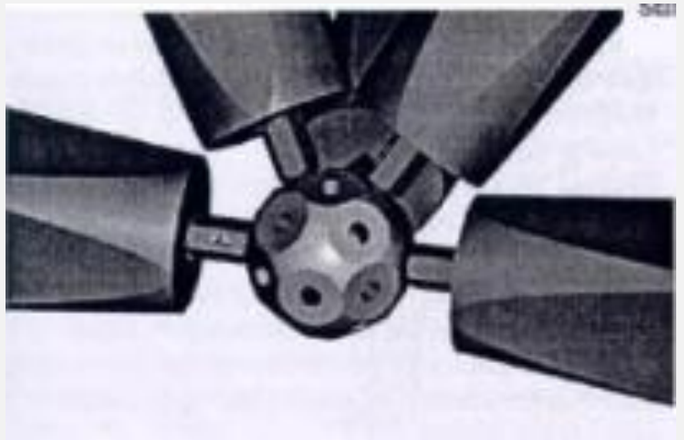
INDUO - ANCHOR TECHNIQUE



For big bamboo diameters, the induo-anchor can transfer nearly 100% of the maximum load of the cane cross section. The induo-anchor consits of a cast iron core with connection teeth on its sides. It can easily be sheded with a bamboo cane. Concrete or artificial resin can be used for that.

Steel neb connection – the connection uses the induo achor in its usual state with bores and threads. The base element of this connection is a conical steel connector which is centric screwed from the inside to the induo anchor bore on one side andto the threadbore of the joint element on the other



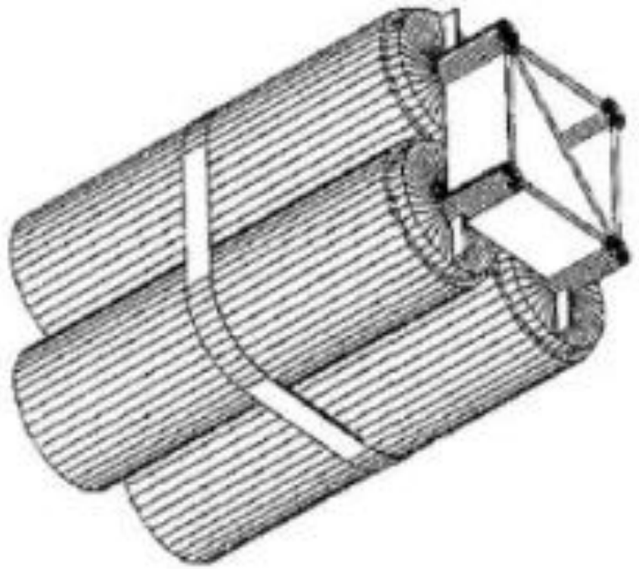


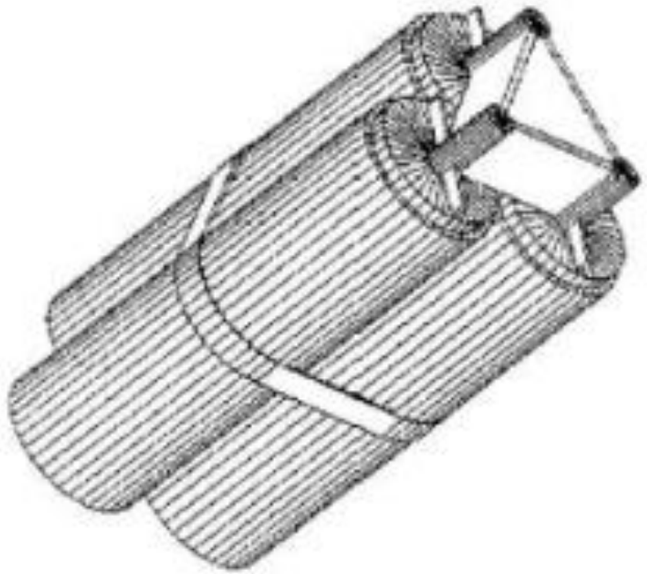
ADVANTAGE
A simple connection can be manufactured with a threaded bar and two counter nuts. Steelballs with treadbores are used as jointpoints.

DISADVANTAGE
The cast iron core is drilled in the perpendicular axis with fitting diameter to connect the screwbolt.

CANE BUNDLES

Probably it will be necessary to keep the canes together at midspan. A steel band can be used for that.





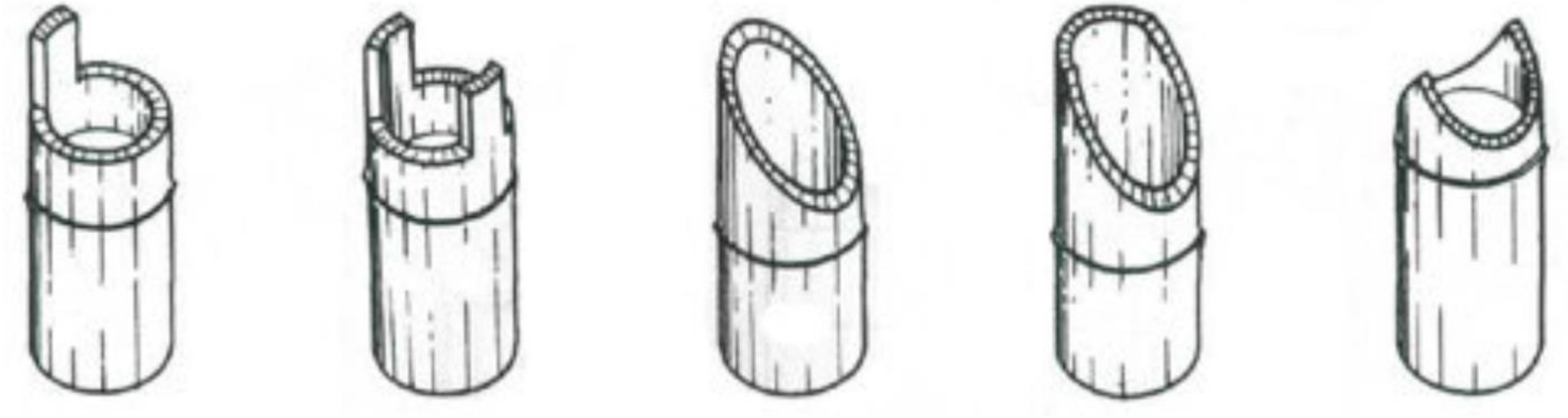
Cane bundles must be used for bigger loads. When using them for construction, a possible connection can be achieved by projecting steel tips out of wood cylinder, so that these tips can be welded to a plate or any other central component, to fix the relative position of the canes

Bamboo Furniture

- It's a very strong and durable material which is surprising given its gentle and delicate nature.
- It's in fact among the hardest woods and, in addition to that, it's also resistant to insects and moisture.
- This makes **a good candidate as a material for outdoor furniture and other elements**

These are the most common cuts to use when making bamboo joints:
one ear / two ear / beveled / flute mouth / fish mouth

Bamboo Cuts

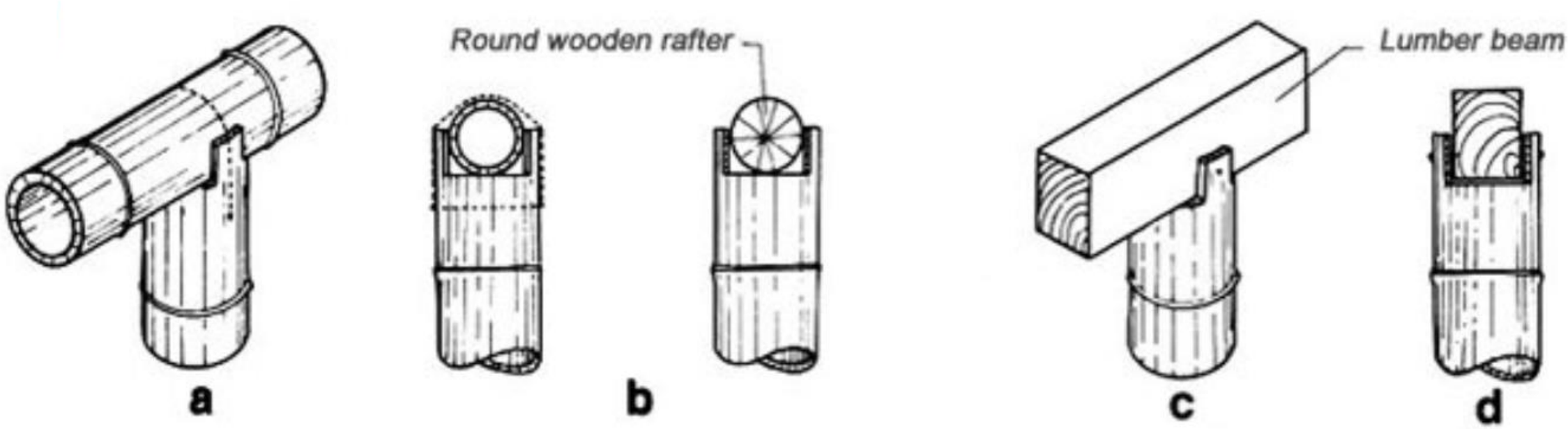


Bamboo Joinery Techniques

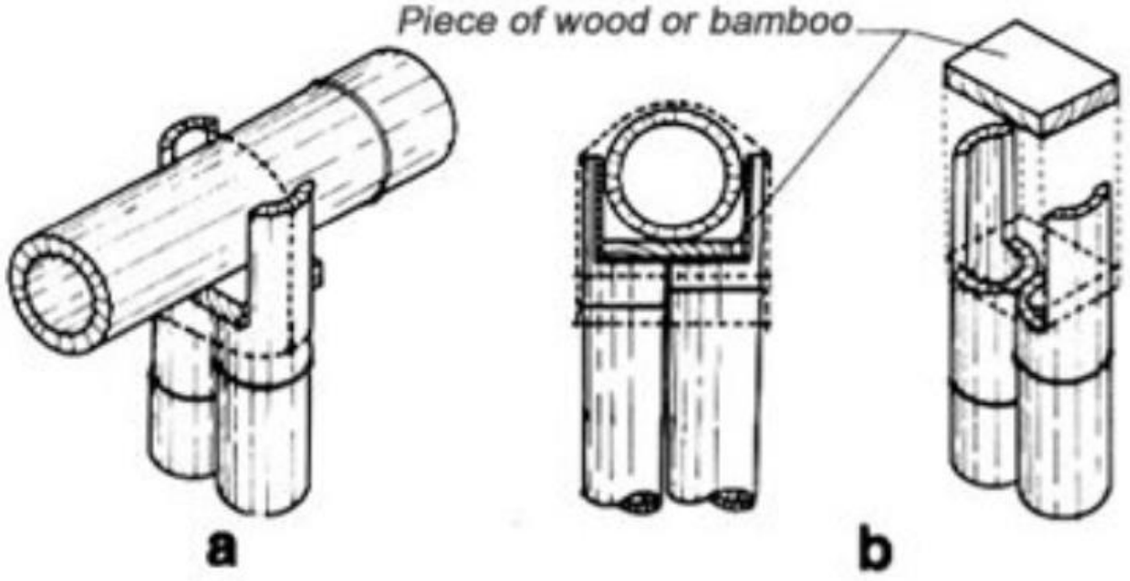
Making good and aesthetically pleasing bamboo joints is rather **complicated** because **bamboo is hollow, tapered, has nodes at varying distances, and it is not perfectly circular**. It is important to keep all these constraints in mind when designing a bamboo joint.

illustrations of **traditional** bamboo joinery techniques**.**

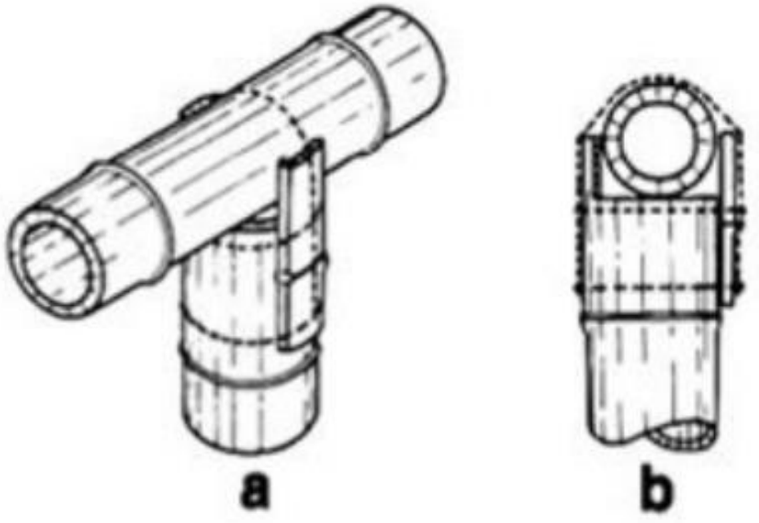
1. **Joint with one or two ears.** Is used to join bamboo rafters, logs or lumber



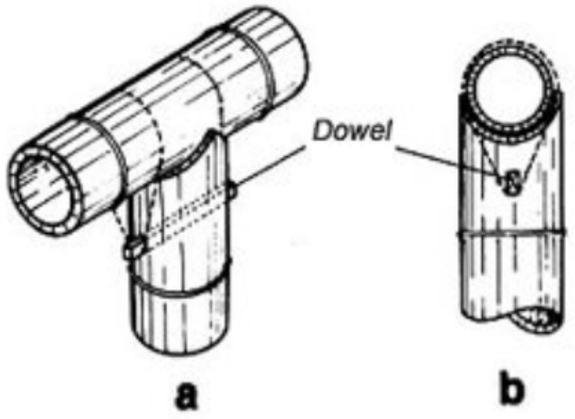
2. **Flap joint**. Is used when there is no lashing wire available.
The flap can be secured with bamboo strips.



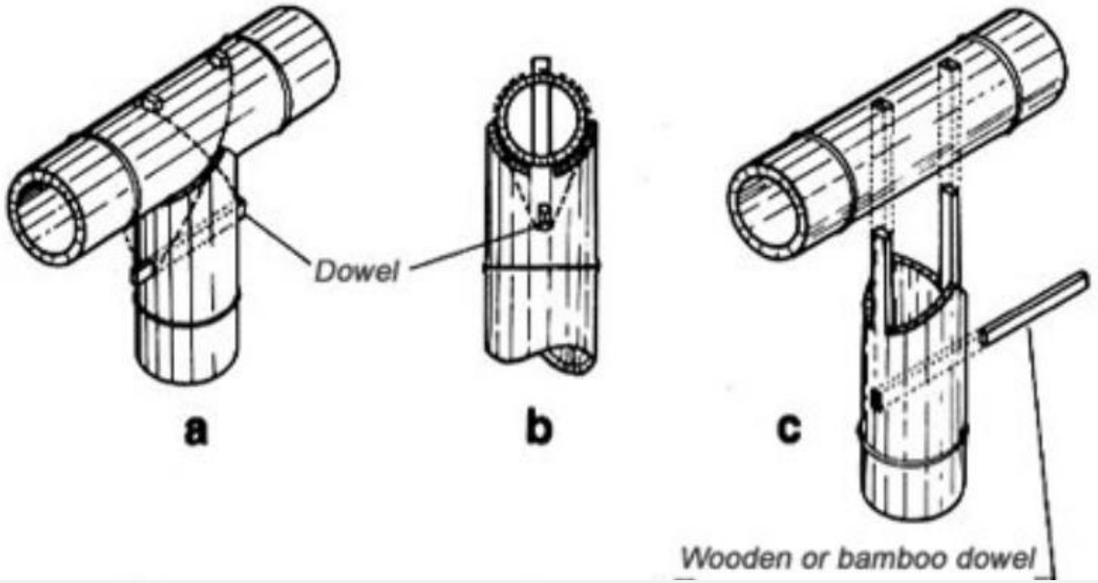
3. **Fish mouth joint.**



Use of dowels and anchors in bamboo joinery

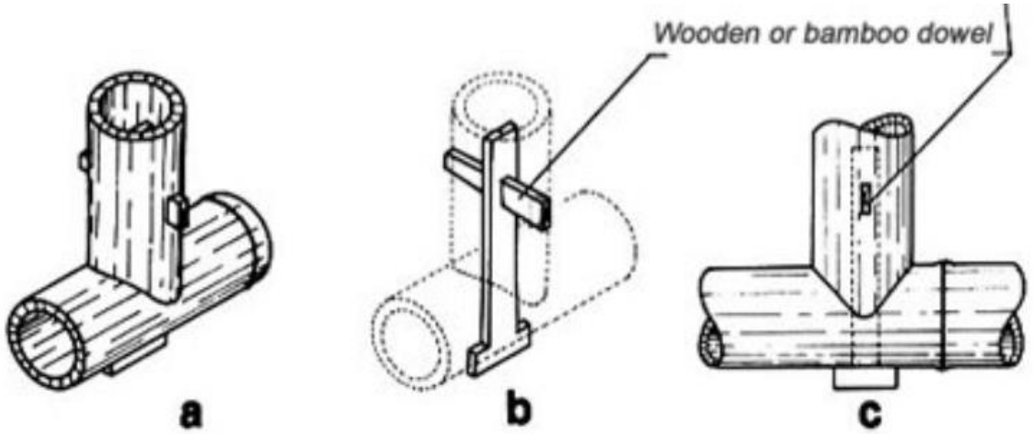


1. Joining bamboo with dowels and lashing. The peg should be placed in the column parallel to the rafter.

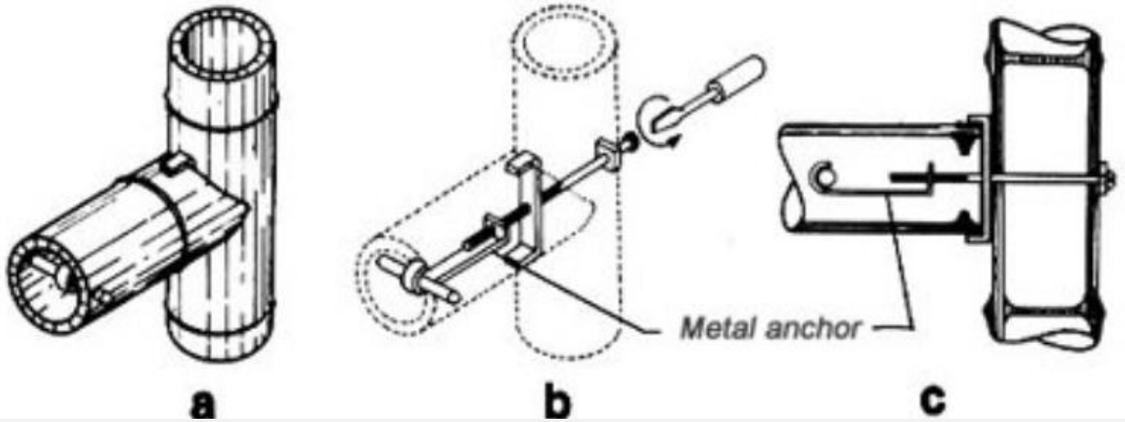


2. Fish mouth joint with pegs.

Use of dowels and anchors in bamboo joinery

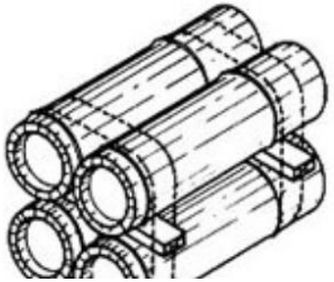


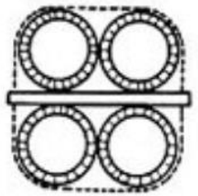
3. Bamboo joint with wooden anchor. Is also used inverted.



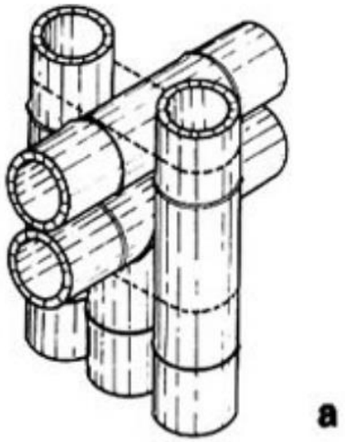
4. Bamboo joint with metal anchor. This technique Is used in various positions.

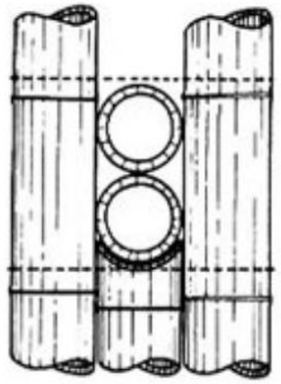
Double and quadruple bamboo rafter support





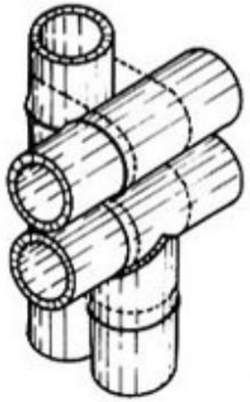
1. Beams formed by 4 or 6 members. The top row is separated from the bottom with bamboo or wood slats so that the upper bamboos do not slide over the lower.

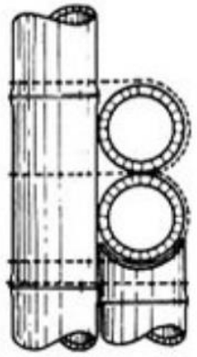




2. Central double rafter. It has a wide range of applications in the construction of bridges and structures for rural facilities.

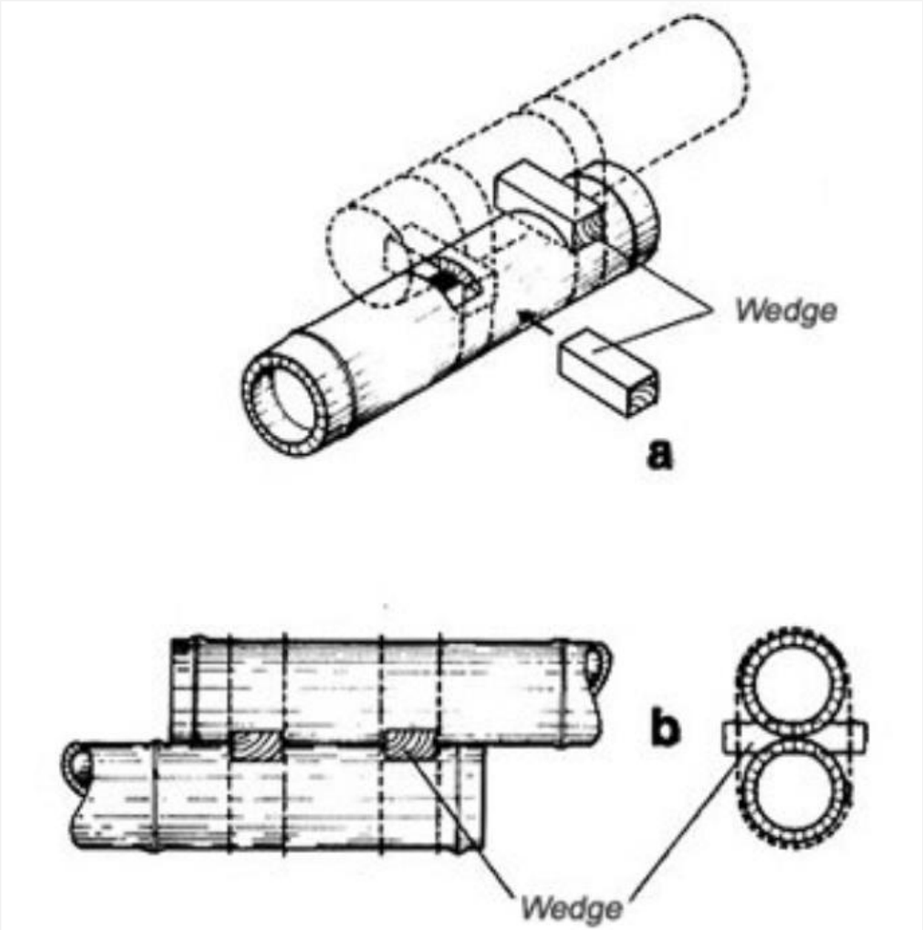
3. Lateral double rafter. Each of the rafters is secured independently at the side support and each other. It is often used in the construction of bridges and structures for rural facilities.



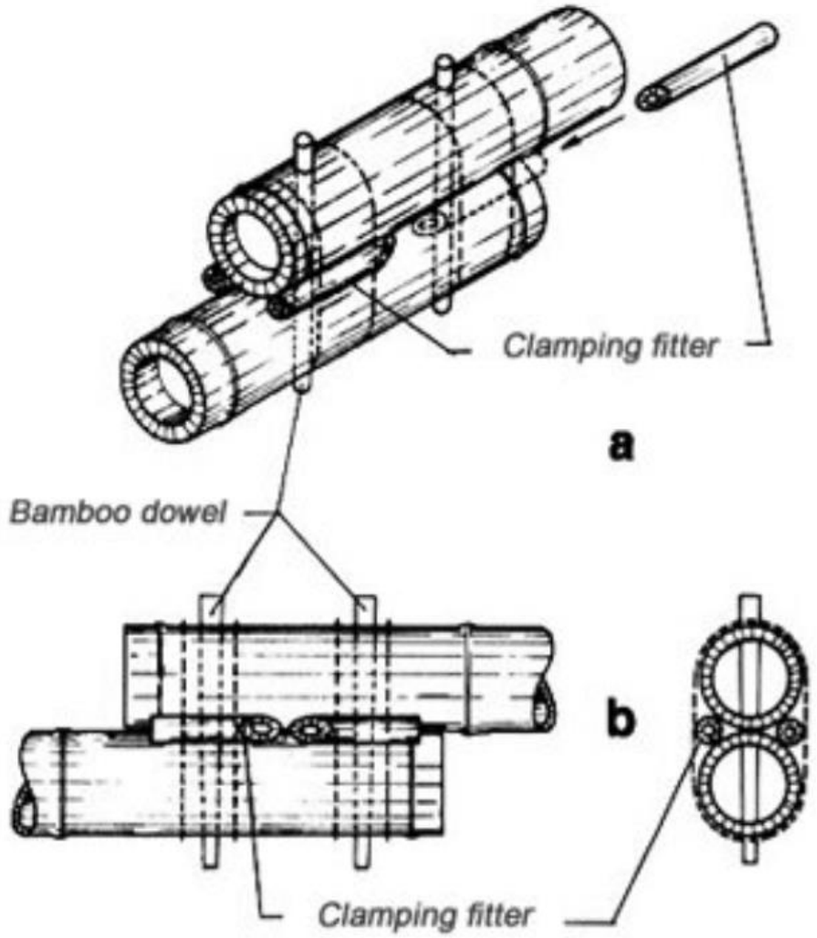


4. Lateral double rafters. Is often used as a central support for bridge structures or sheds.

Joining and fixation of bamboo poles

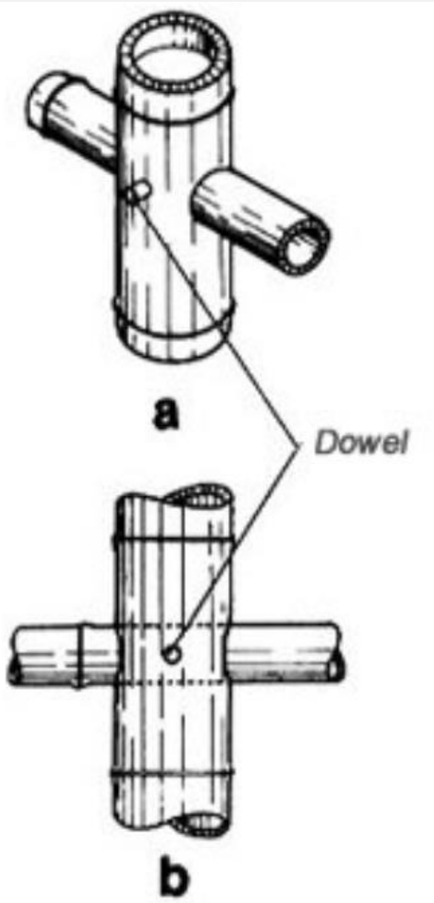


1. Joint with double wooden wedge.

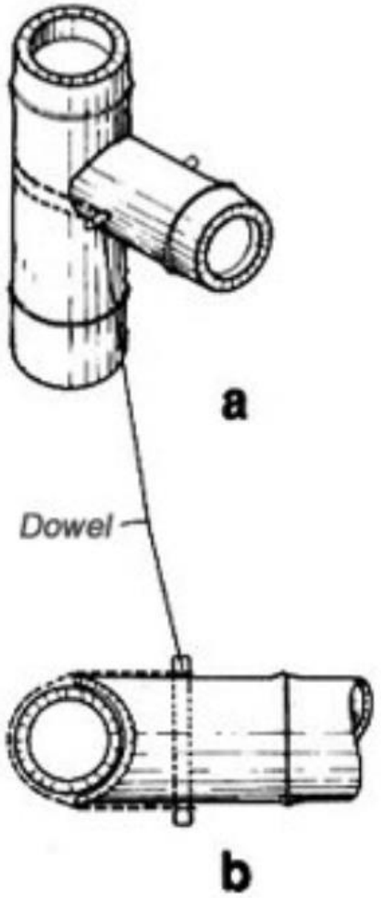


2. Joint with dowels and clamping fitters.

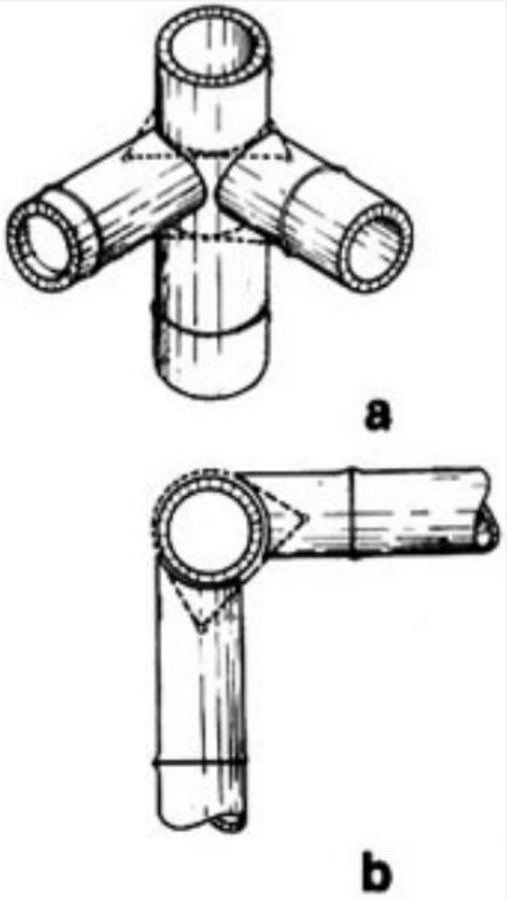
Joining and fixation of bamboo poles



3. **Cross joint with dowel.**

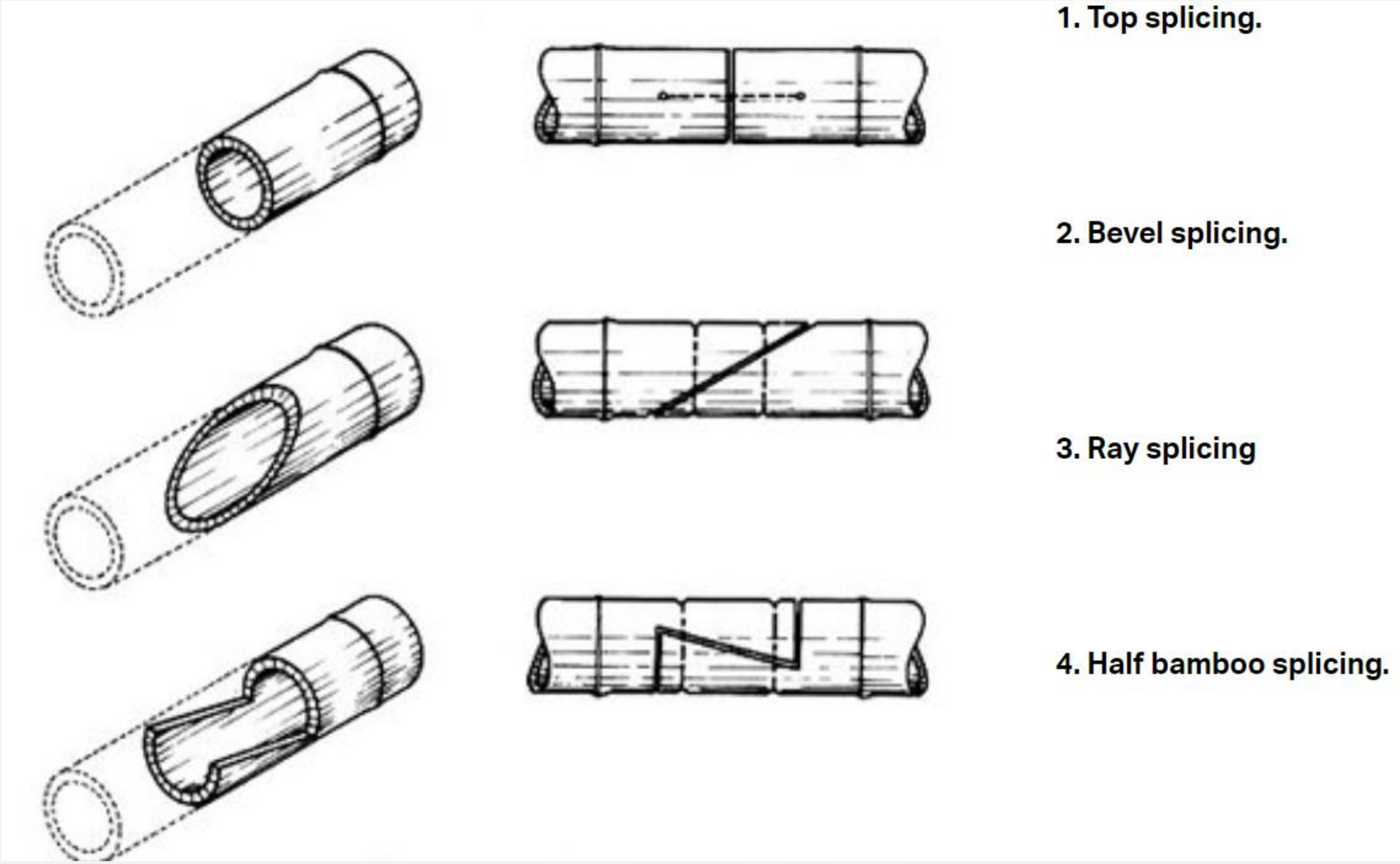


4. **Lateral joint with dowel.**



5. **Corner joint.**

Splicing bamboo poles



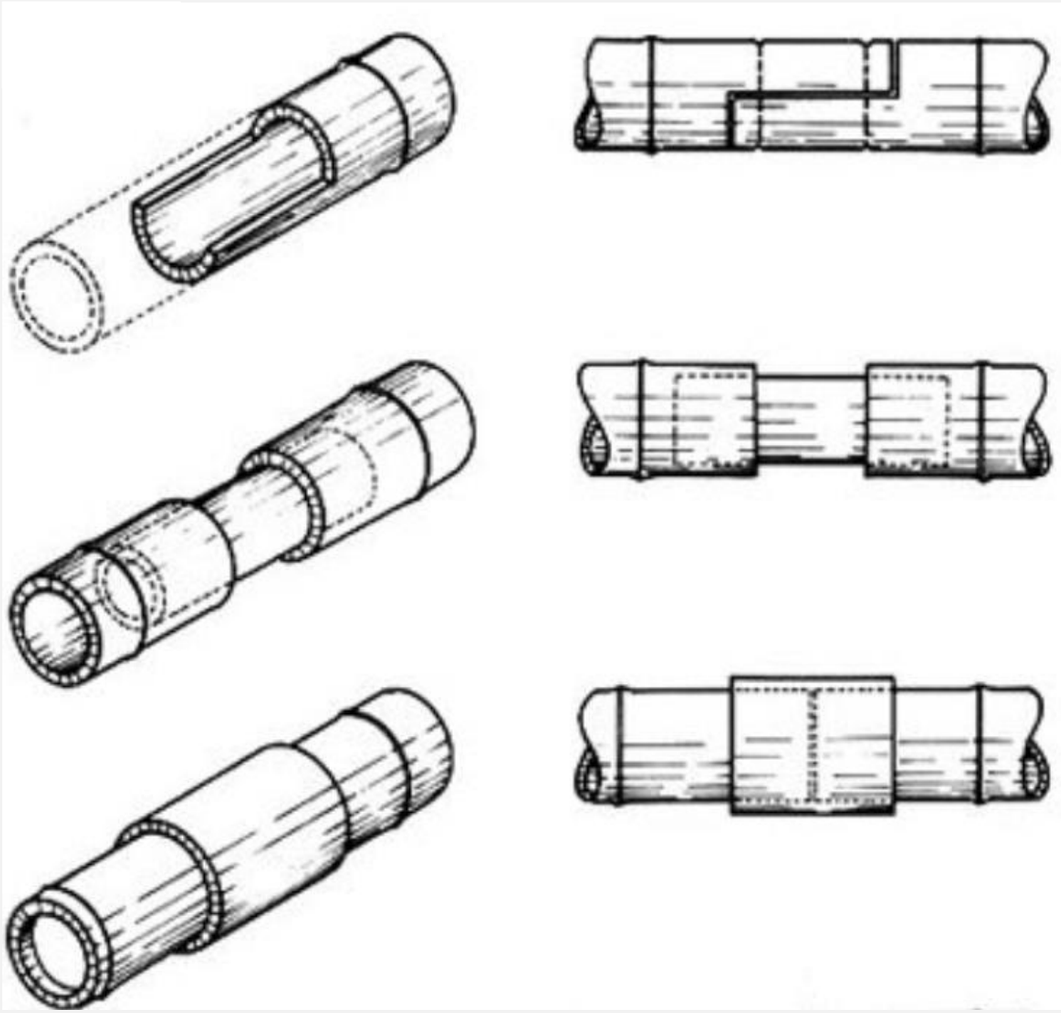
1. Top splicing.

2. Bevel splicing.

3. Ray splicing

4. Half bamboo splicing.

Splicing bamboo poles



5. Splicing with internal union.

6. Splicing with external union.

7. Telescope splicing.

1 Initial joinery sketches

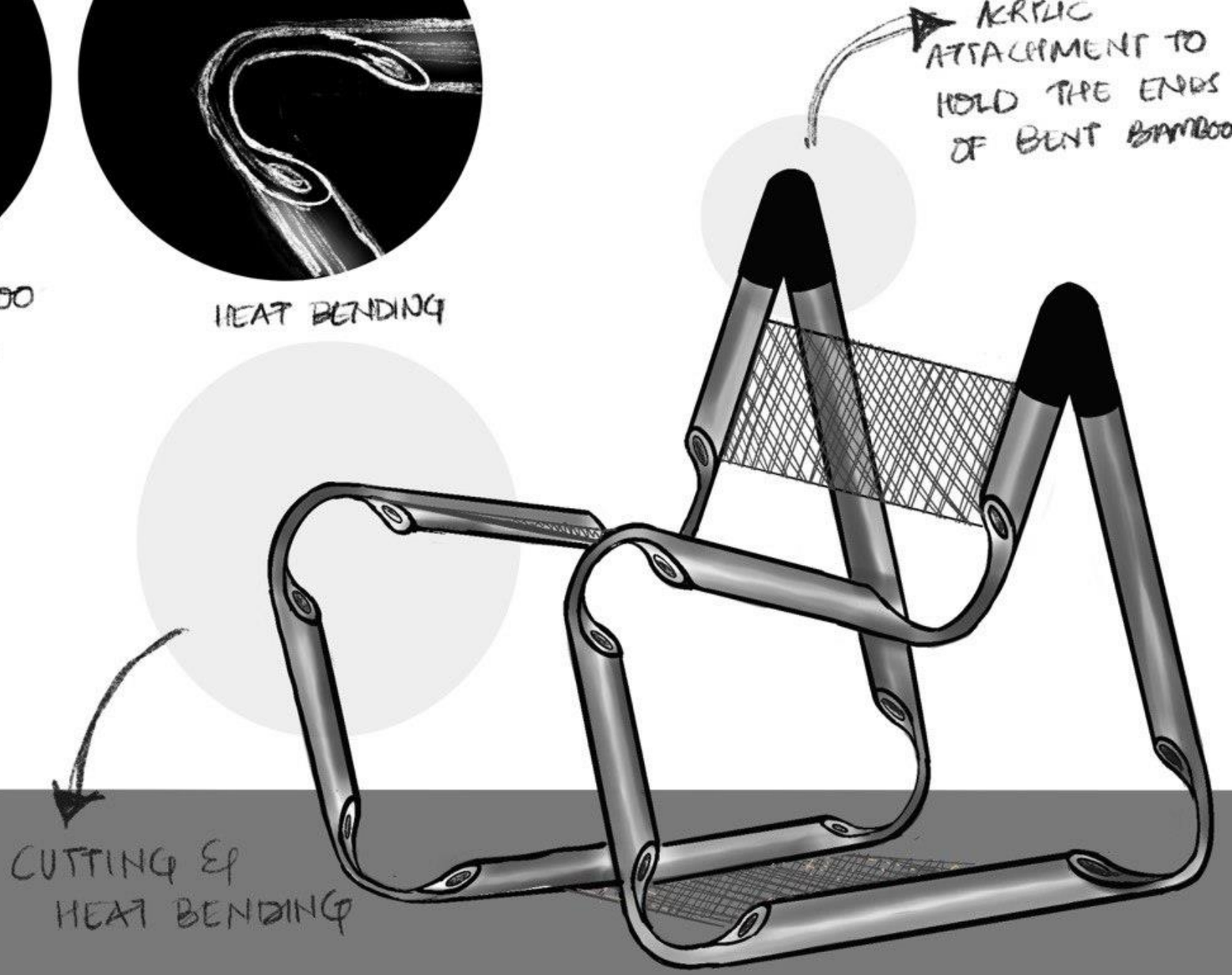
Bamboo as the joinery material

- Coffee table using cutting and bending of bamboo

2 Initial joinery sketches

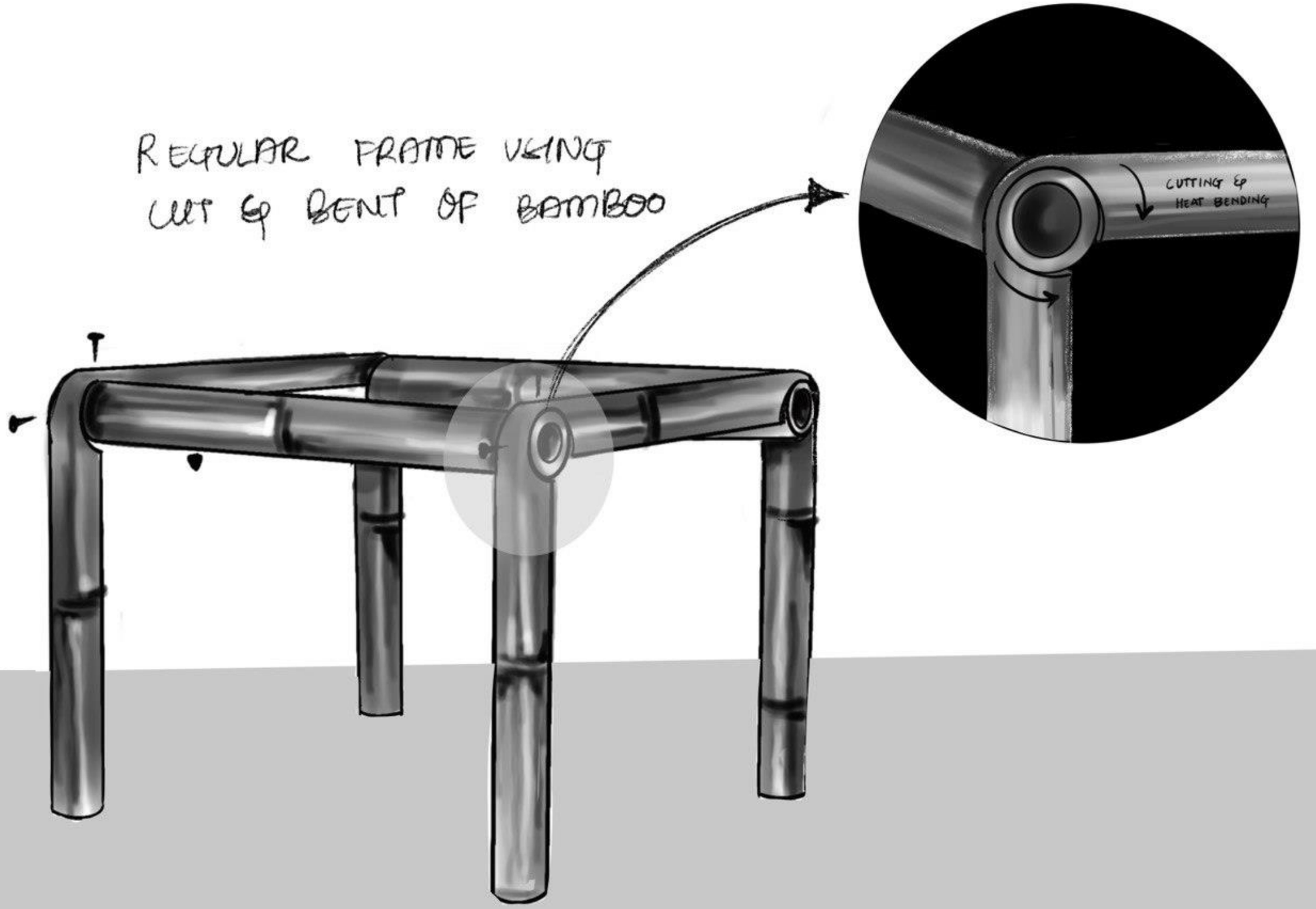
CUTTING BAMBOO AT REQUIRED ANGLE

HEAT BENDING



- Coffee table using cutting and bending of bamboo

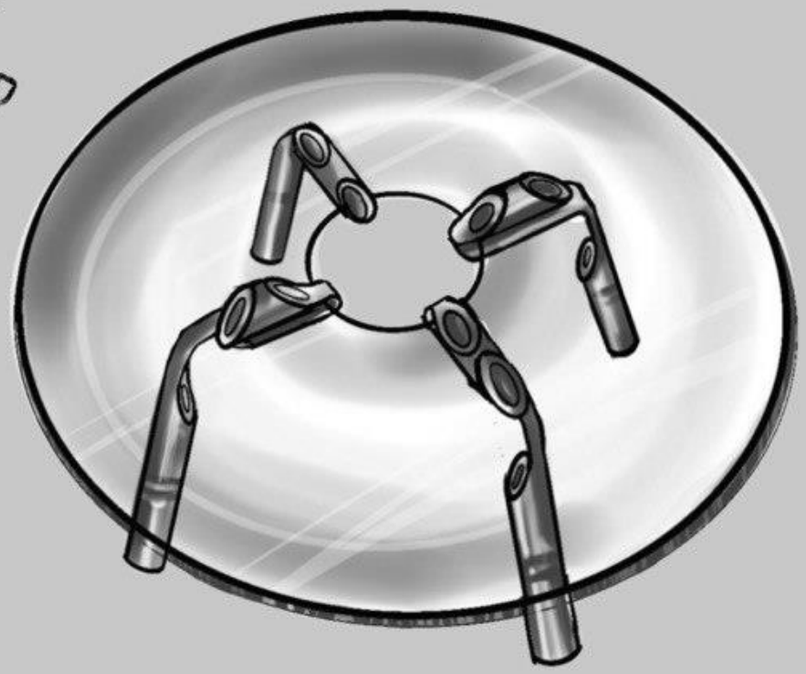
3 Initial joinery sketches



- Coffee table using cutting and bending of bamboo

4 Initial joinery sketches

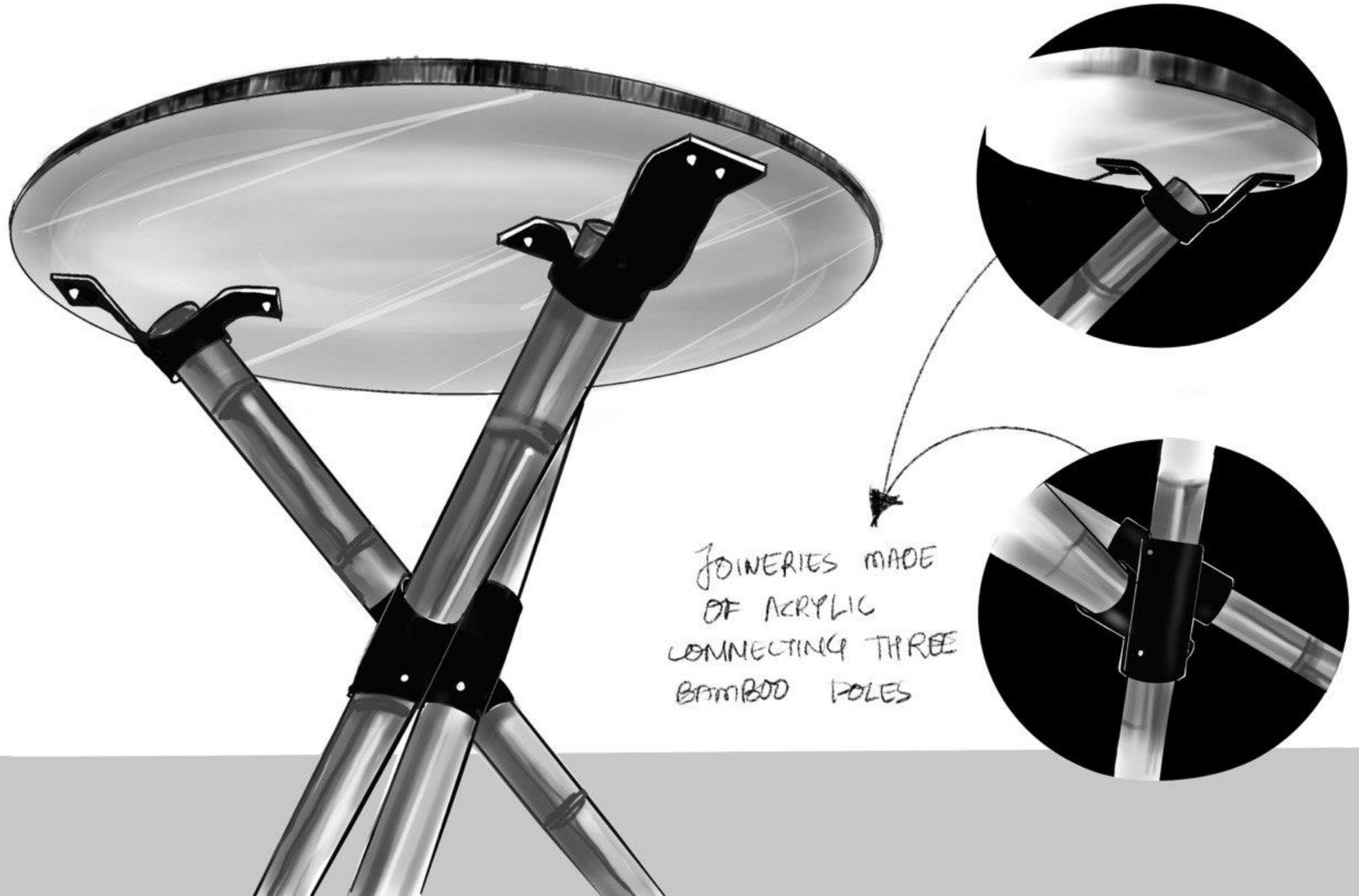
- Coffee table using cutting and bending of bamboo



1 Initial joinery sketches

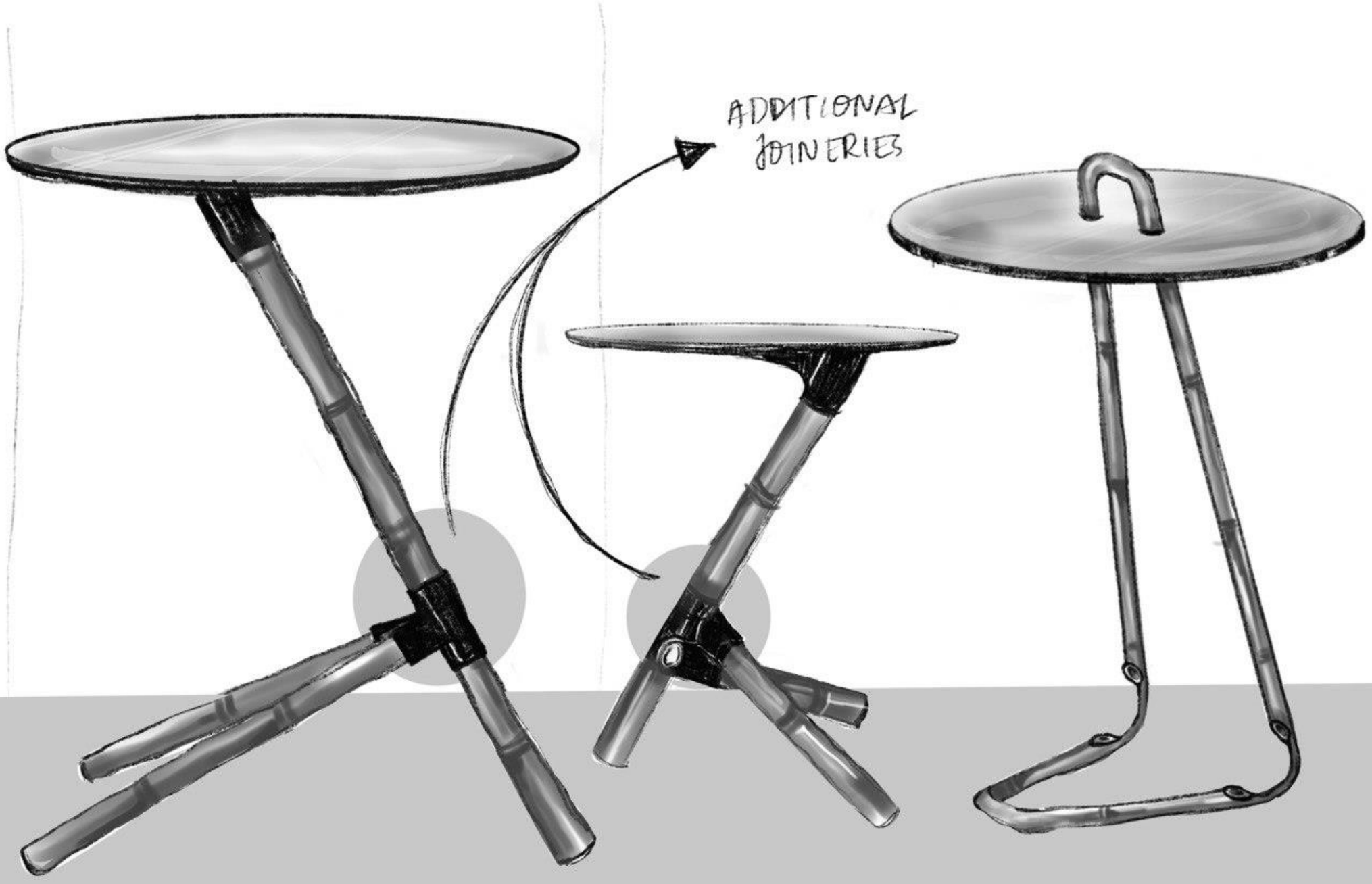
Acrylic as the joinery material

- Coffee table using a combination of acrylic joinery and bamboo
- The joinery helps in attaching legs to three directions

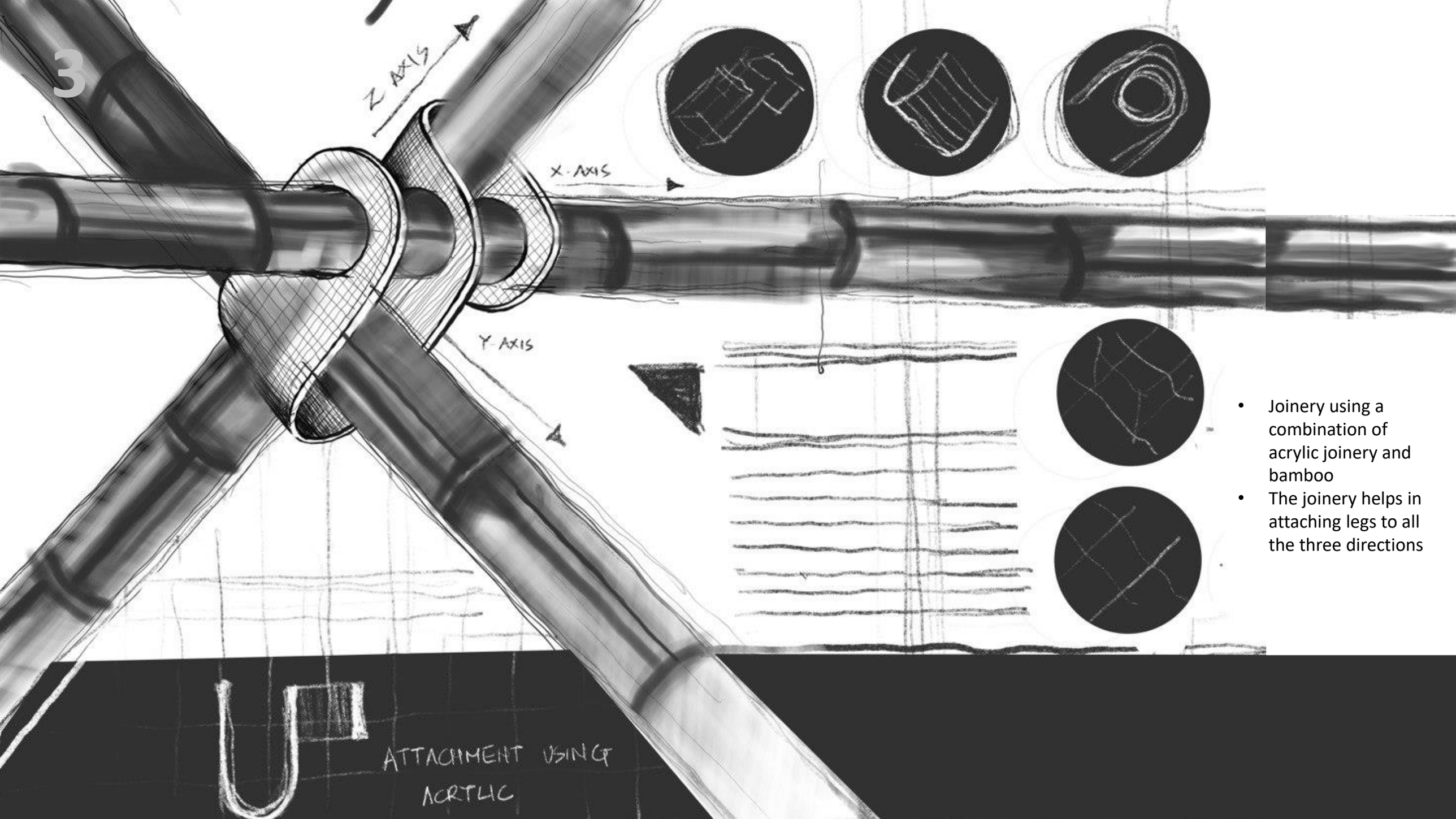


2 Initial joinery sketches

- Coffee table using a combination of acrylic joinery and bamboo
- The joinery helps in attaching legs to three directions



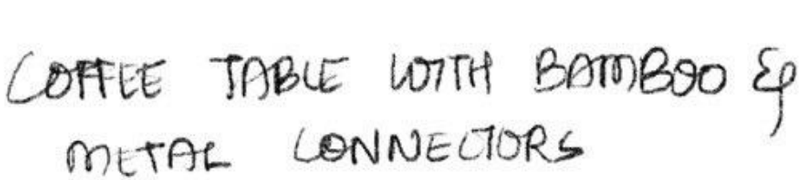
3



- Joinery using a combination of acrylic joinery and bamboo
- The joinery helps in attaching legs to all the three directions

1 Initial joinery sketches

Metal as the joinery material

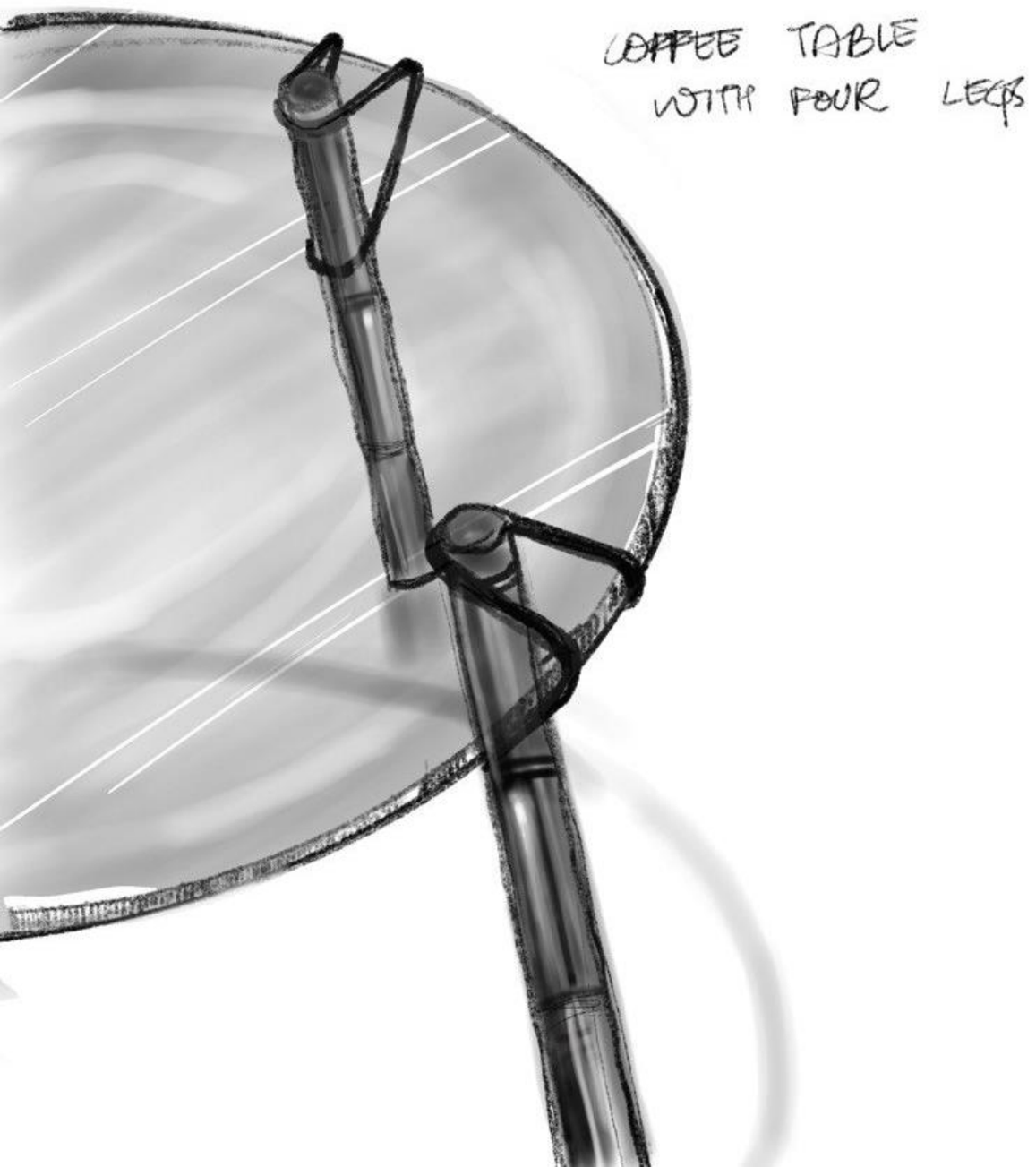


- Coffee table using a combination of metal and bamboo
- Three pieces of metal are bend in required angle and inserted into the 3 legs which is then screwed.
- Second option is also an example of coffee table using metal and bamboo where a single metal pole stands upright as a vertical support and the two metal rods are attached to this in an angle.

2 Initial joinery sketches

- furniture using a combination of metal insertions and bamboo
- C shaped metal insertions are attached in the two legs and handle with the help od screws in a seamless manner
- Similar metal insertions are used I the stool but in an exposed manner

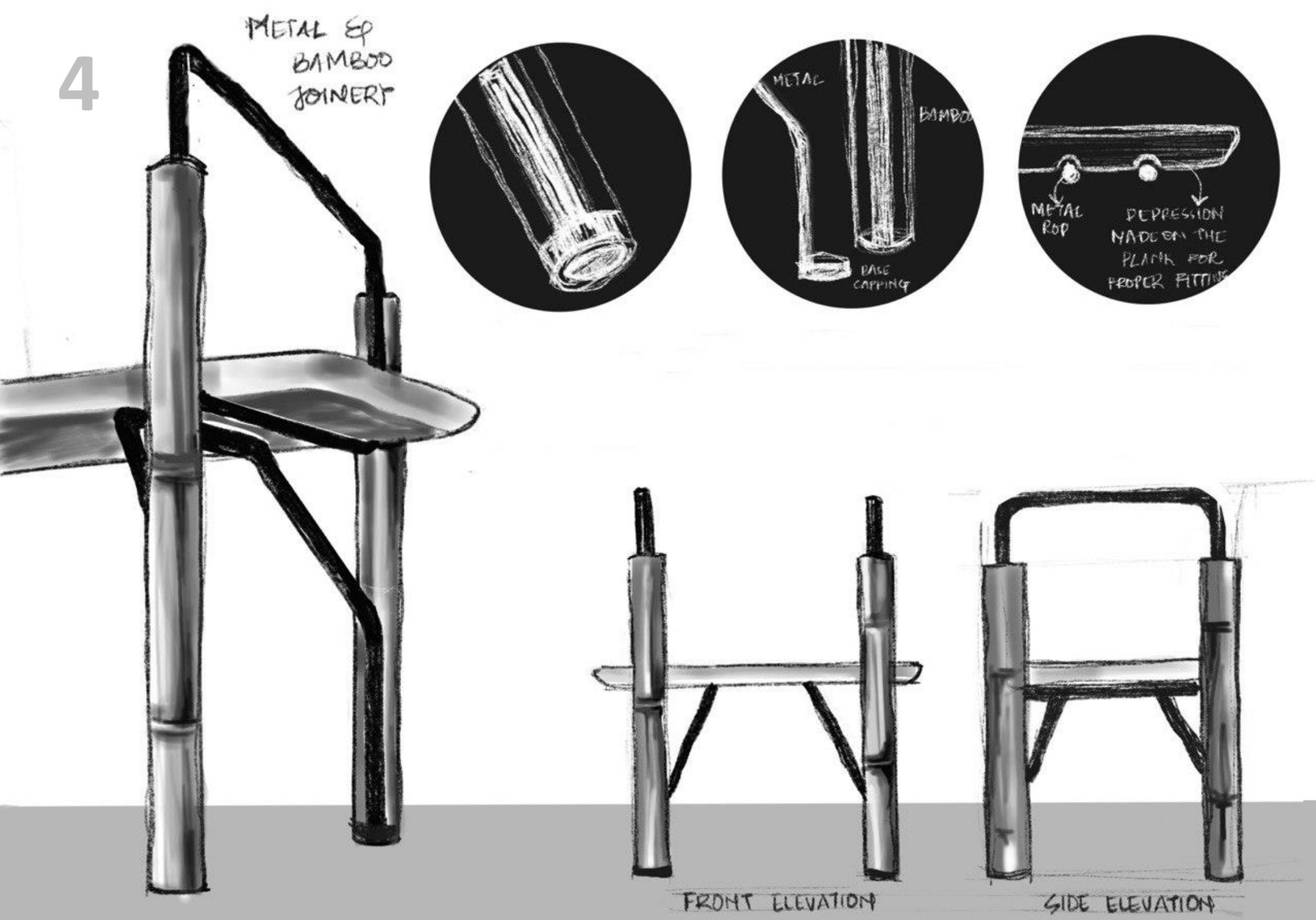
3 Initial joinery sketches



- Coffee table using a combination of metal and bamboo
- Bamboo poles are used for the legs
- Top splicing with external union is done to hold the glass in place
- Depressions are made on the pole to fit the metal ties bar
- 4 holes are made in the glass
- Bottom piece of bamboo is placed
- The metal ties bar is connected
- cap is attached to the bottom piece to hold the legs in place

Splicing with external union

4



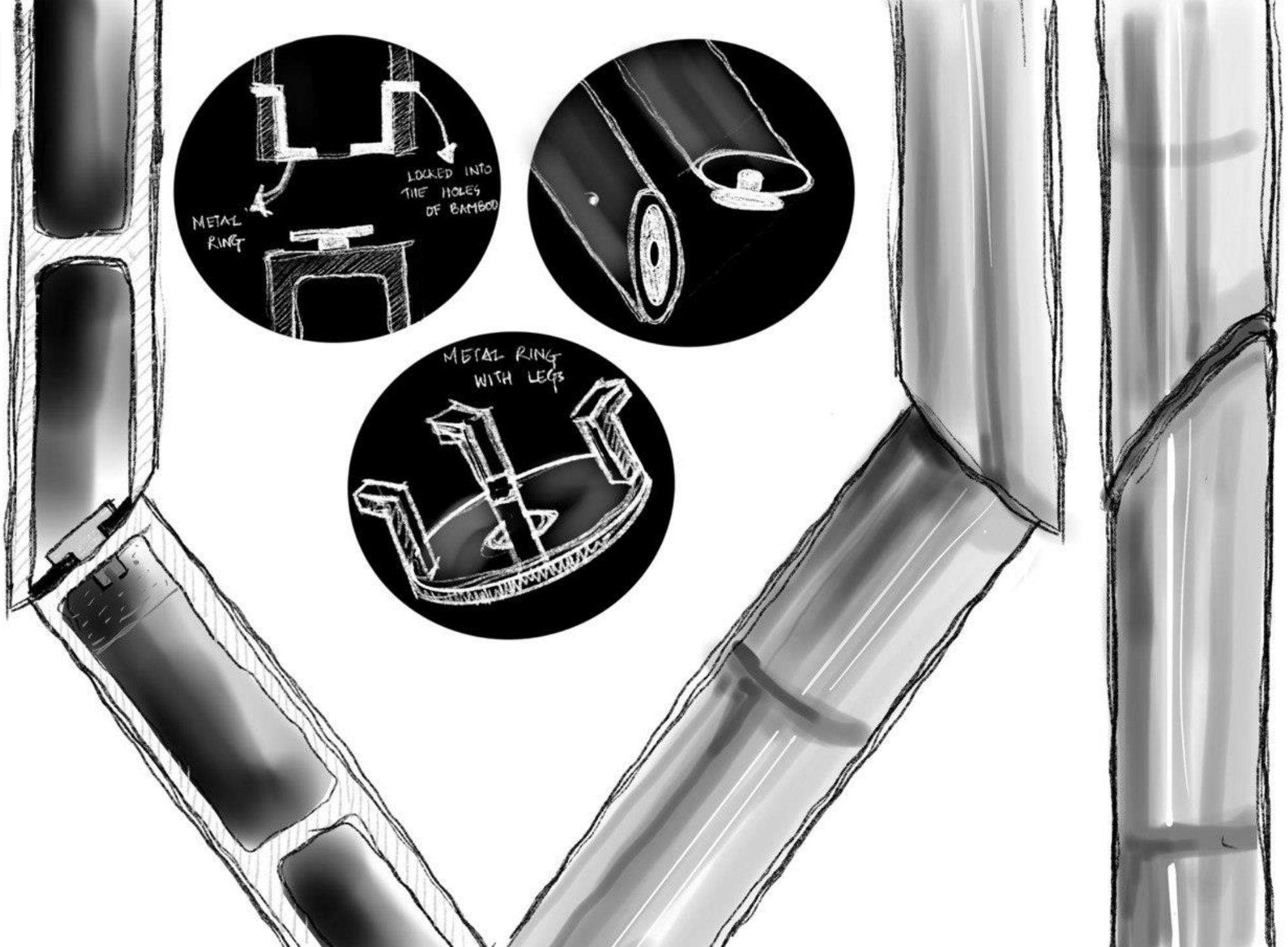
Initial joinery sketches

- Chair using a combination of metal and bamboo
- Bamboo poles cut into halves are used for the legs
- Metal rod with the diameter same as the inner diameter of the bamboo is chosen
- Metal cap is provided at the base and rod is bent in such a manner to support the seat
- Similarly another metal rod is bent and inserted inside the half cut bamboo to act as the handle of the chair

1 Initial joinery sketches

Joineries connecting bamboo from inside

- joinery using a combination of metal and bamboo
- Bamboo is cut in 45 degree angle.
- Metal ring with legs are inserted to the first piece in such a way that the legs fits inside the hole of the first piece
- A disc is fixed on to the node of the second piece of bamboo which acts as a pivot and allows 335 degree movement
- Hole s made in the bamboo and a mixture of saw dust and resin is poured through this hole to fix the joinery firmly to the second piece.





2 Initial joinery sketches

Joineries connecting bamboo from inside

- joinery using a combination of metal and bamboo
- A rotating disc with a square shaped joinery is fixed to the first piece with allows rotational motion
- Two slits are made in the second piece and connected with a peg to the square metal joinery of first piece
- This allows sing motion

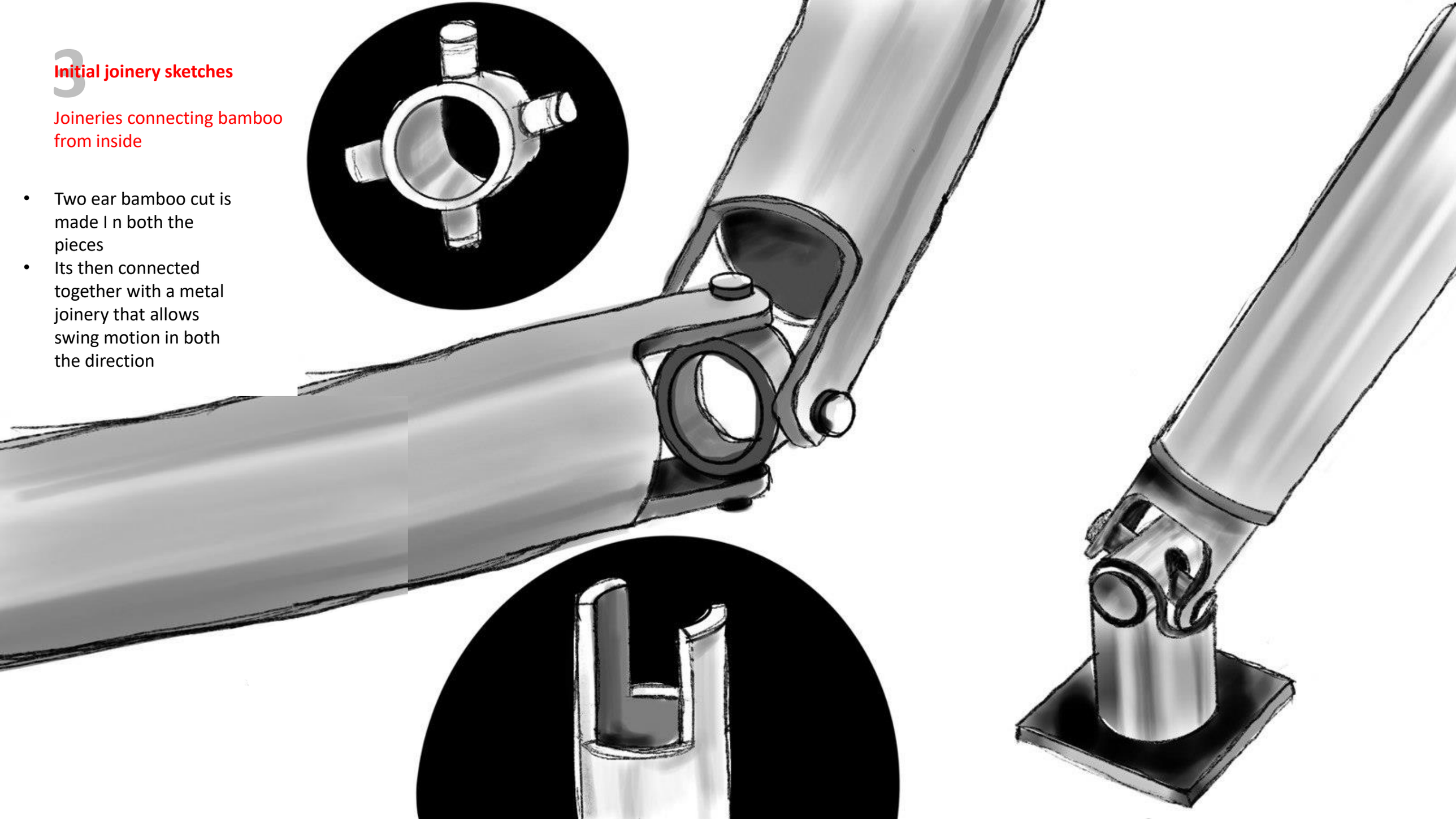


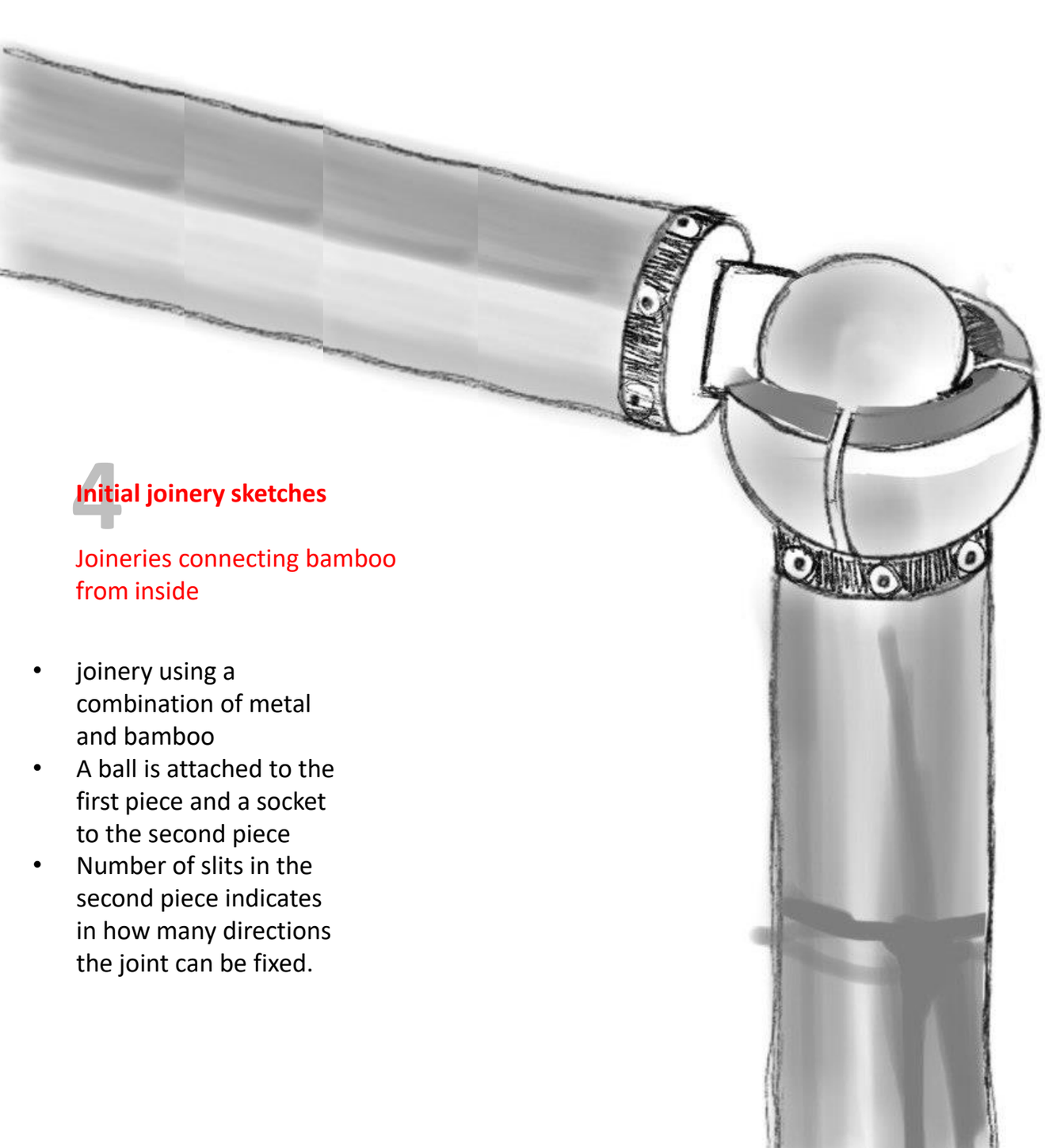
3

Initial joinery sketches

Joineries connecting bamboo from inside

- Two ear bamboo cut is made I n both the pieces
- Its then connected together with a metal joinery that allows swing motion in both the direction





4

Initial joinery sketches

Joineries connecting bamboo from inside

- joinery using a combination of metal and bamboo
- A ball is attached to the first piece and a socket to the second piece
- Number of slits in the second piece indicates in how many directions the joint can be fixed.

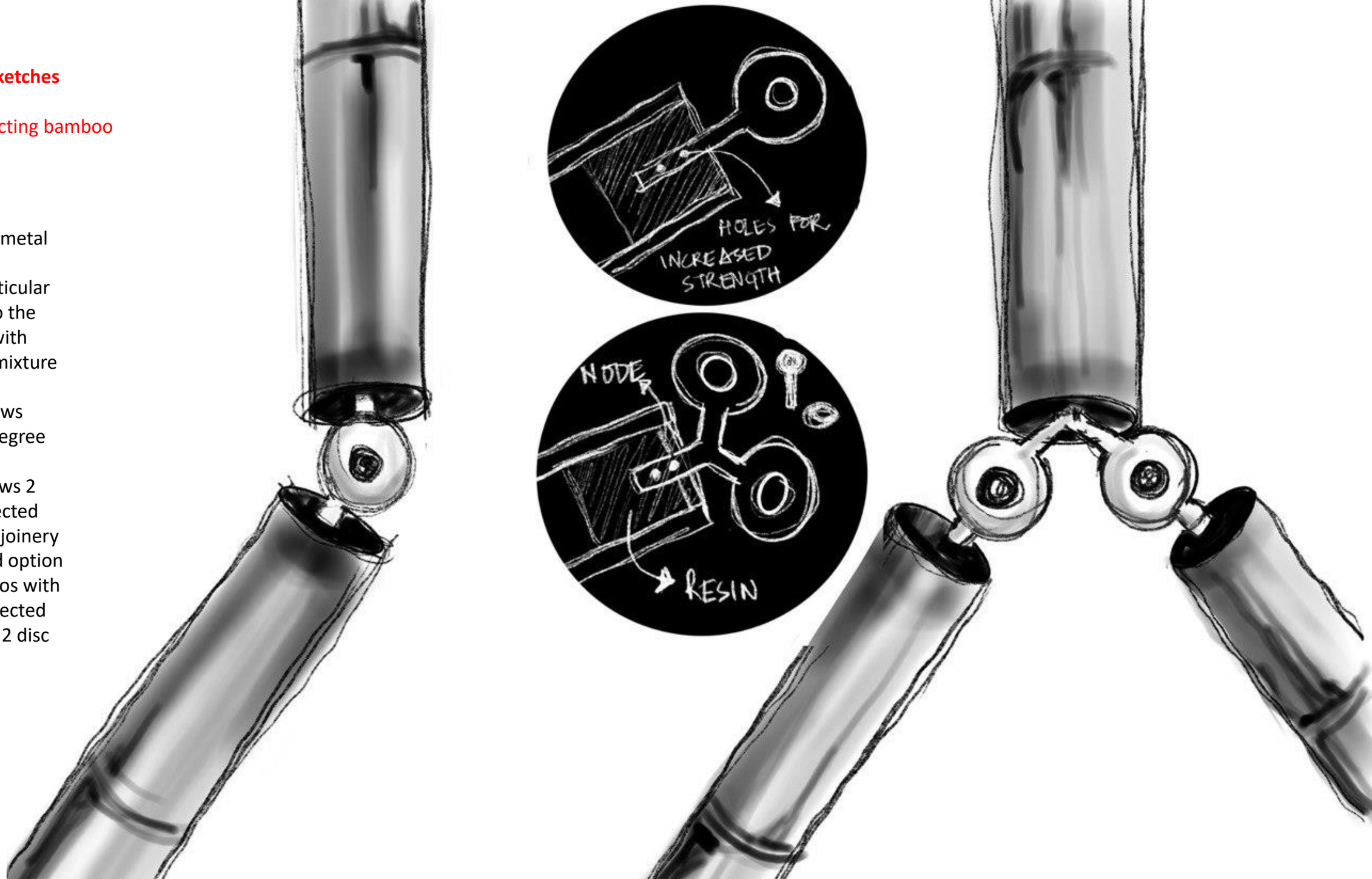


5

Initial joinery sketches

Joineries connecting bamboo from inside

- joinery using a combination of metal and bamboo
- Joinery of a particular shape is fixed to the bamboo node with resin saw dust mixture
- Each joinery attachment allows complete 360 degree rotation
- First option shows 2 bamboos connected with single disc joinery whereas second option shows 2 bamboos with single disc connected to 1 bamboo of 2 disc joinery

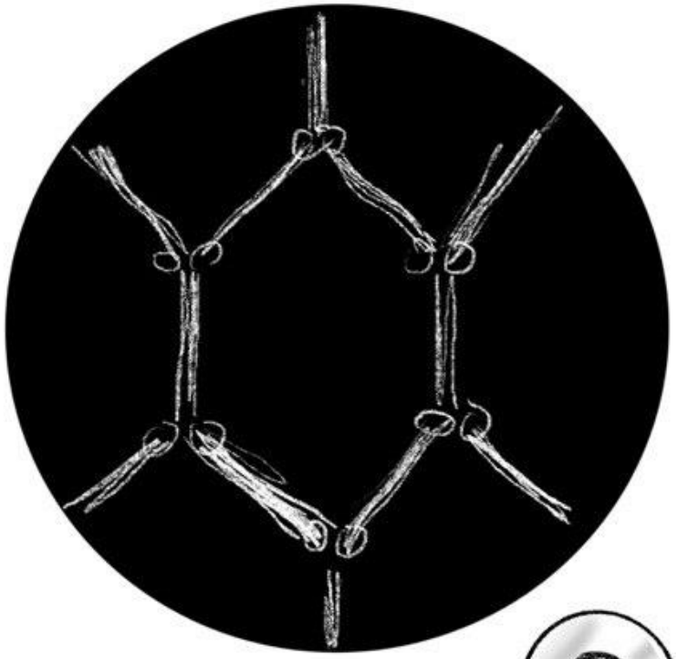


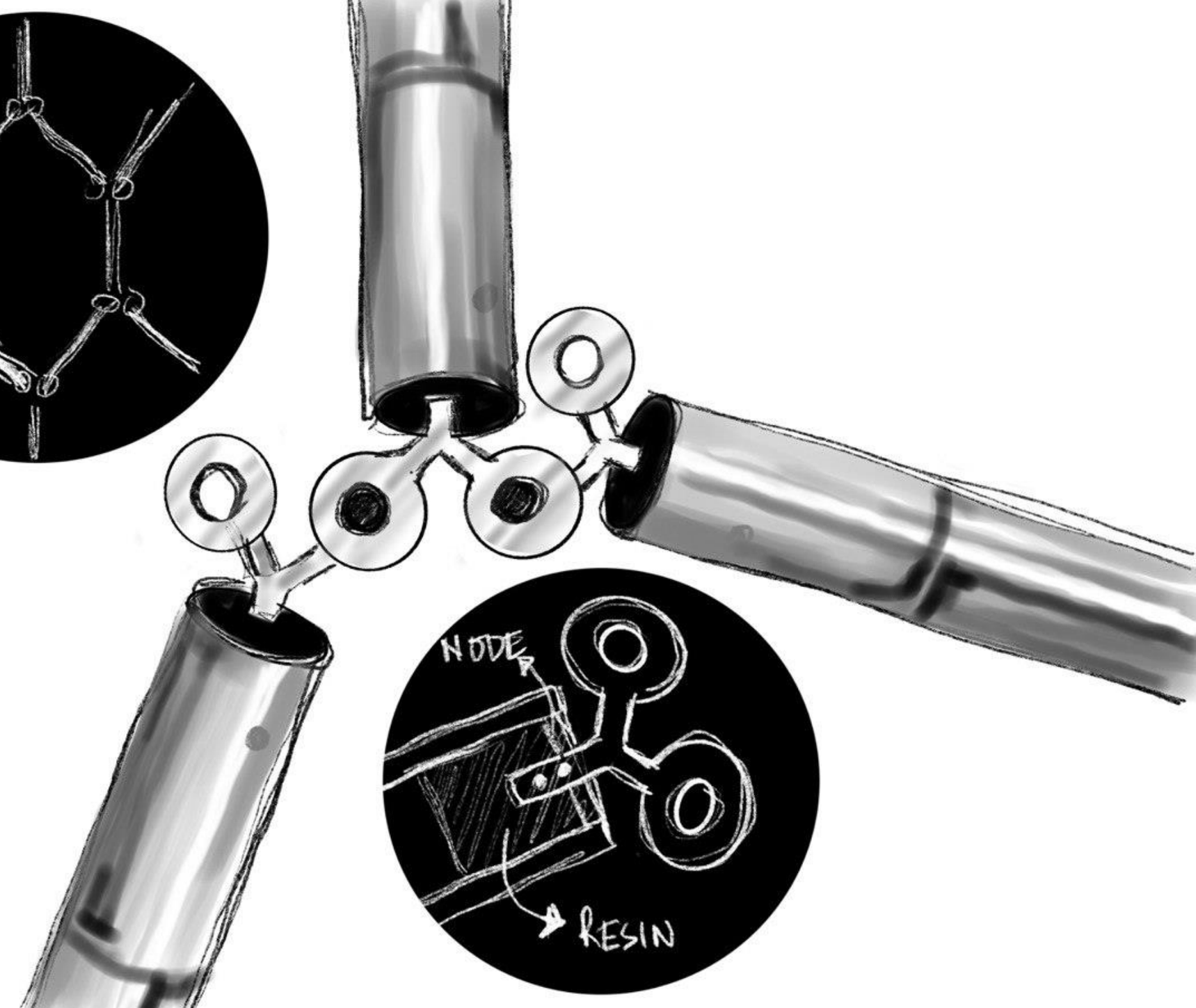
6

Initial joinery sketches

Joineries connecting bamboo from inside

- joinery using a combination of metal and bamboo
- Joinery of a particular shape is fixed to the bamboo node with resin saw dust mixture
- Each joinery attachment allows complete 360 degree rotation
- Here all three bamboos are connected together with two disc bamboo joinery.
- This can be used to easily form hexagonal patterns or frameworks.

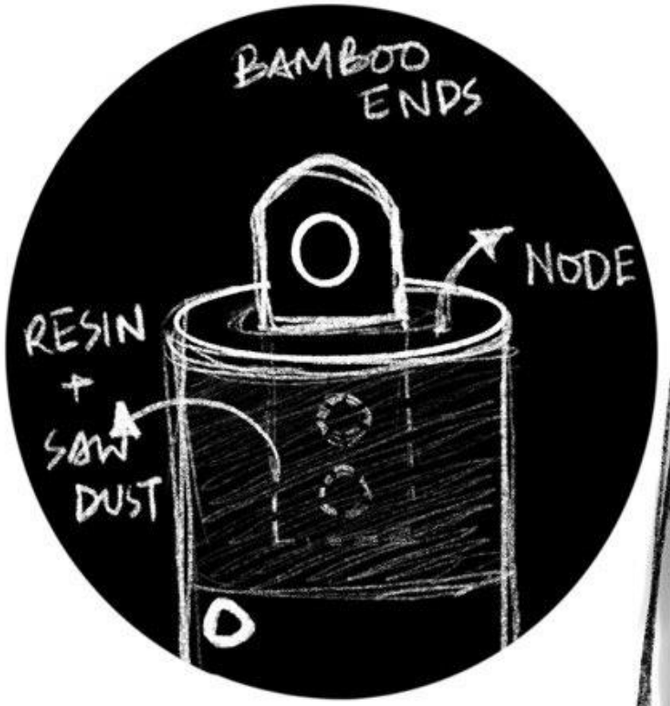


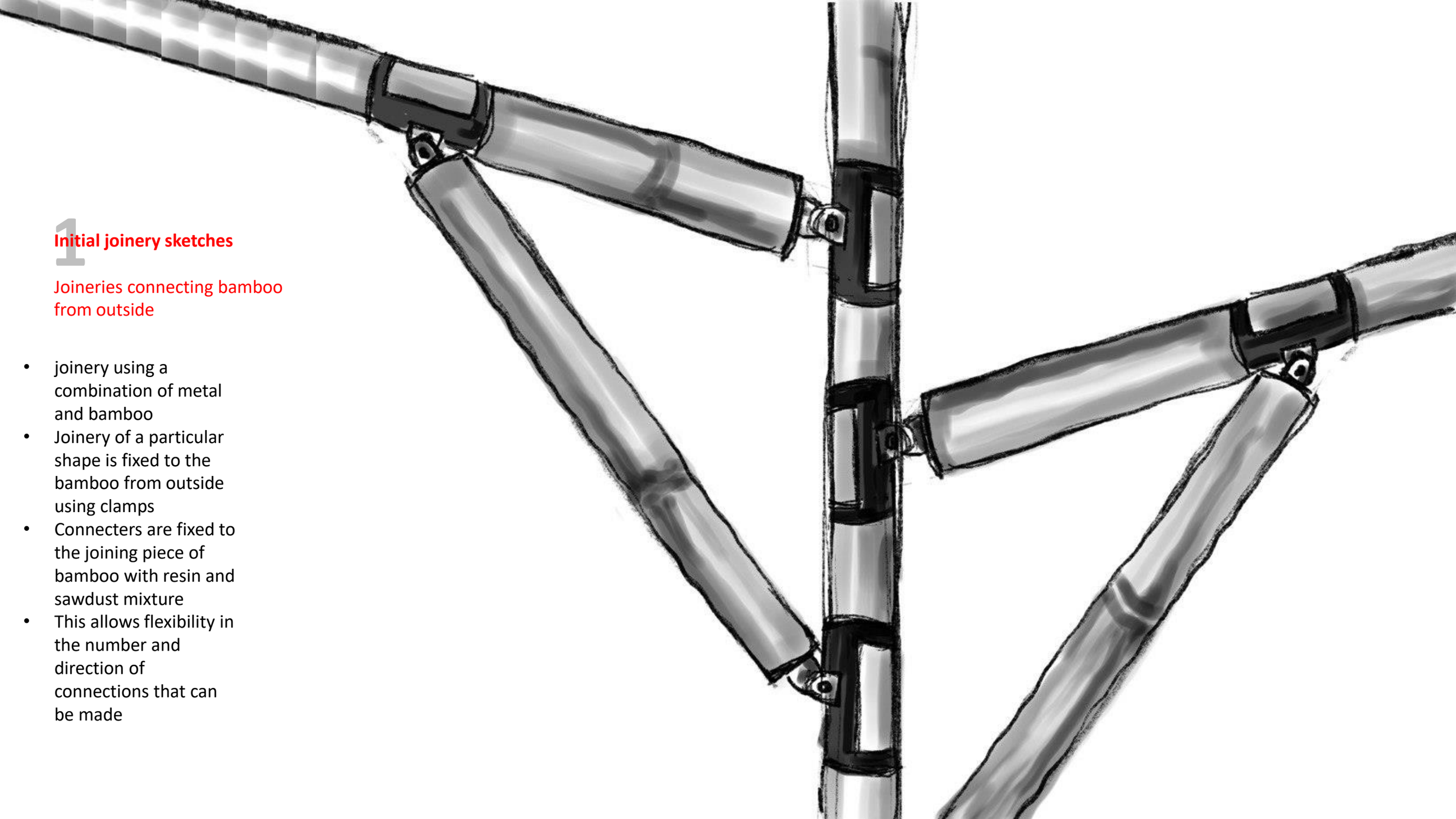


1 Initial joinery sketches

Joineries connecting bamboo from outside

- joinery using a combination of metal and bamboo
- Joinery of a particular shape is fixed to the bamboo from outside using clamps
- Connecters are fixed to the joining piece of bamboo with resin and sawdust mixture
- This allows flexibility in the number and direction of connections that can be made





1

Initial joinery sketches

Joineries connecting bamboo from outside

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- This allows flexibility in the number and direction of connections that can be made

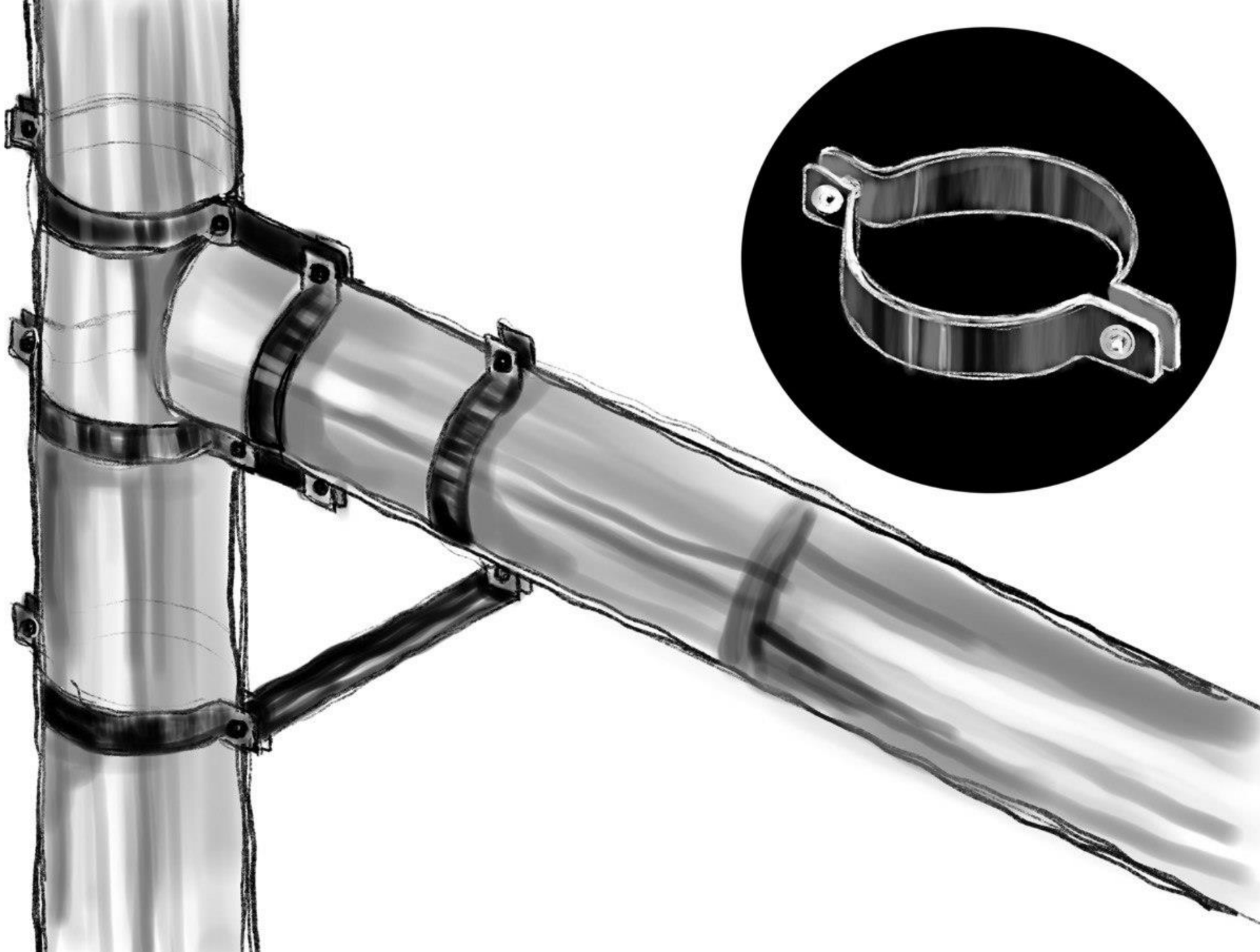


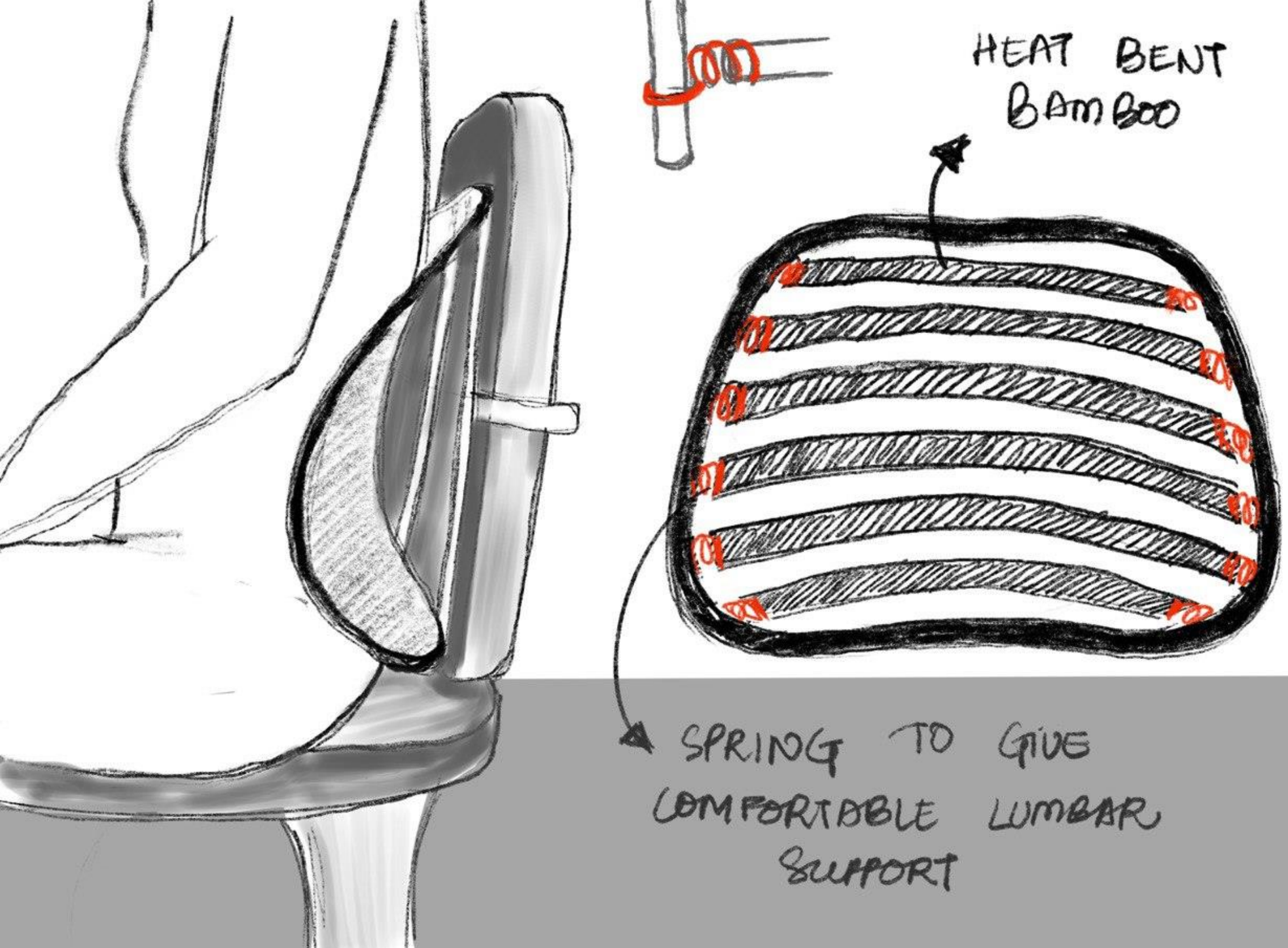
2

Initial joinery sketches

Joineries connecting bamboo from outside

- joinery using a combination of metal and bamboo
- Metal clams and bars are used as connectors
- This joinery allows connections multiple number of ways





3 Initial joinery sketches

Joineries connecting bamboo with spring

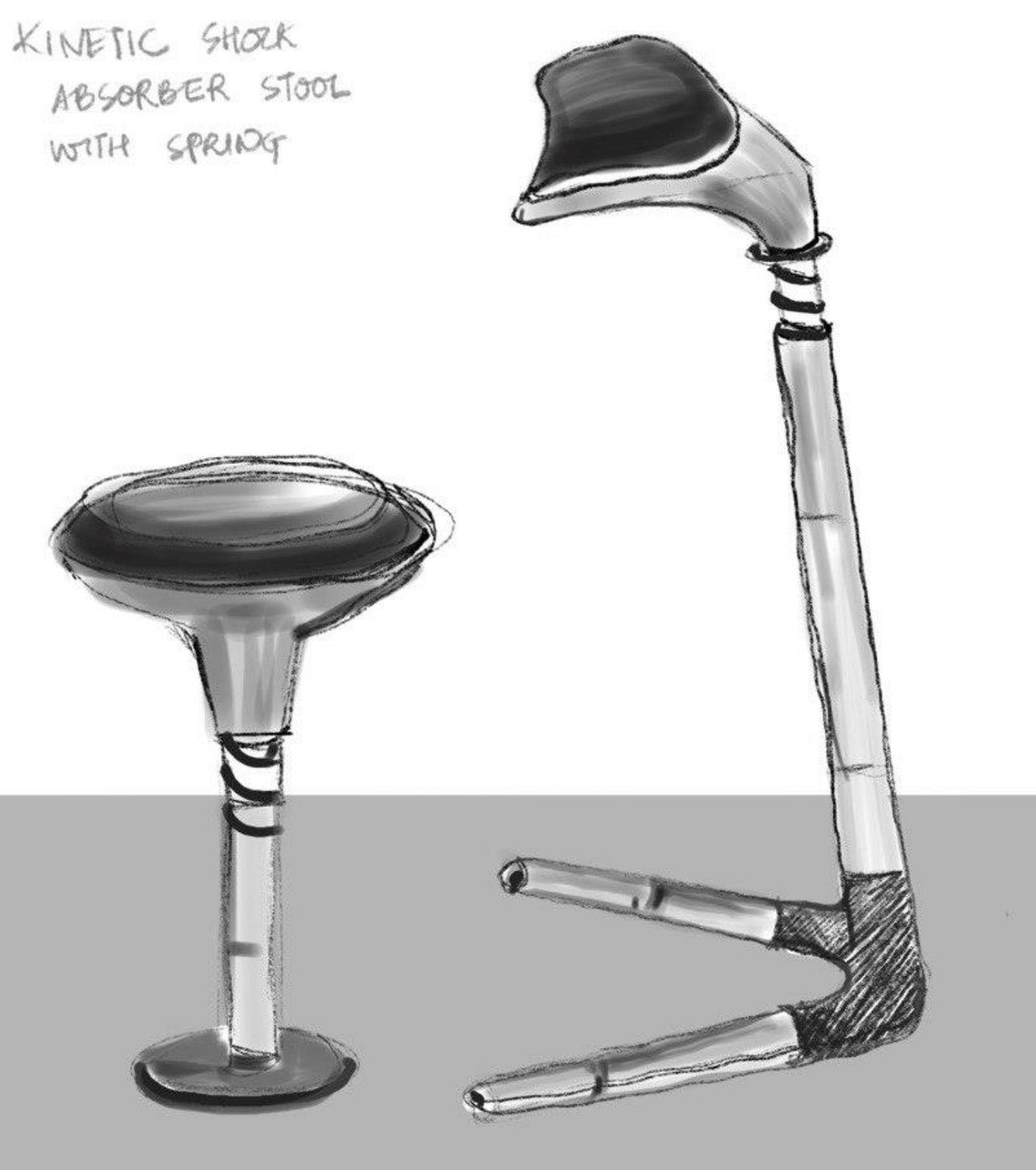
- joinery using a combination of metal spring and bamboo
- The elastic property of bamboo helps in giving a comfortable lumbar support

3

Initial joinery sketches

Joineries connecting bamboo with spring

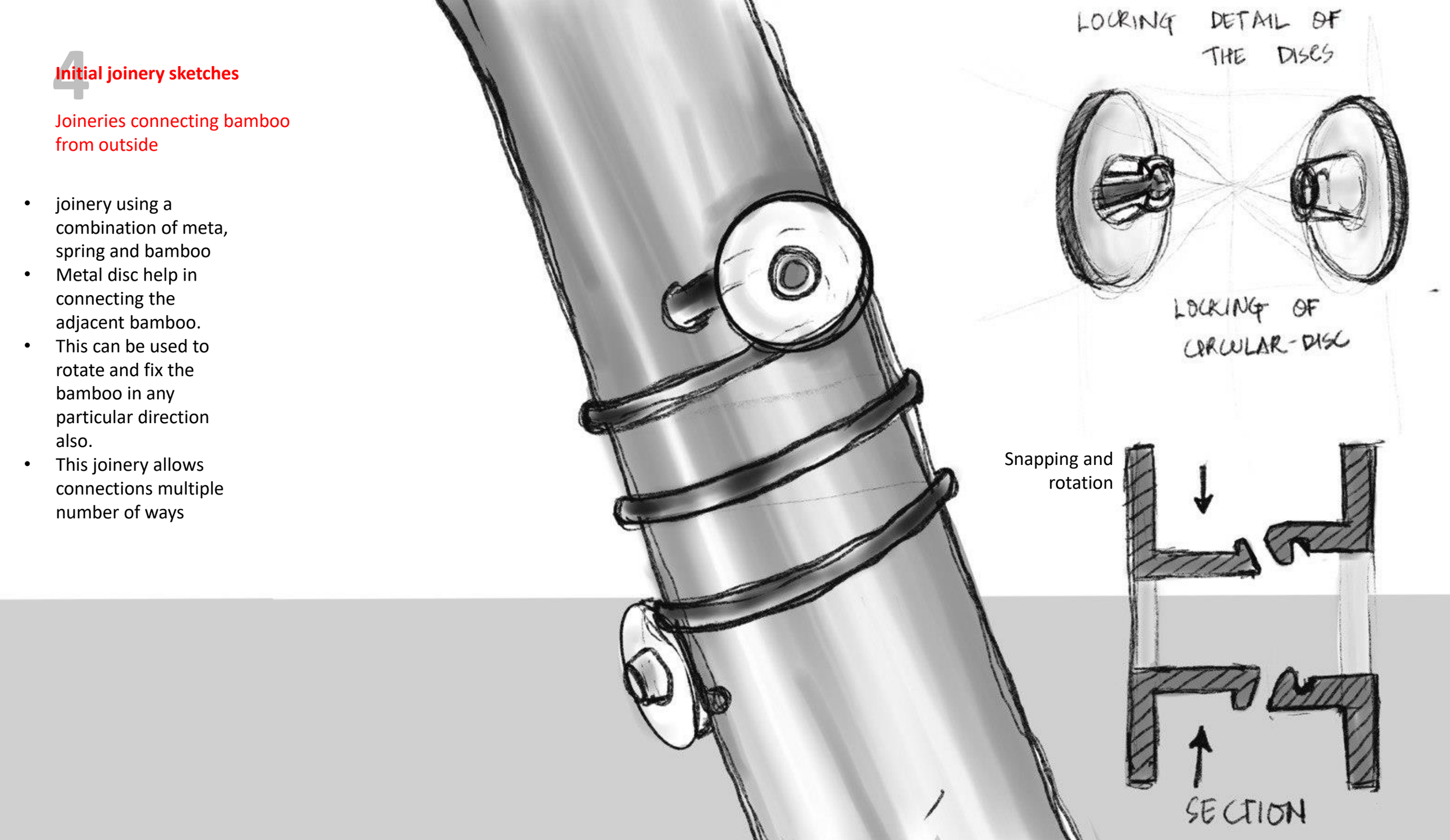
- joinery using a combination of metal spring and bamboo
- The elastic property of bamboo helps in giving a comfortable cushioning effect for seats.

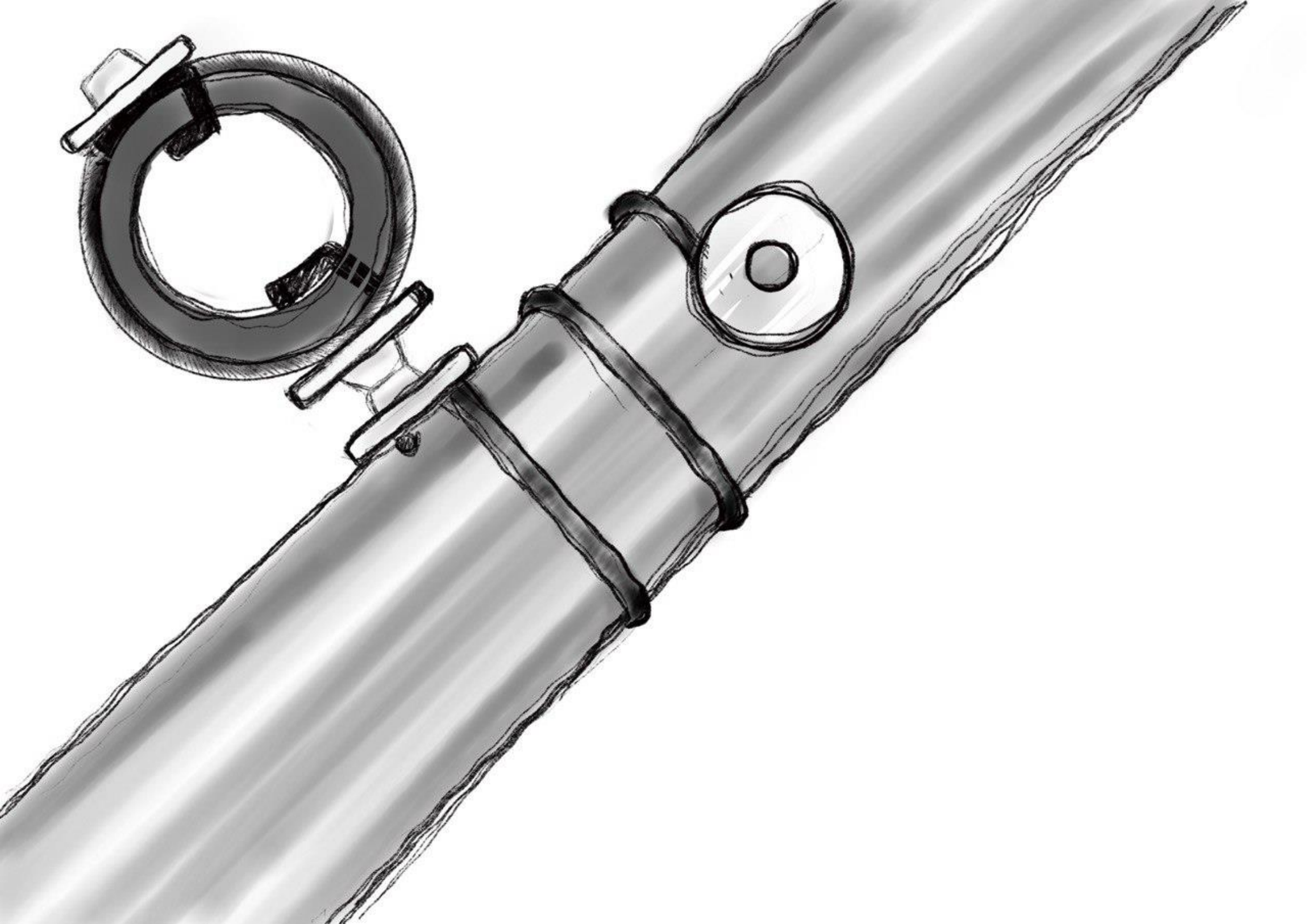


4 Initial joinery sketches

Joineries connecting bamboo from outside

- joinery using a combination of meta, spring and bamboo
- Metal disc help in connecting the adjacent bamboo.
- This can be used to rotate and fix the bamboo in any particular direction also.
- This joinery allows connections multiple number of ways





4 Initial joinery sketches

Joineries connecting bamboo from outside

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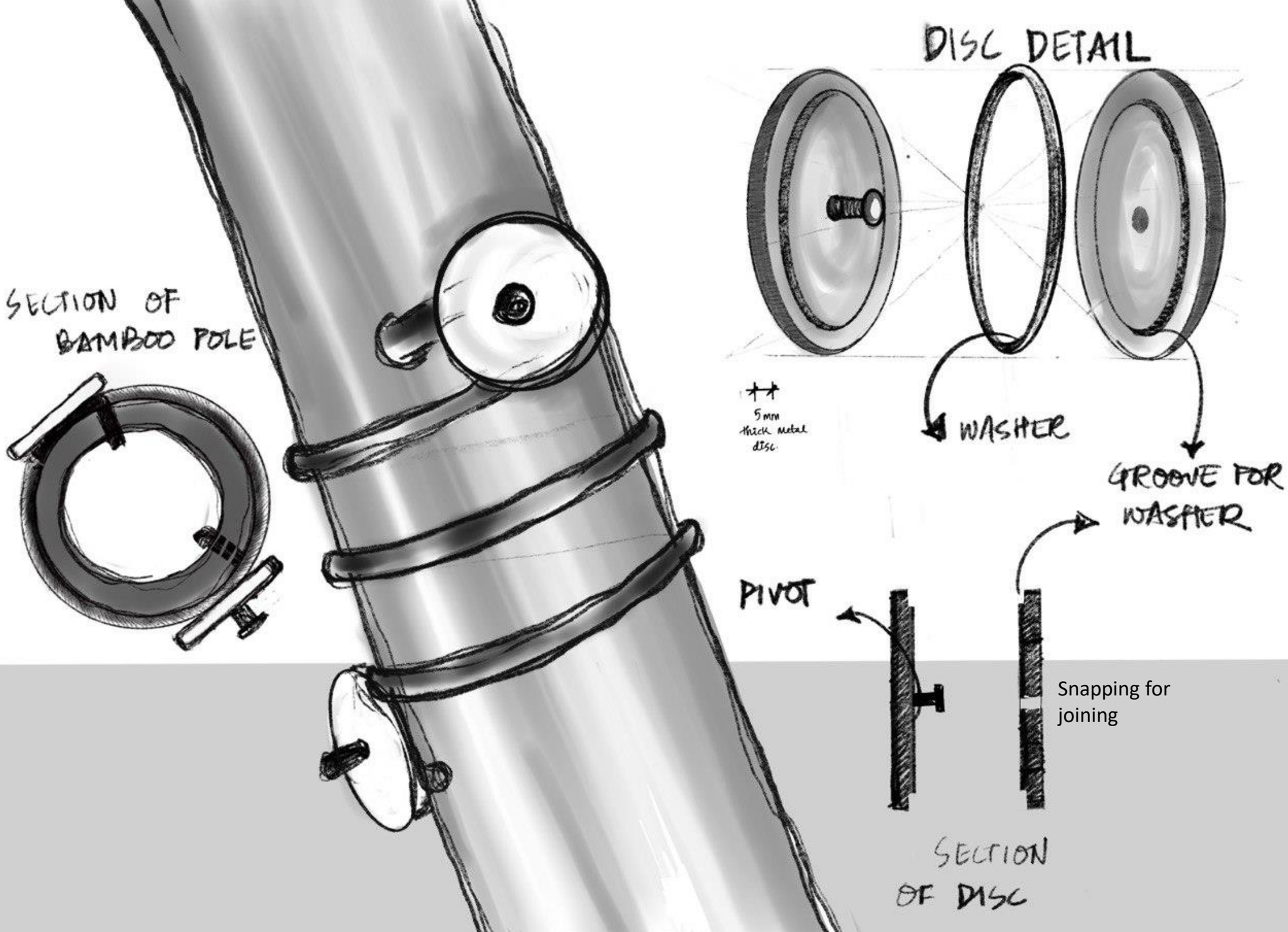
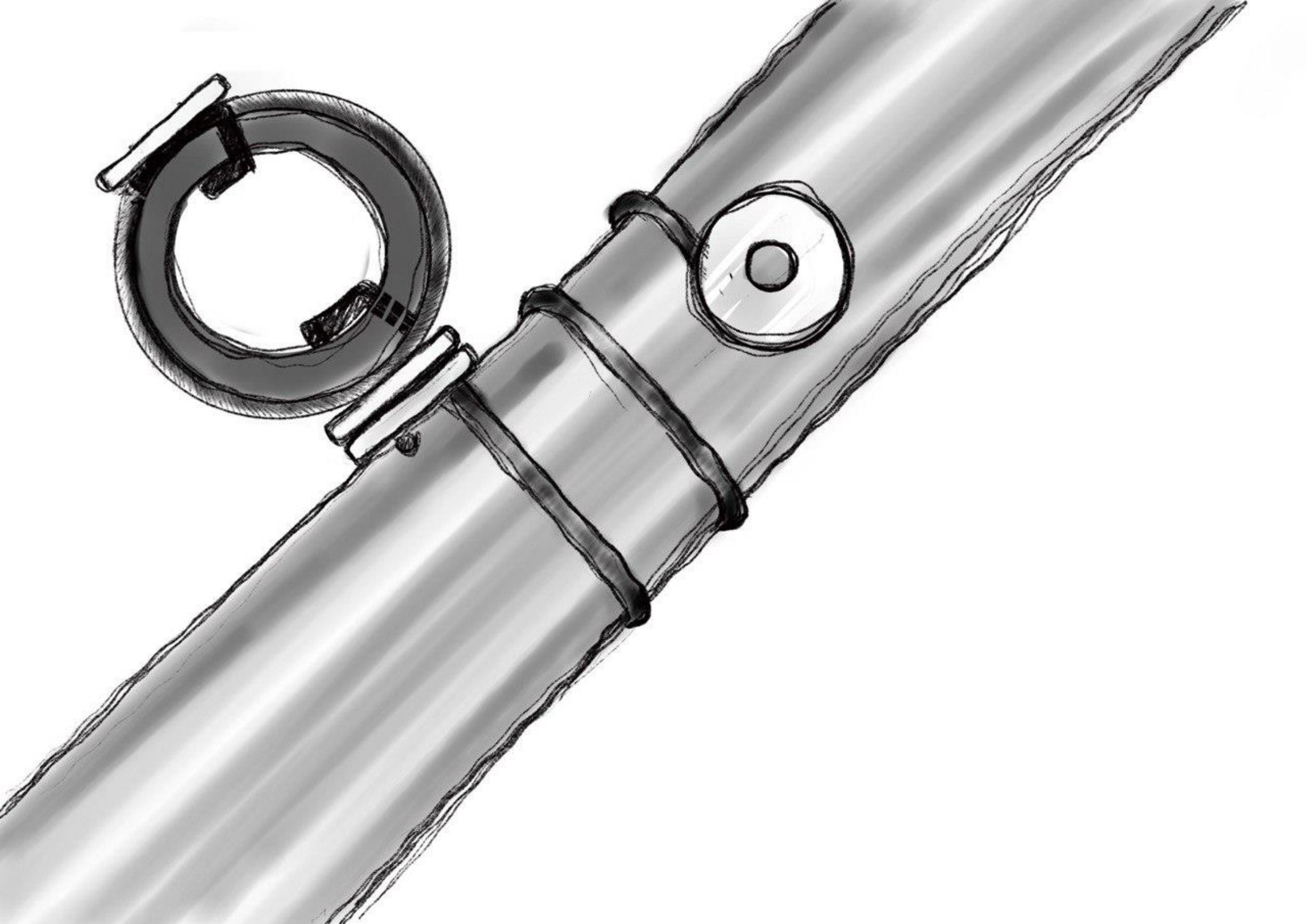


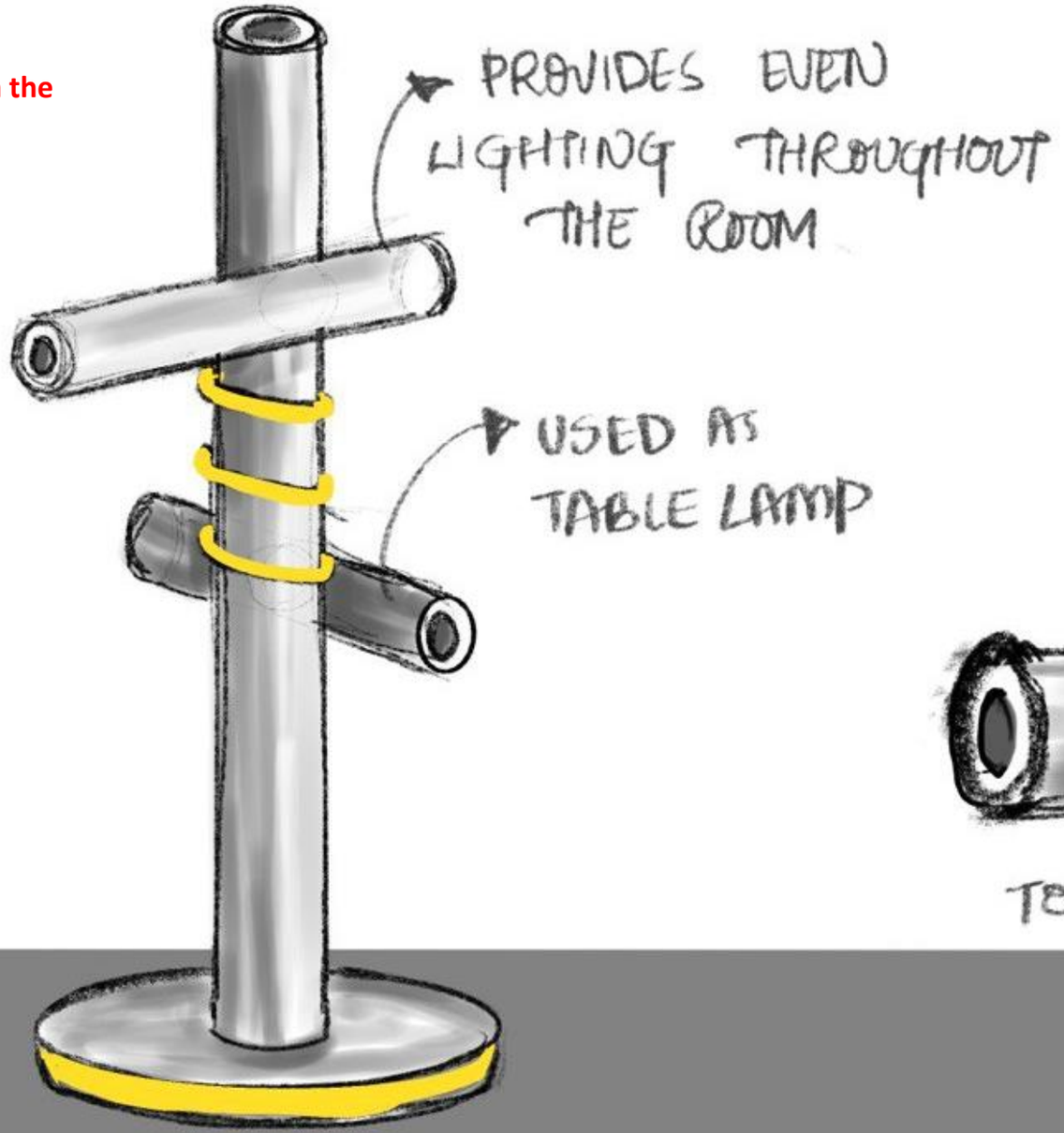


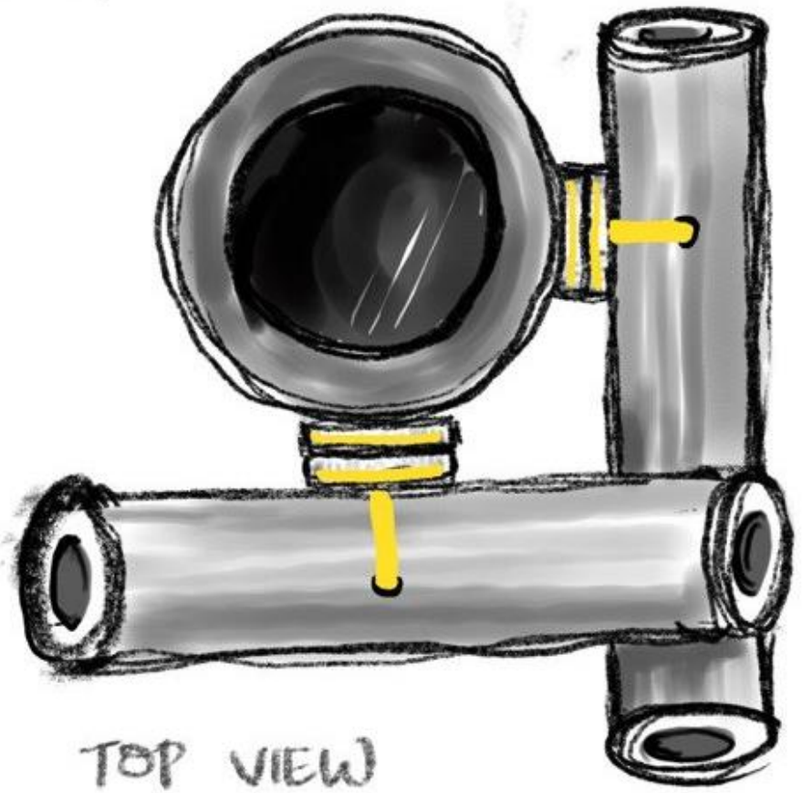
Mock-up model

Mock-up model

Product Developed with the above joinery

Lampshade

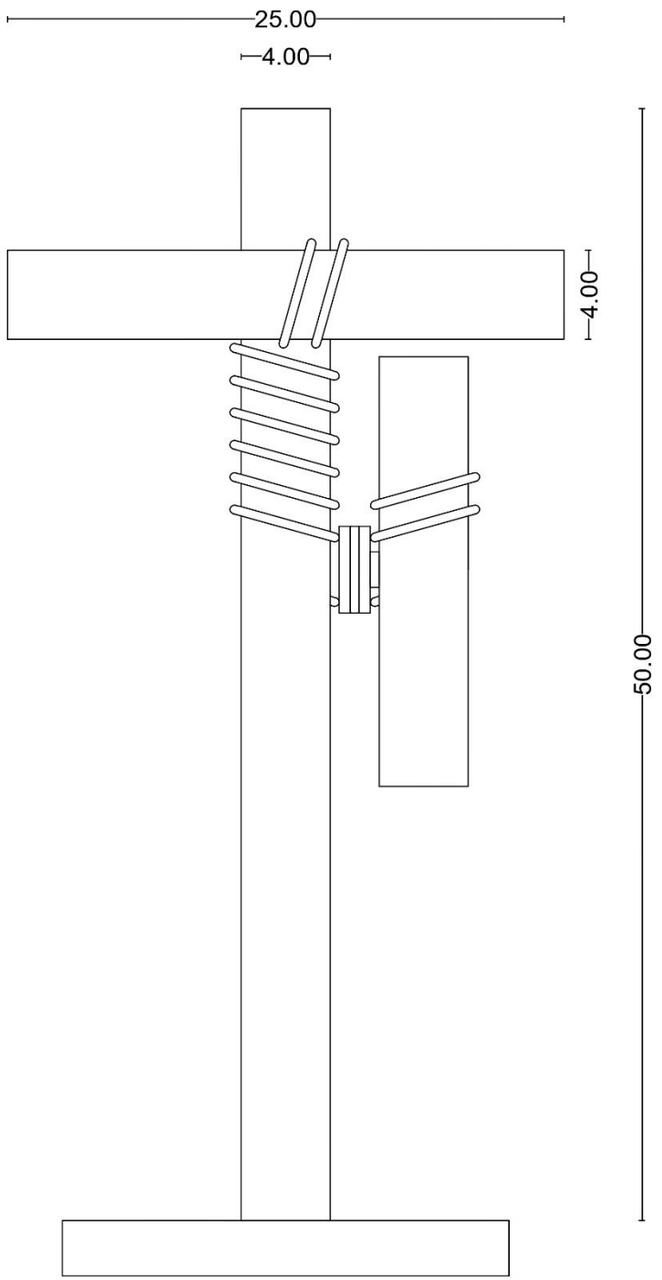




Product Developed with the above joinery

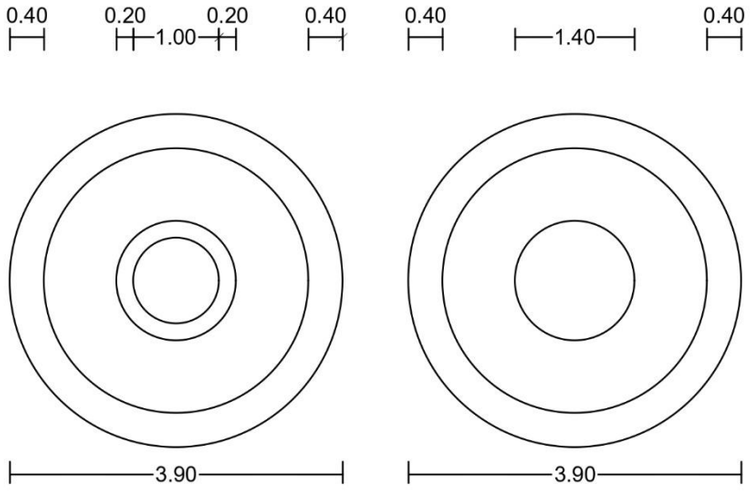
Lampshade dimension drawing

- Thickness of the spring – 4mm
- Number of LED – 3 nos



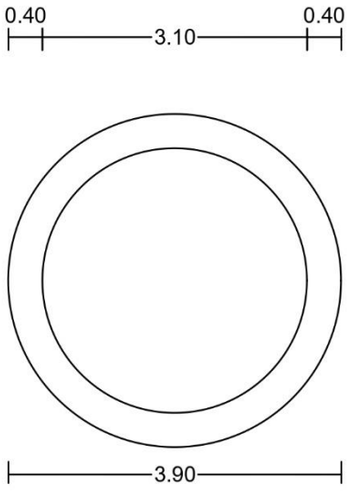
Product Developed with the above joinery

Lampshade dimension drawing

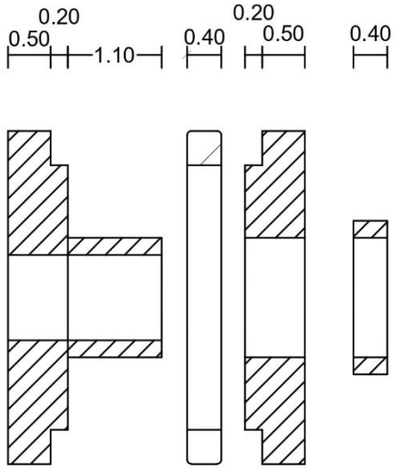


METAL DISC 1
FROM INSIDE

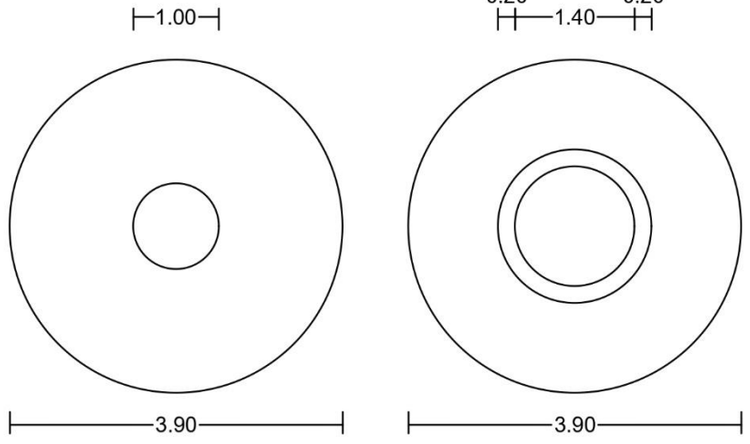
METAL DISC 2
FROM INSIDE



WASHER

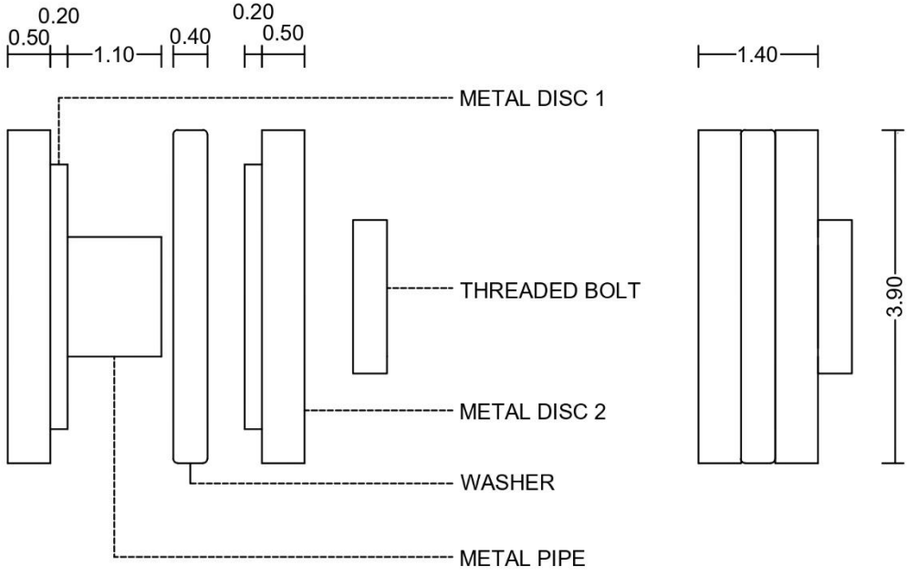


SECTION



METAL DISC 1
FROM OUTSIDE

METAL DISC 2
FROM OUTSIDE



Renders of Lampshade

Lampshade joinery
Prototype

Process of making the final product

final product

final product

final product

Thank you