Fundamental limitations of the Mechanical Guidewires in CTO-PCI

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limitations of mechanical GW

- Whipping; we can not completely control the direction of GW tip.
- We can not predict and control how GW tip will be deflected.
- We can not deflect GW tip in a space: semilunar space and CTO entry.
- Limitation of wire penetration force; we can not penetrate an extremely hard tissue such as high dense fibrous plaque and calcification.

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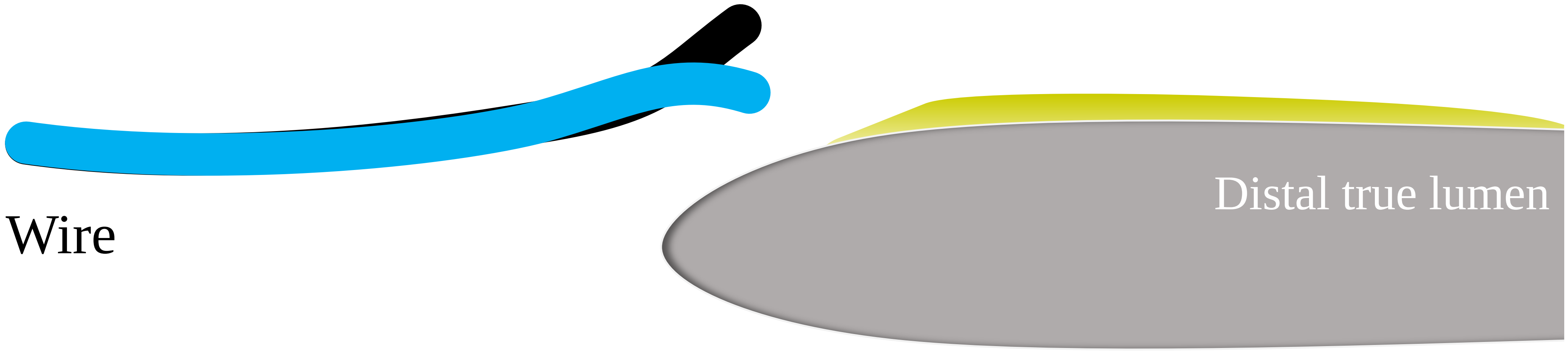
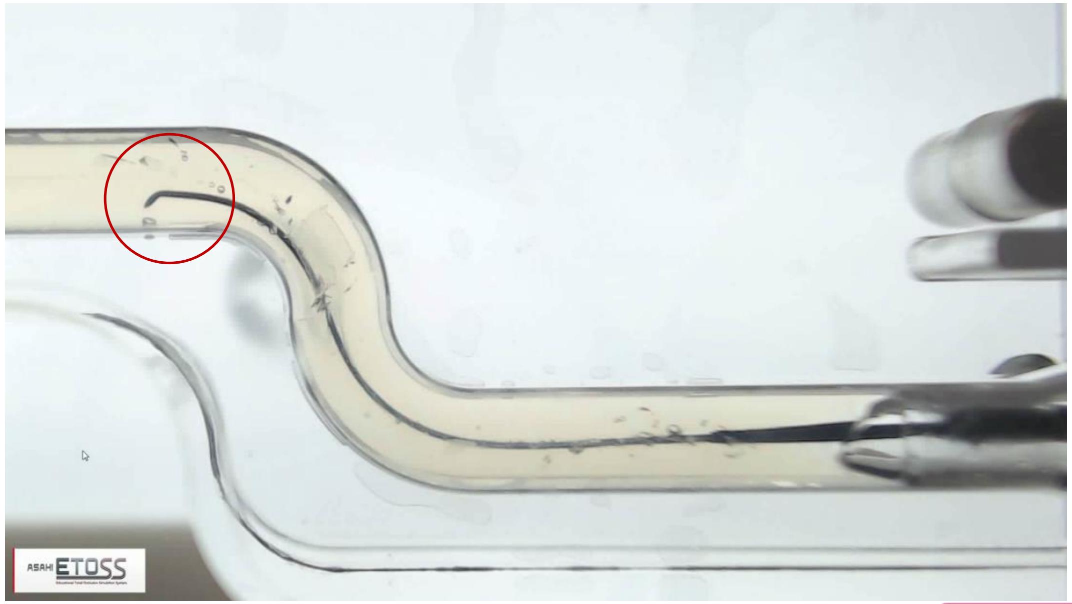
Whipping; we can not brake the rotating GW tip at the appropriate direction.

GW tip is overrotated by whipping.

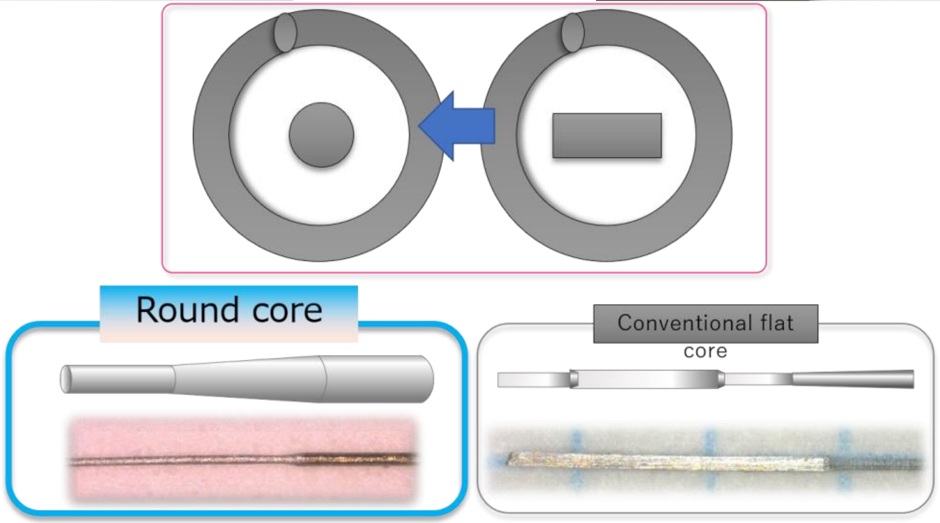


Round core is advantageous over flat core.

Gaia Next 2 with round core



Miracle 6 with flat core



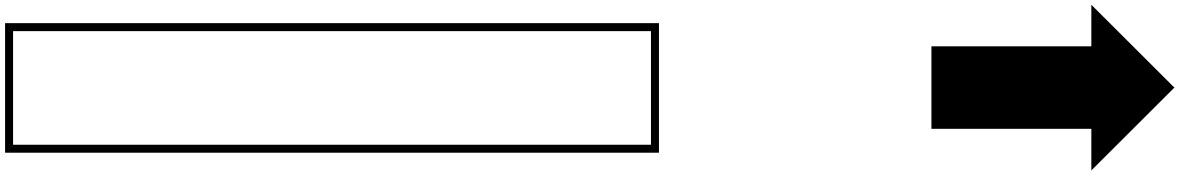
The other reason for whipping is bending moment at GW shaft and tip curve.

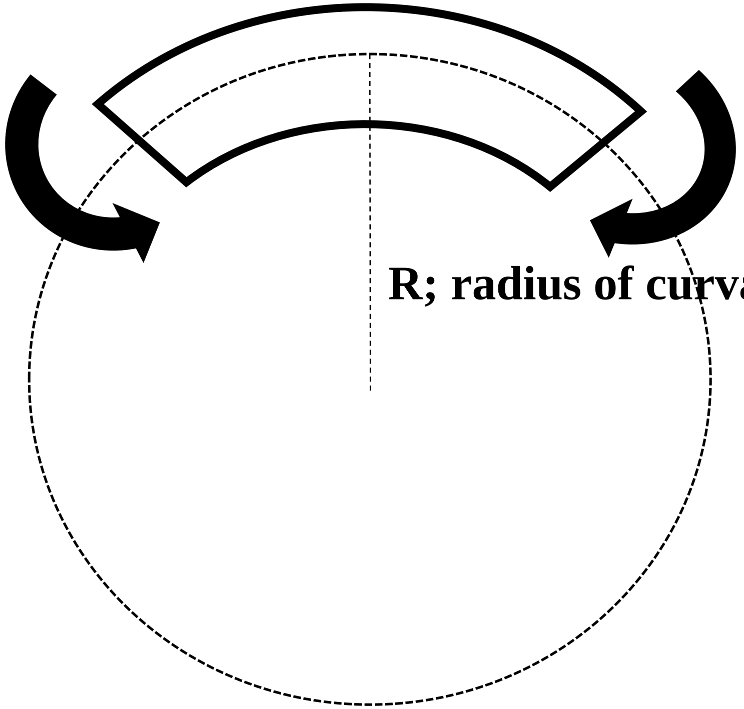
Bend at GW shaft and tip curve generate bending moment that results in whipping motion.

Even using same GW, if no bend, whipping does not occur.

Bending moment is a kind of internal stress which is generated when straight wire is bent into an arc.

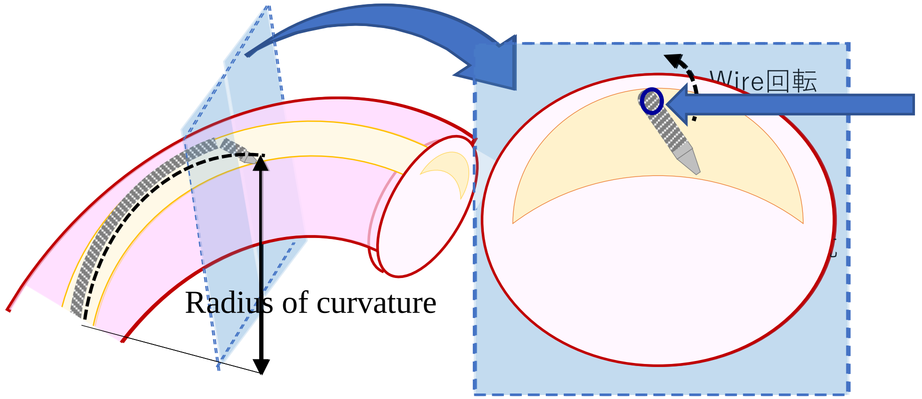
Bending moment (M)
= flexural rigidity(EI) /radius of curvature (R)



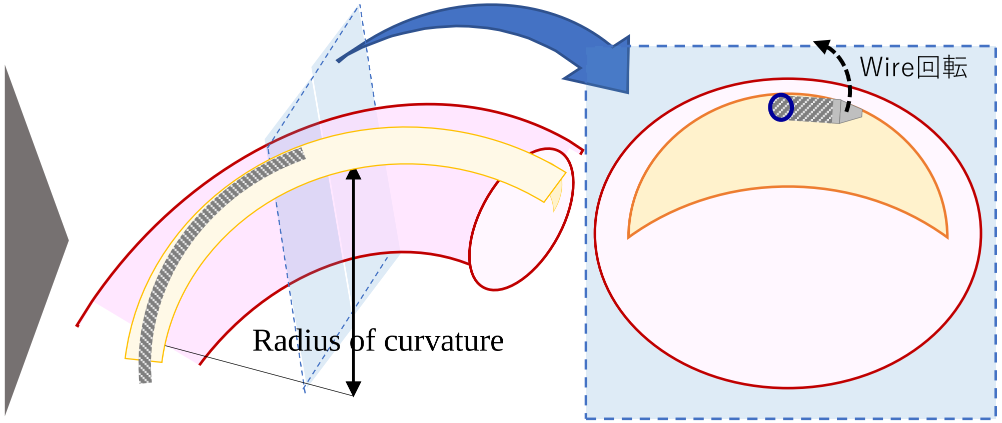


The higher the rigidity is, and the smaller the radius is, the larger internal stress (i.e. bending moment) will be.

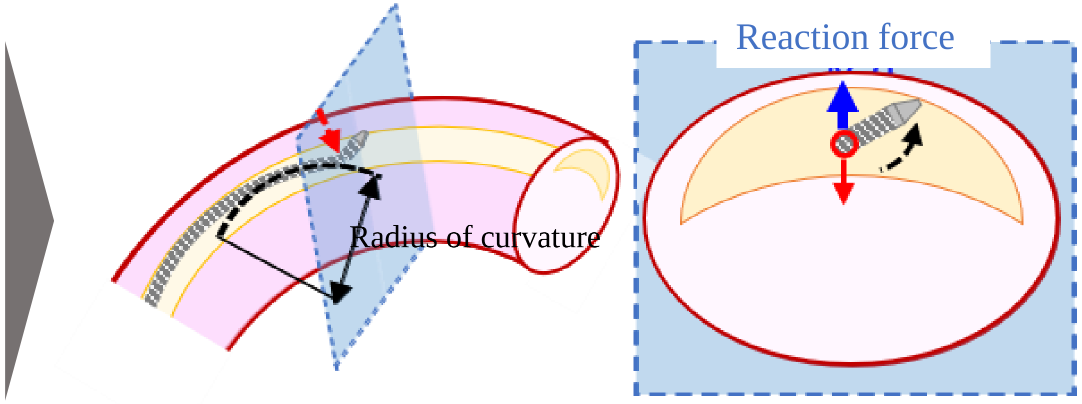
When we rotate GW…



Initially, the center of rotation does not move.

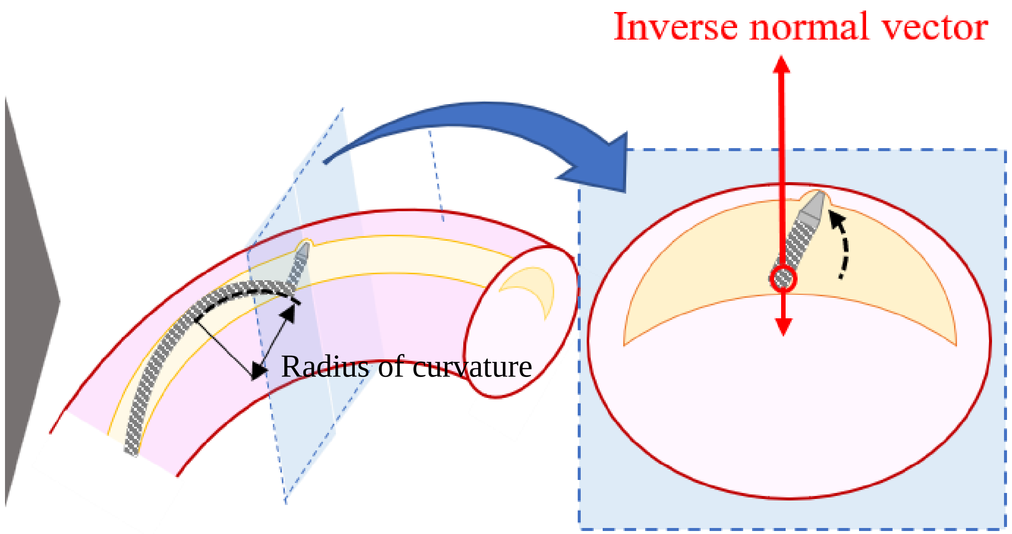


Radius of curvature is constant until the wire tip is at this position, therefore, bending moment is constant as well.



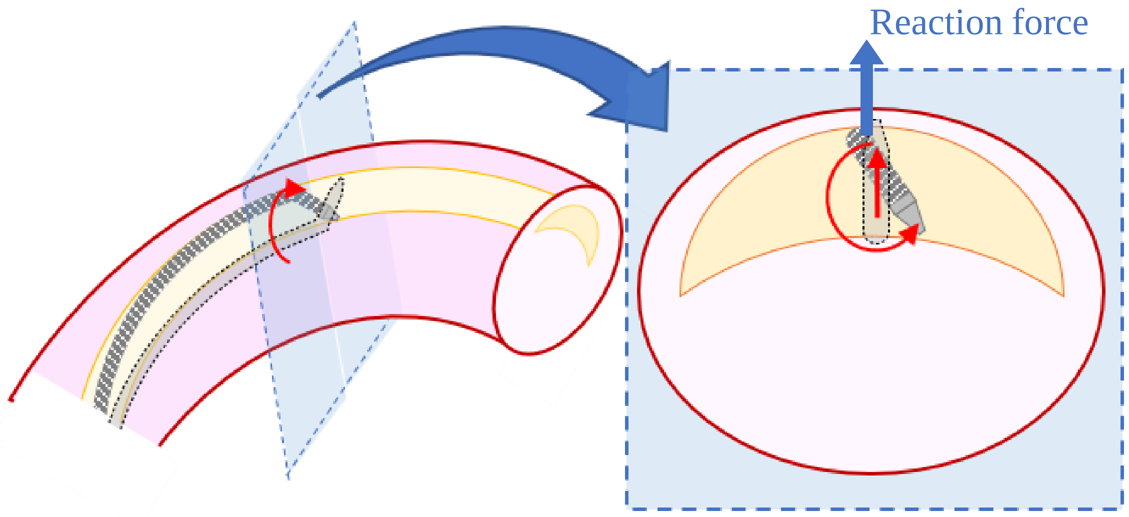
1. Radius of curvature decreases because the center of rotation moves downward, therefore both bending moment and its reaction force increase.

2. Reaction force starts to act as a resistance; a ‘brake’ for GW tip rotation.



As radius of curvature decreases, both bending moment and its reaction force continues to increase…

until the GW tip is directed to the inverse normal vector.



Whipping!

Just after GW tip passed through the direction of the inverse normal vector direction, reaction force suddenly starts to act as an 'accel'.

Summary; Conceptual schema

Specific point of whipping;
Inverse normal vector

At the direction of inverse normal vector, a 'brake' suddenly changes into an 'accel' and torque force released.

Accel

This gap depends on bending moment.

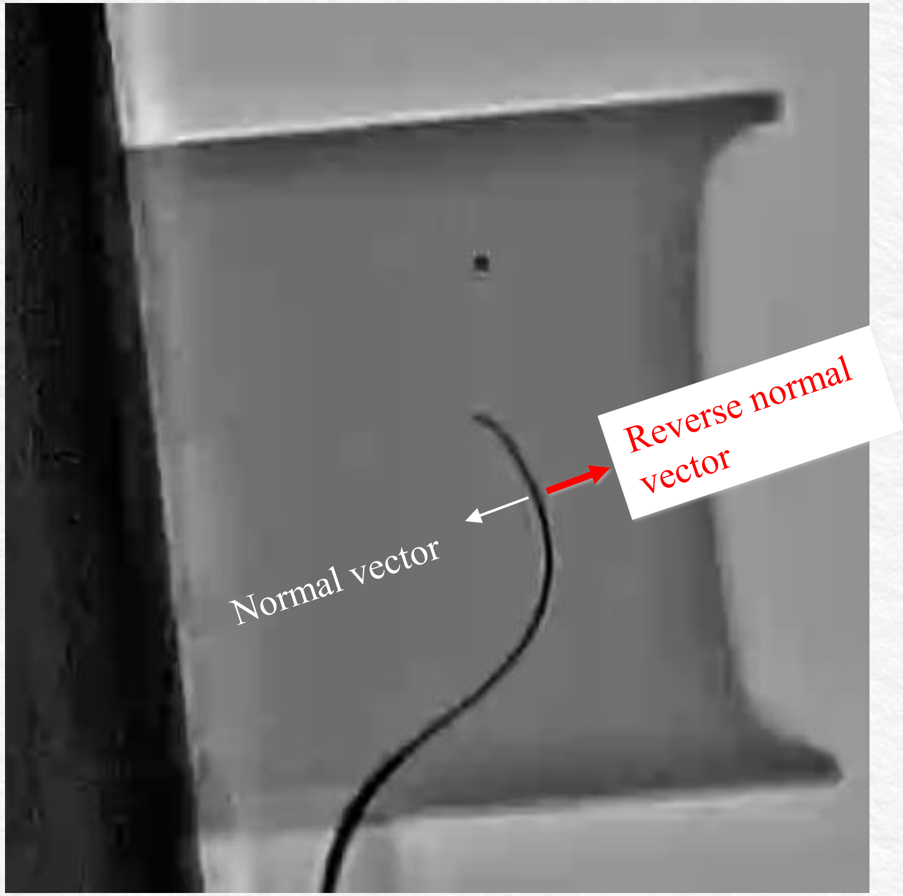
GW tip rotation

Again, bending moment = EI(wire rigidity)/R(radius of curvature).
The higher GW shaft rigidity is and the smaller the radius of curvature is, the gap is larger and GW easily whipped.

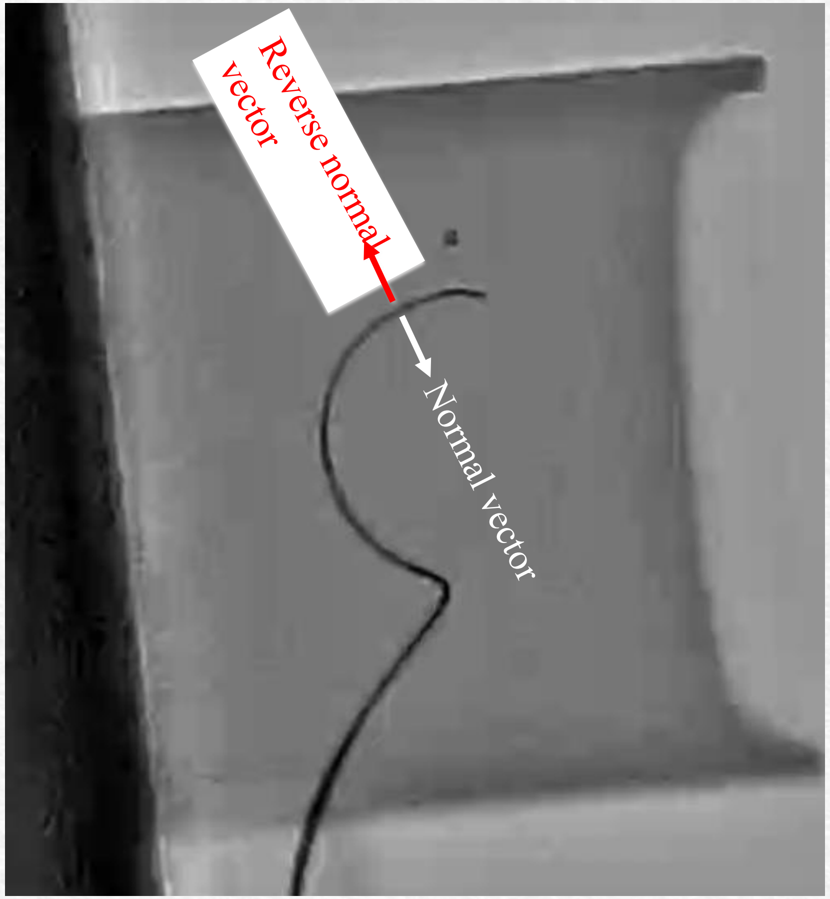
Brake

Whipping occurs at the direction of reverse normal vector.

2-dementional shaft curve



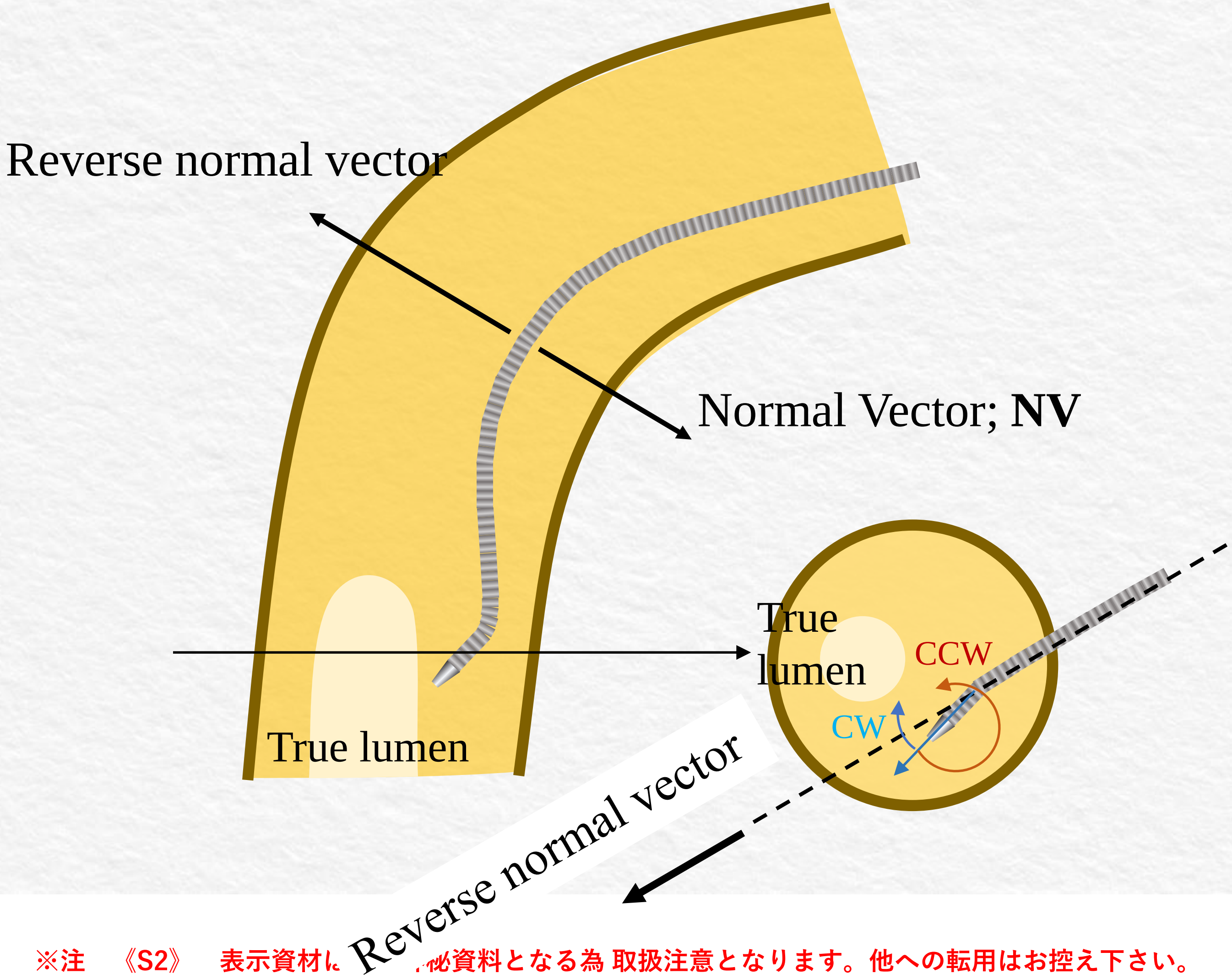
3-dementional shaft curve



Model
Cubic ETOSS

Guide Wire
Conquest Pro 12

Management of whipping



Because of shaft curve just proximal to GW tip, we can predict that whipping motion will easily occur.

Which is better to rotate GW tip, CW or CCW?

CCW is the better.

Because CW rotated GW tip should be routed via the reverse normal vector before it is directed to the true lumen, and will result in whipping there.

Management of whipping

- To manage whipping, we should know the factors which relate whipping; radius of curvature, GW stiffness and specific point of whipping.

- When there is a possibility of whipping, we should judge which direction is better to rotate not to be routed via the specific point of whipping; reverse normal vector.

- We should identify the direction of both normal and reverse normal vectors angiographically.

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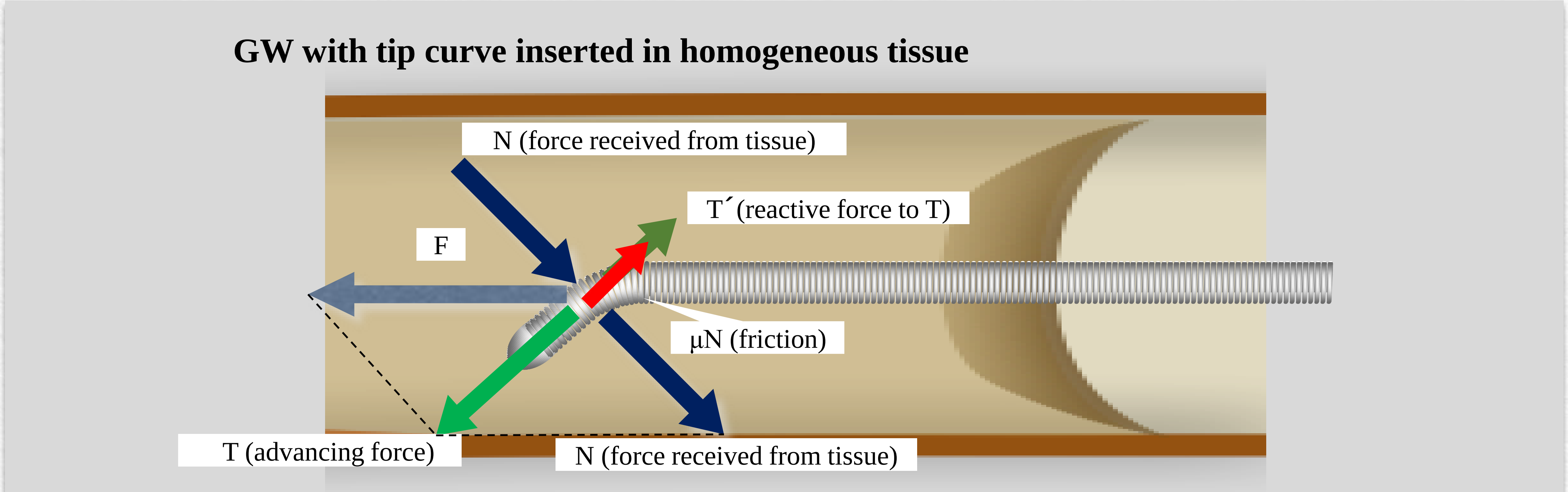
Tip Deflection

In a large space, tip deflection does not occur.



1.**F** is a force transmitted to GW tip when we push GW shaft.

2.GW is received **N** from solid tissue at its tip curve

3. **F** is redirected to **T** by **N**; Deflection.

4. As GW tip advances to the direction of **T**, **μ**N and **T**´ are generated.

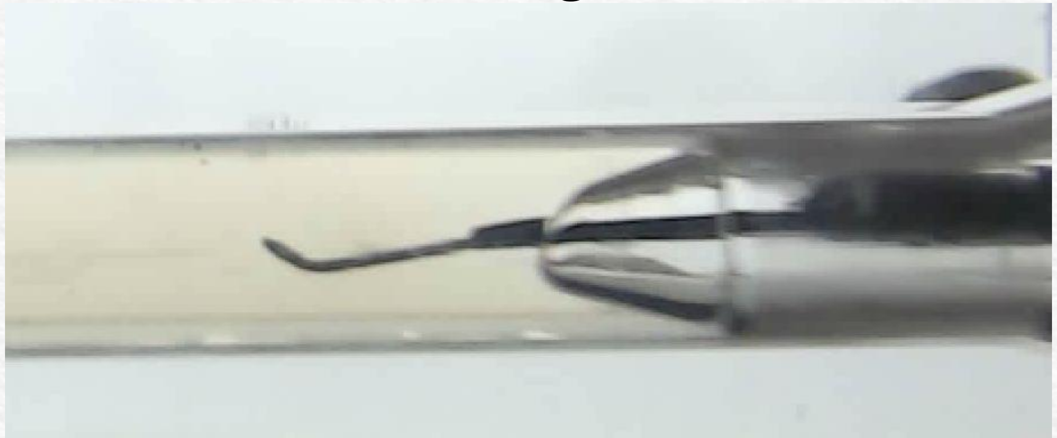
Tip Load affects how it is deflected.

ETOSS 8000

Conquest Pro 12 〈12.0gf〉

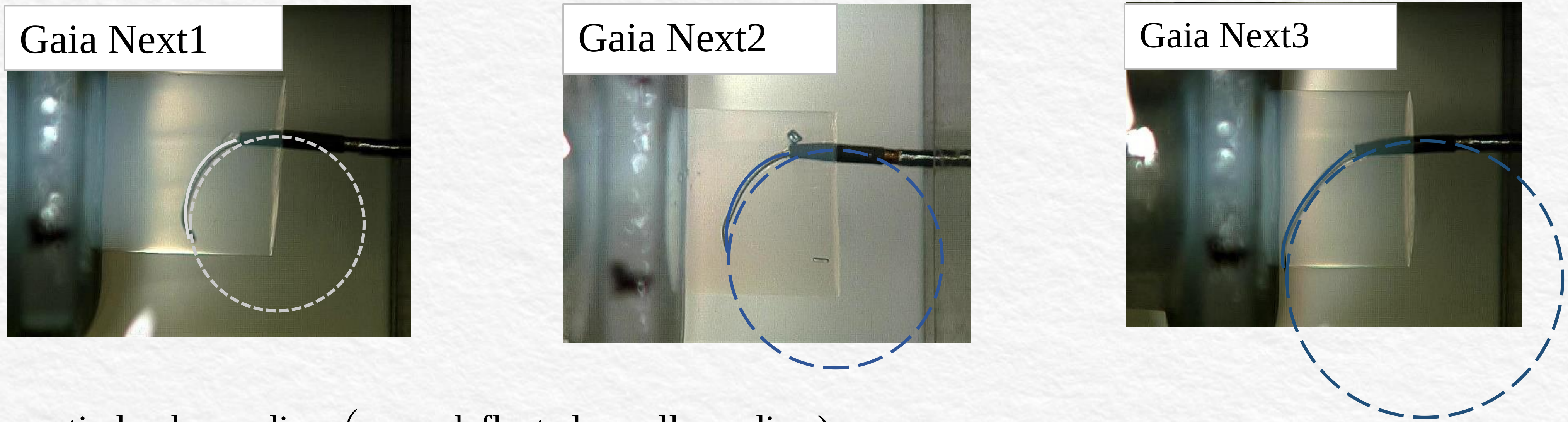
Conquest Pro 12 with higher tip load tends to advanced straight.

Gaia Next 1 〈2.0gf〉

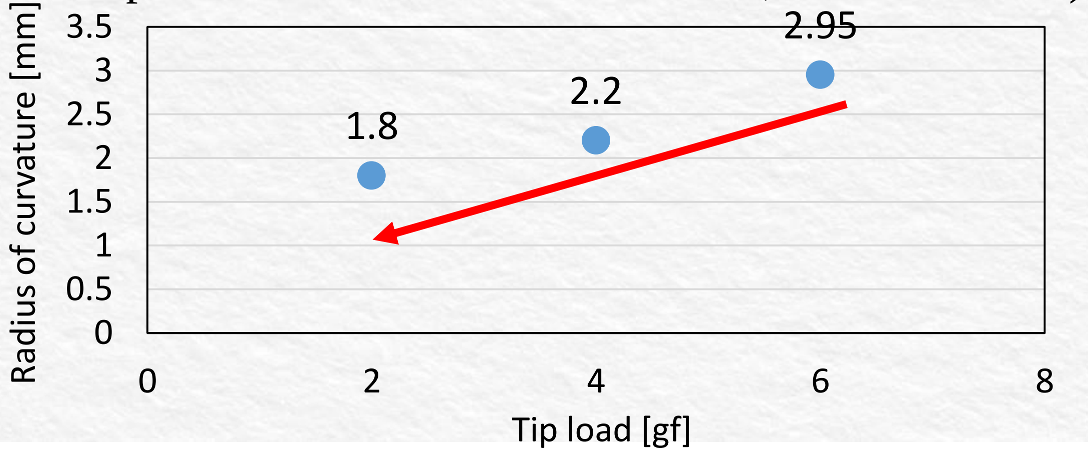


Gaia Next 1 with lower tip load tends to be deflected.

Correlation between tip Load and deflection



tip load vs radius（more deflected, smaller radius)



The smaller tip load, the more tip deflection.

Tip Length affects how it is deflected, as well.

Miracle 6 〈1mm 45° 〉

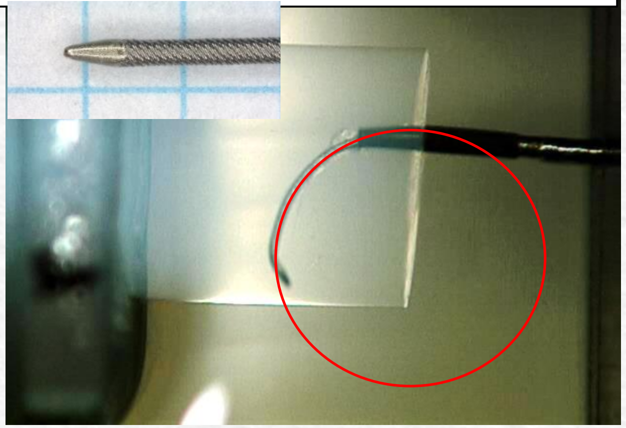
Miracle12 with shorter tip length tends to be less deflected.

Miracle 6 〈2mm 45° 〉

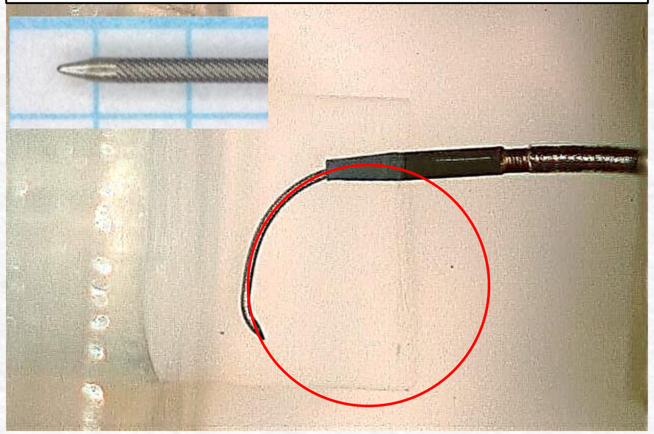
Miracle12 with longer tip length tends to be more deflected.

Tip diameter also affects how it deflected.

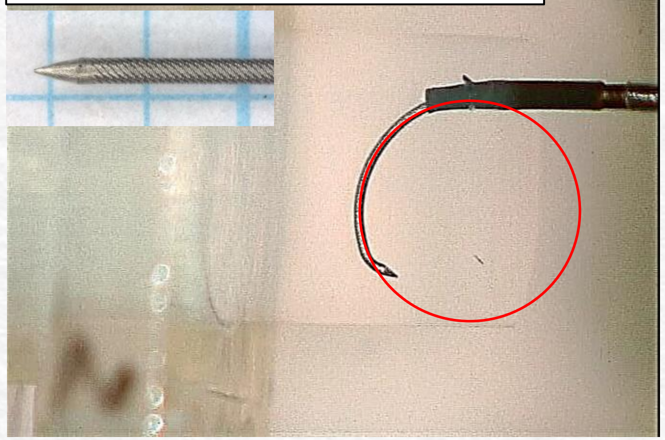
① Normal Gaia Next1 / 0.141mm



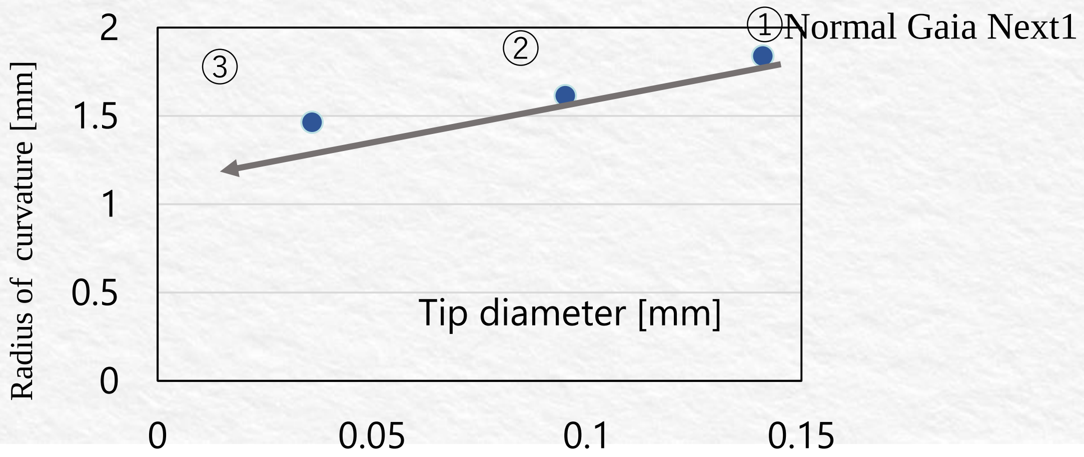
② Gaia Next 1 with 0.095mm tip



③ Gaia Next1 with 0.036mm tip



Diameter vs とTip Deflection



The smaller tip diameter, the more tip deflection.

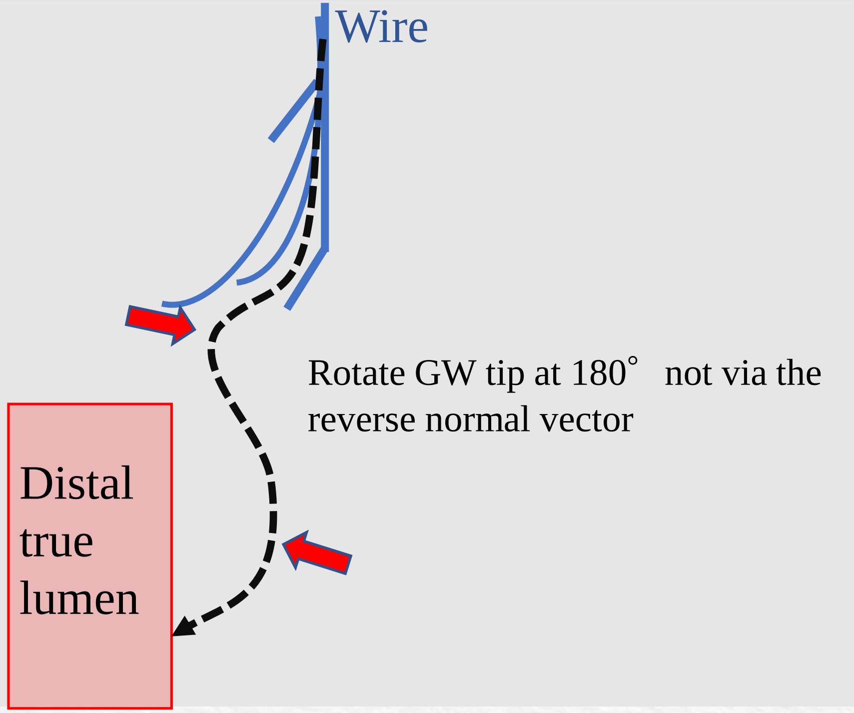
Various factors affect tip deflection.

Lesion associated	Tissue hardness
	Tissue homogeneity
	Semilunar space
GW associated	Tip curve
	Penetration efficiency; tip diameter, tip load, coating
	Rigidity gap at GW tip
	Shaft rigidity

It is extremely difficult to predict and control how GW tip deflects.

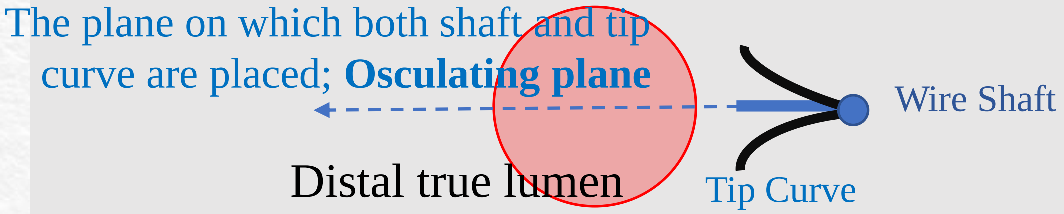
GW manipulation utilizing tip deflection

GW tends to advance in a zig-zag route, because we can not precisely predict how tip will be deflected therefore should repeatedly rotate GW **at 180°** .



As long as GW penetration works, the direction of tip deflection is limited on the osculating plane on which both GW shaft and tip curve are placed as well.

In contrast, when we apply a torque to GW to rotate it and GW tip escapes from the plane, it would be impossible to predict where GW tip to be deflected.



To control CTO wire, we should be familiar with both mechanism of tip deflection and basics of geometry concerning a 3-dementional space curve.

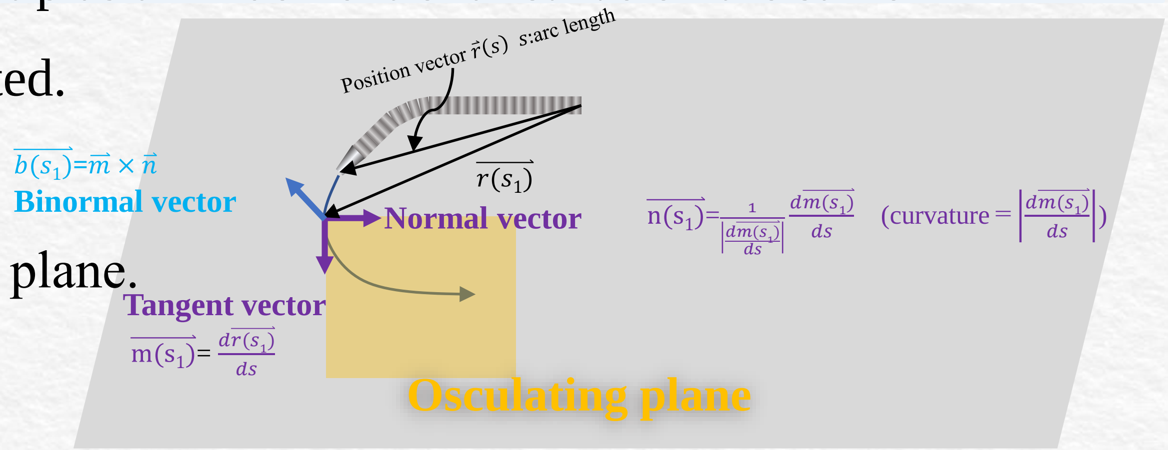
The principle of wire control utilizing tip deflection

The plane on which both GW tip curve and shaft are placed is identical to the osculating plane which is spanned by tangent vector and normal vector.

Therefore, without applying torque to GW, its tracking route will be constantly placed on the same plane: tip curve does not escape from the plane.

It means that we can strictly limit the tracking curve of GW tip as an 2-dementional curve on the same osculating plane even if unexpected tip deflection is generated.

‘Penetration plane (PP)’ is synonymous with this osculating plane.



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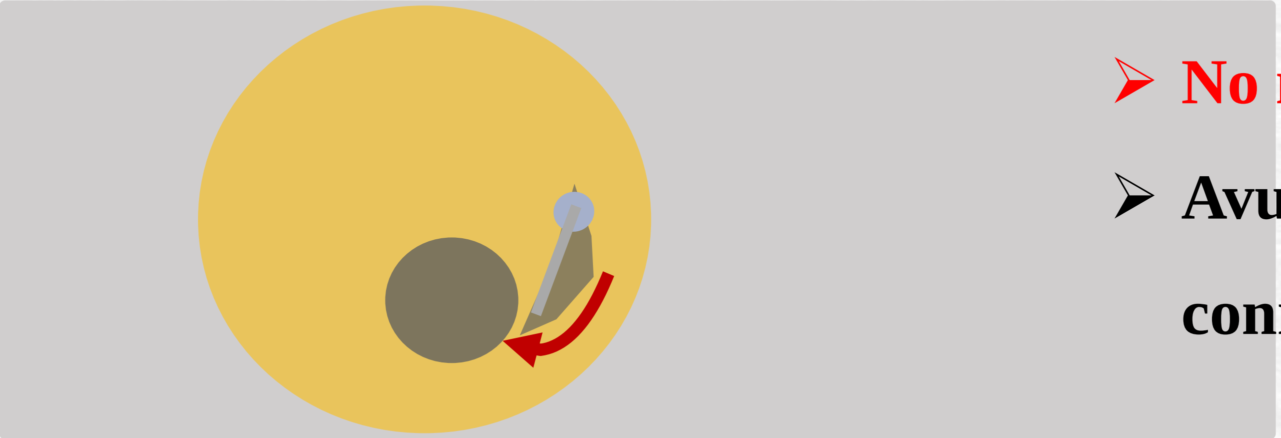
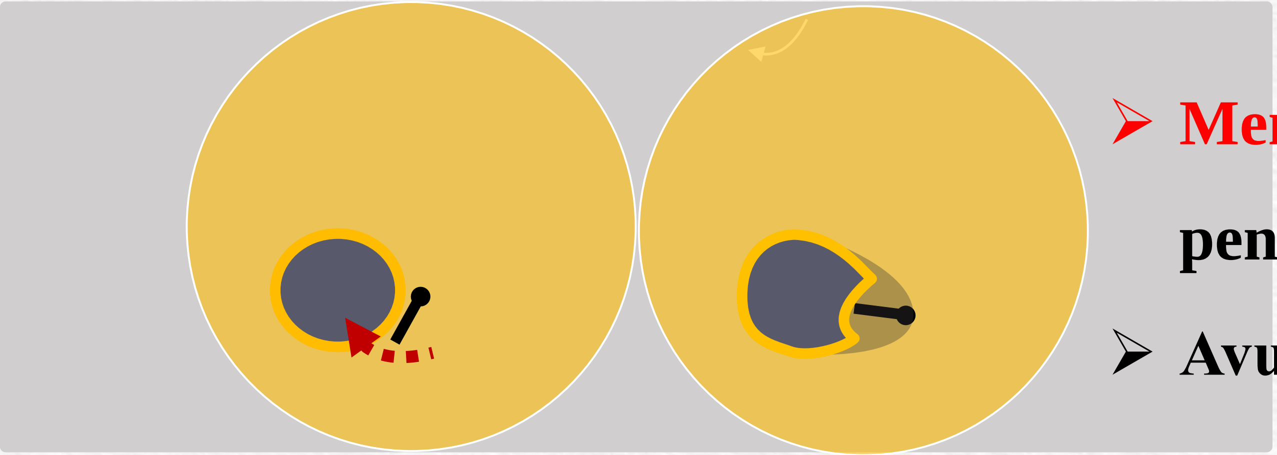
Difference between avulsion and penetration



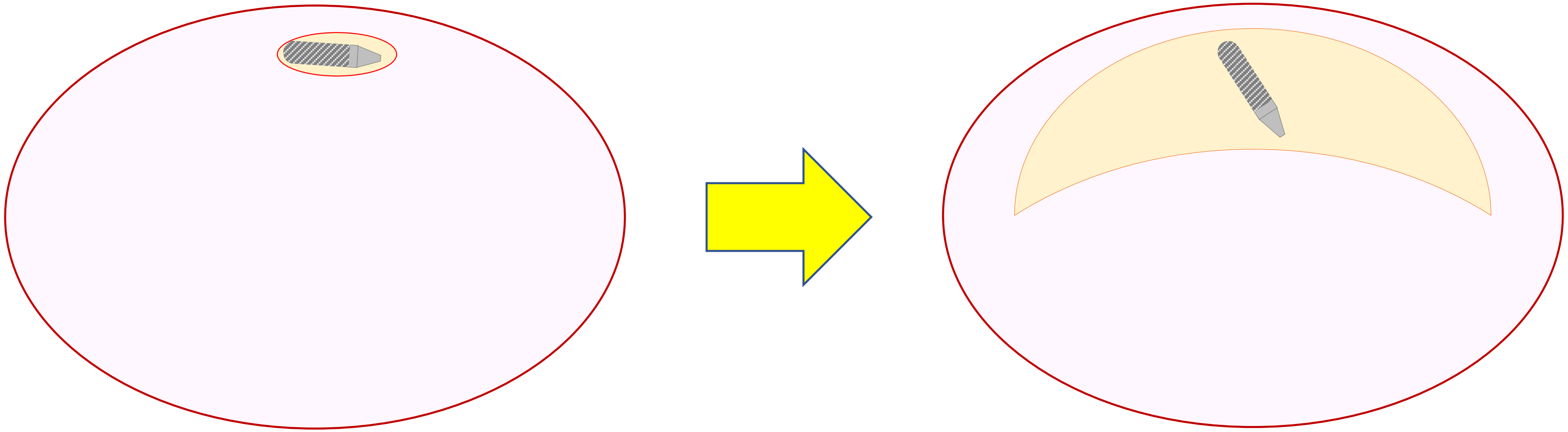
- **No membrane** ➡ **No need for penetration**
- **Avulsion by rotation of GW can make connection to the distal true lumen.**



- **Membrane (layered structure)** ➡ **Need for penetration**
- **Avulsion by rotation of GW doesn't work.**

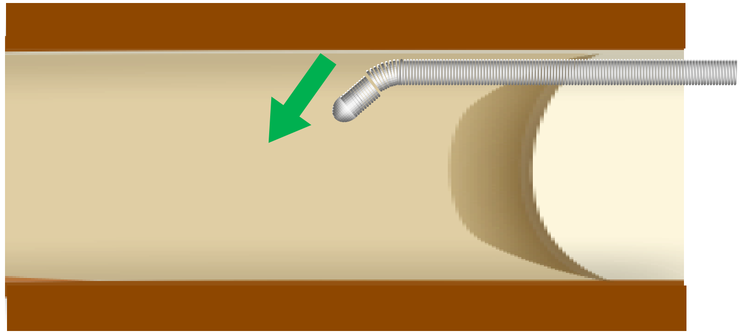
When membrane exists, intentional penetration utilizing tip deflection is mandatory.

Just after whipping of GW…

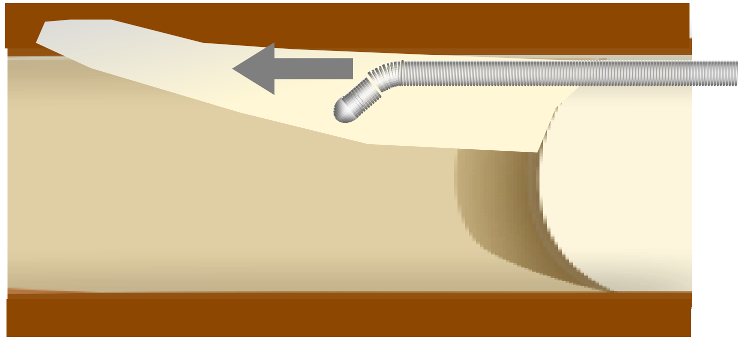


big space (semilunar space) will be created.

After making space around GW tip, deflection of GW becomes uncontrollable

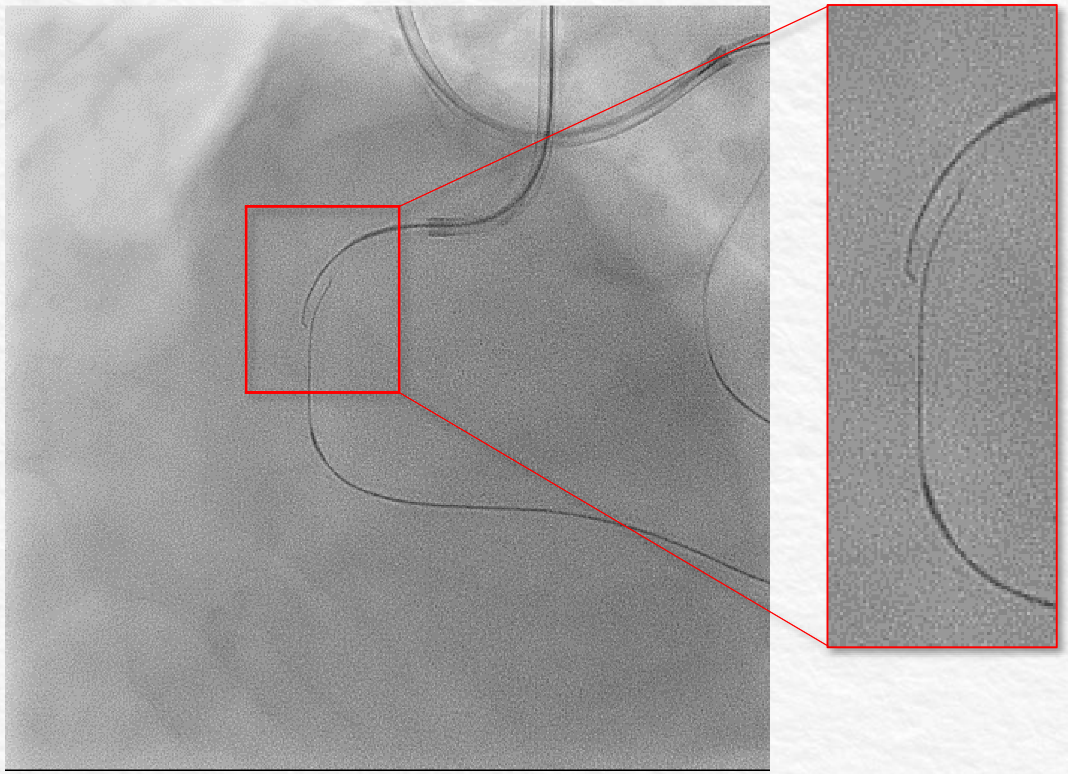


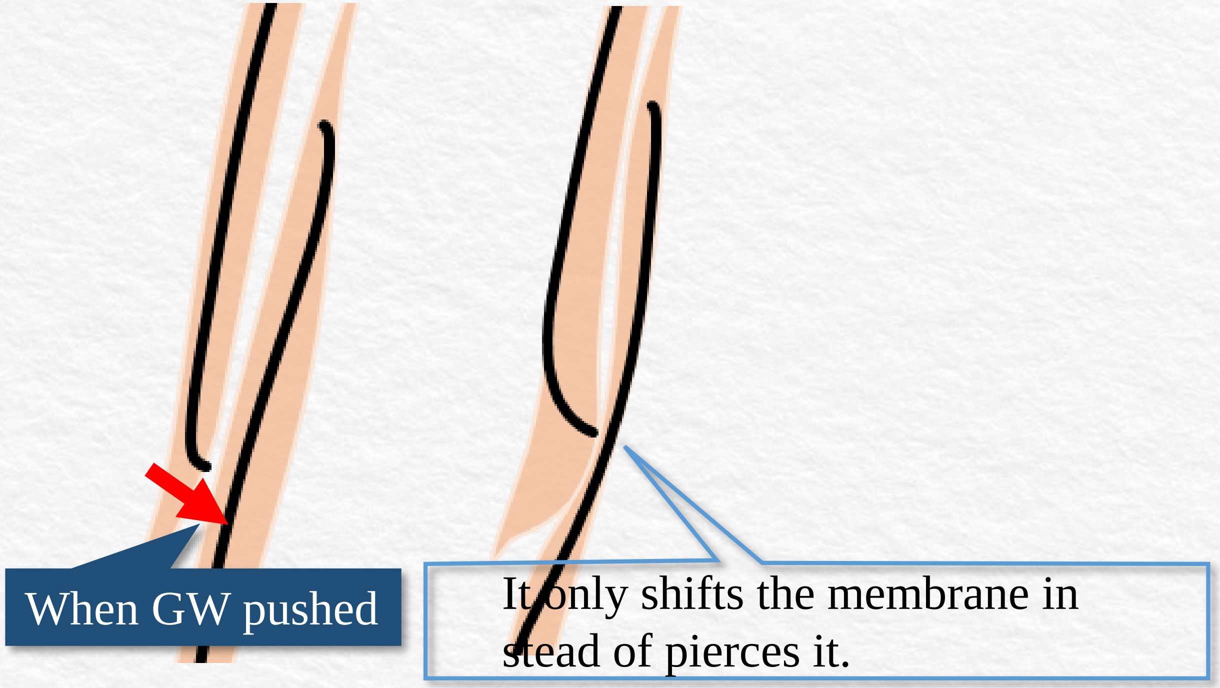
CTO wire can be controlled only inside solid tissue and small space around the tip of guidewire.



In big space, no deflection occurs in the first place.

Mechanical GW sometimes can not penetrate a membrane.





To overcome this situation, 2nd curve is needed to fix GW tip at the membrane and then deflected by reactive force from membrane.
However, 2nd curve sometimes makes it difficult to control its direction and reactive force sometimes enlarges hematoma.

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- Limitation of wire penetration force; we can not penetrate an extremely hard tissue such as high dense fibrous plaque and calcification.

Because of heterogeneous solidity of lesion, GW tip tends to be advanced to the direction where less solid.

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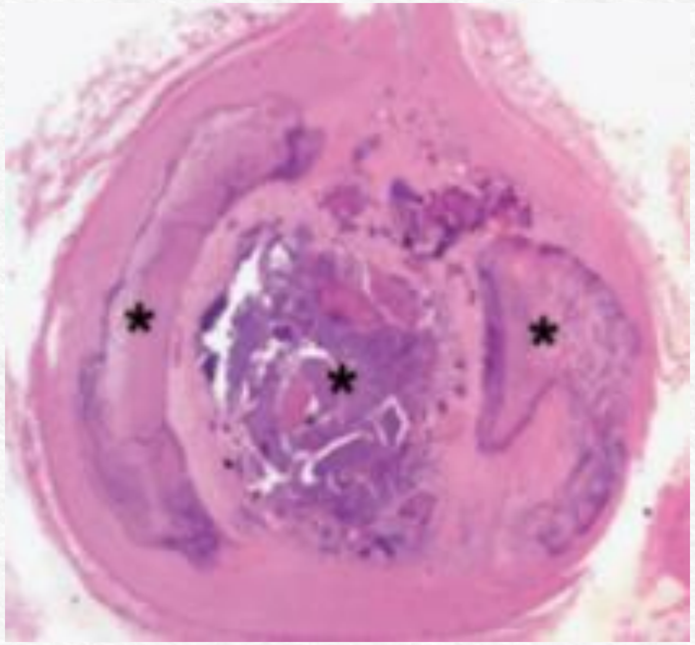


We sometimes take it true that GW with high tip load and shaft rigidity is advantageous in controllability because of its high torque and penetration force.

Actually, however, GW with high tip load and shaft rigidity is disadvantageous because it easily enlarges semi-lunar space by its shaft and whipping easily occurs as well.

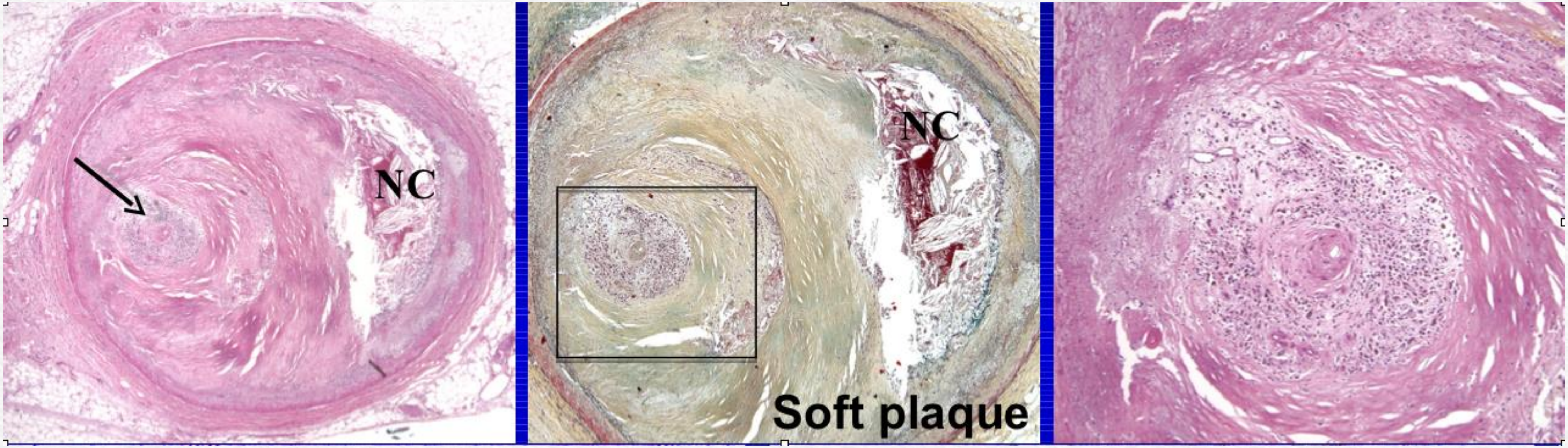
Summary

Mechanical GW has several limitations yet to be overcome.

- Whipping; we can not completely control the direction of GW tip.
- We can not predict and control how GW tip will be deflected.
- We can not deflect GW tip in a space: semilunar space and CTO entry.
- Limitation of wire penetration force; we can not penetrate an extremely hard tissue such as high dense fibrous plaque and calcification.

Thank you for your kind attention.

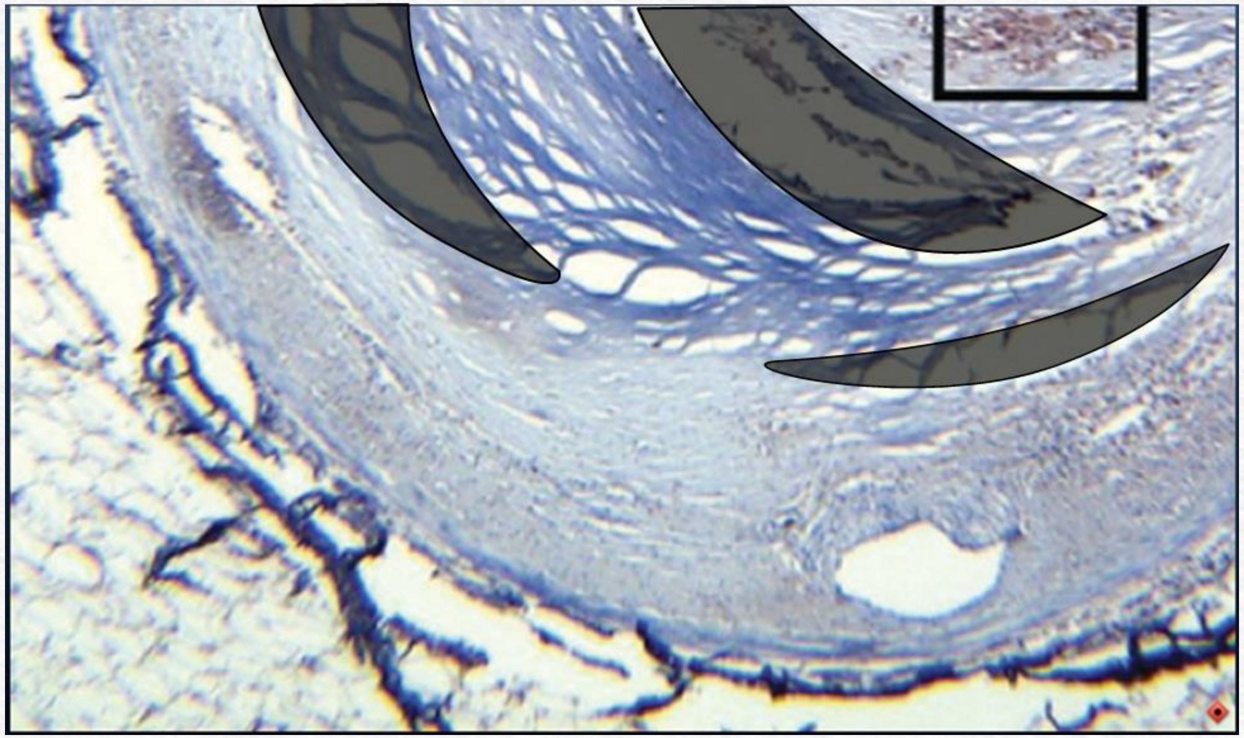
Layered structure of CTO lesion

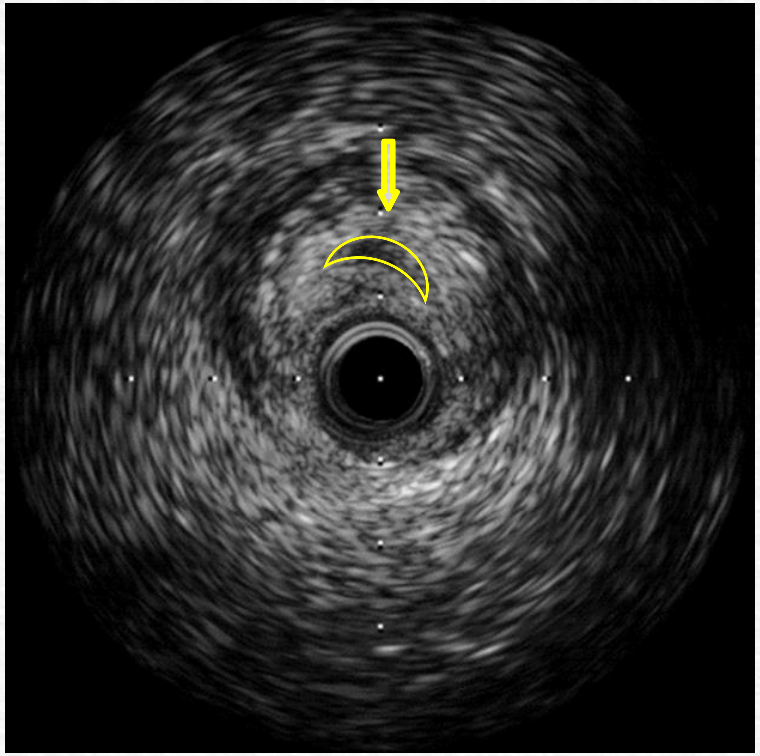


GW tip creates a semilunar space inside CTO lesion because of its layered structure.
The behavior of GW tip is extremely affected by surrounding semilunar space.

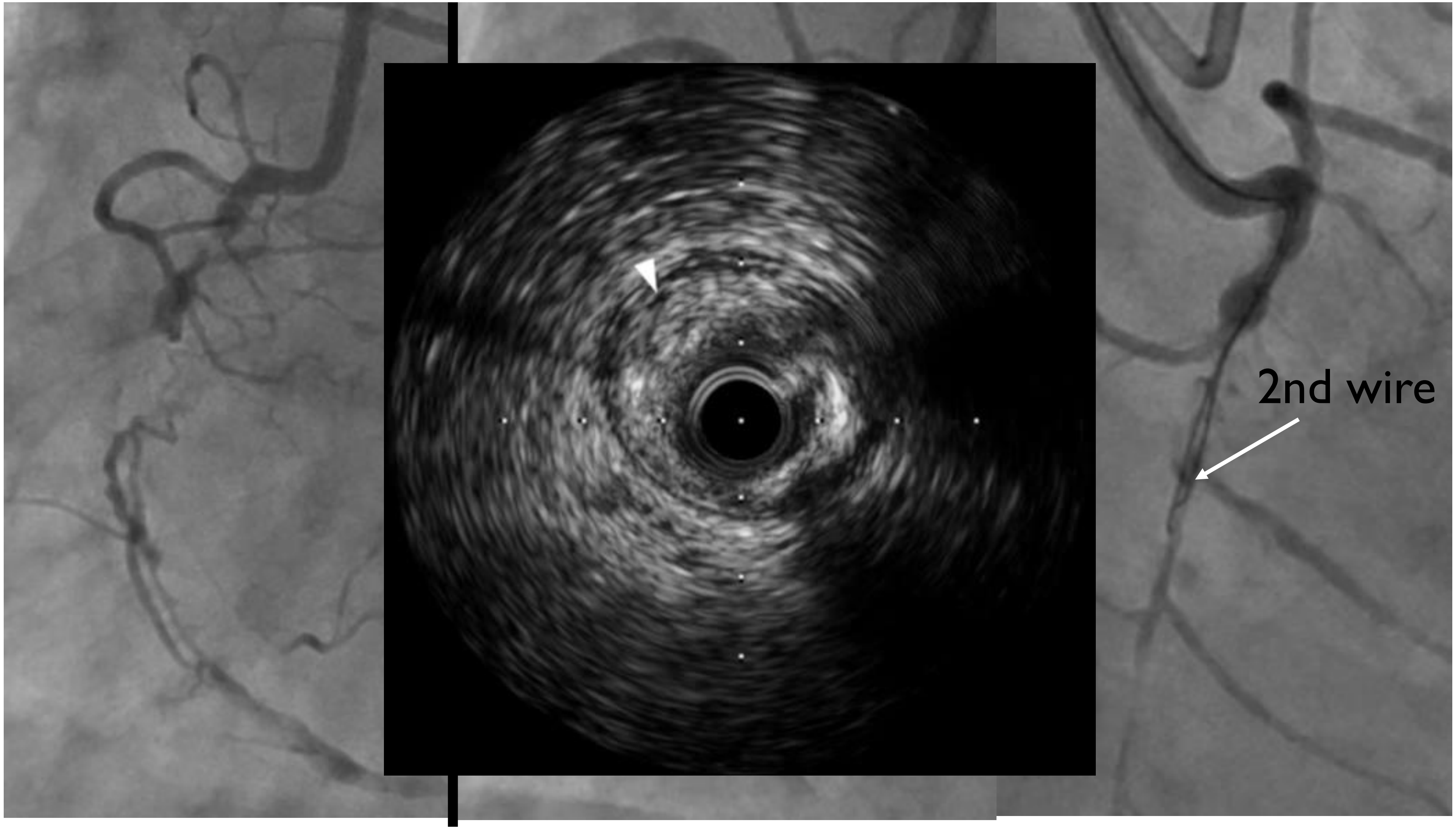
Semilunar Space

- GW tip is never deflected in a semilunar space and it will be extremely difficult to control it.
- Semilunar space is created by only **90° rotation at the maximum size.**

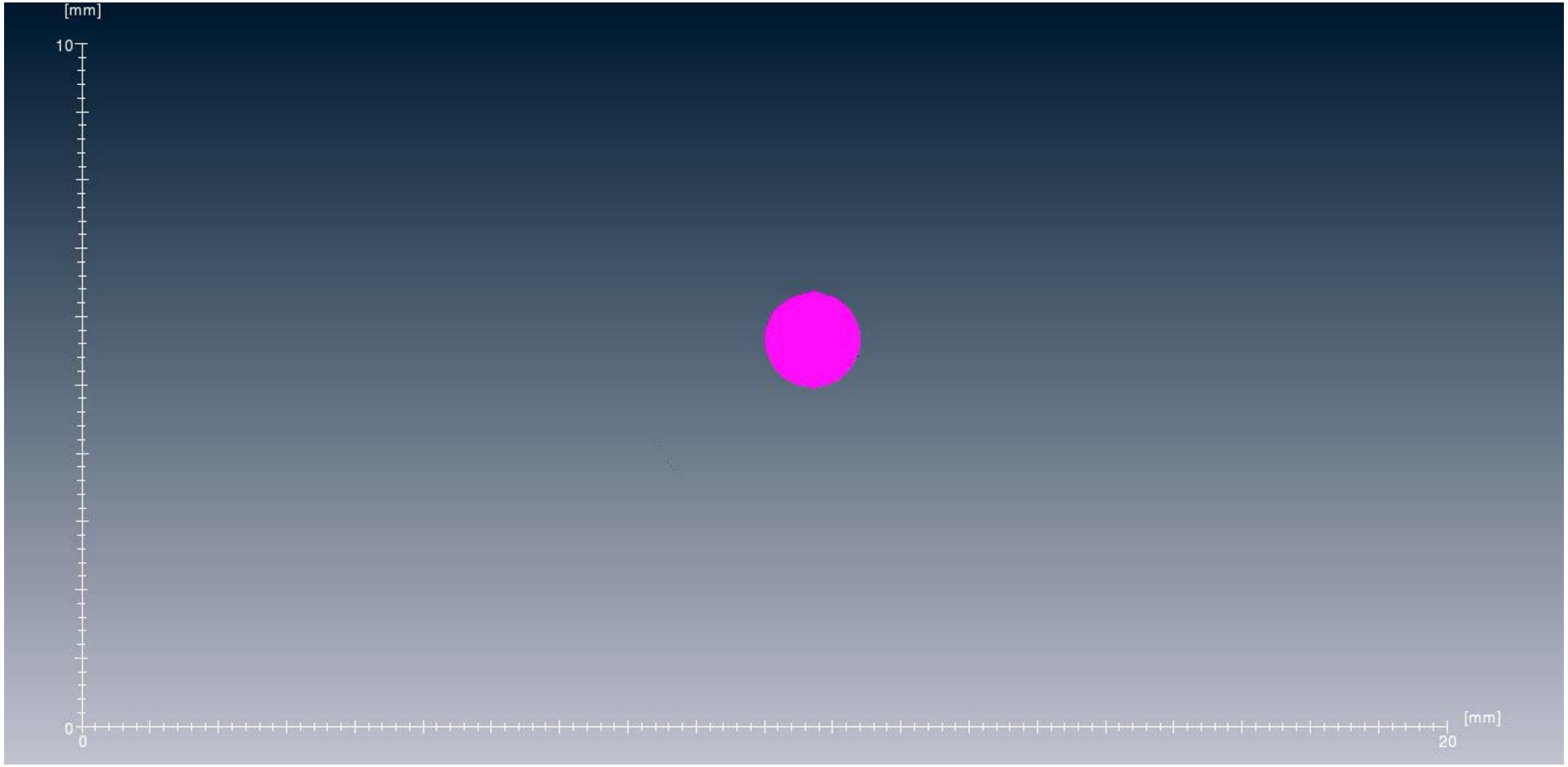




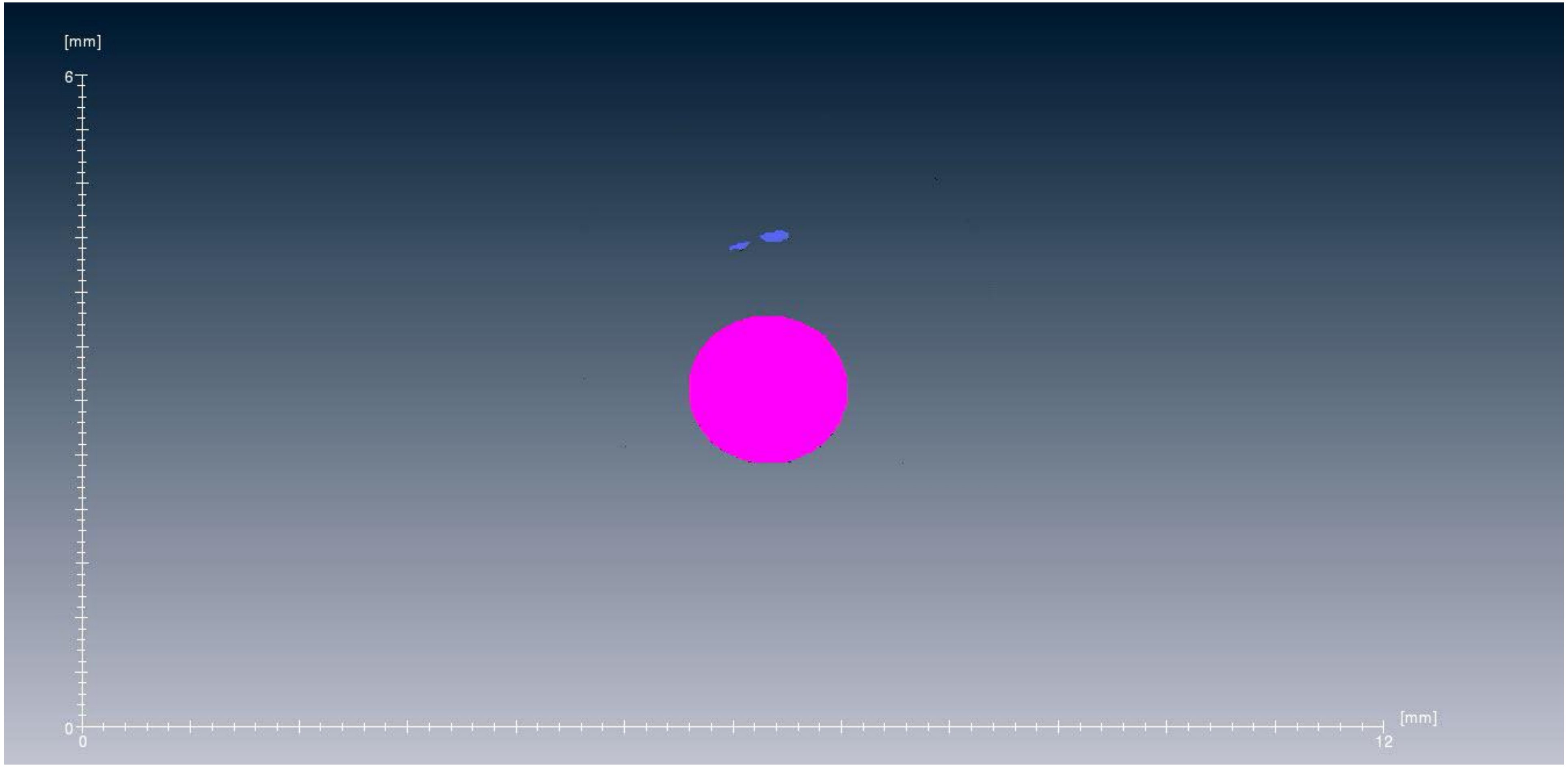
Semi-lunar space created by Gaia



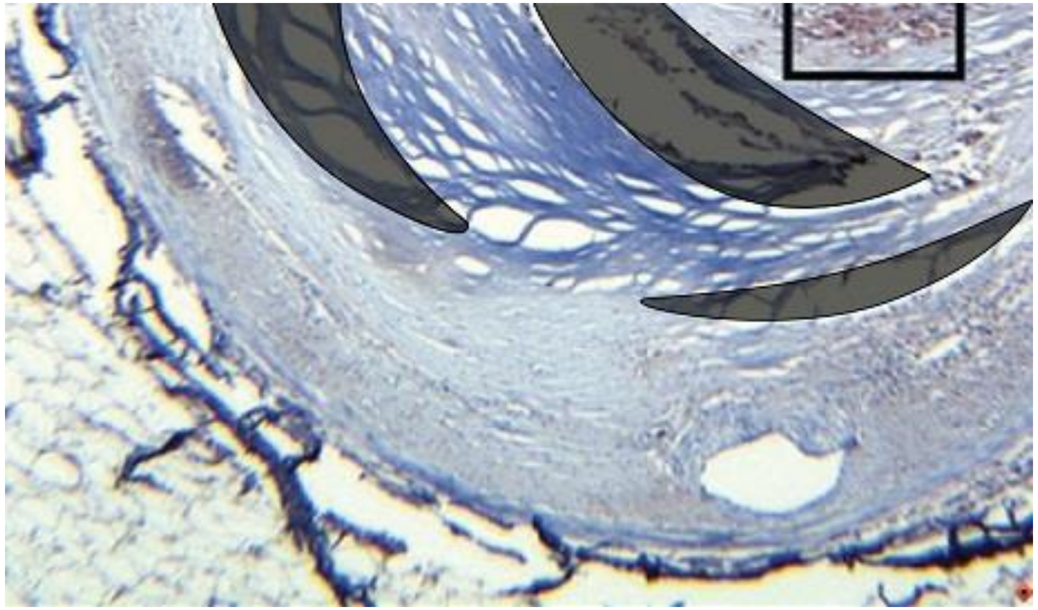
Semi-lunar space in 3D IVUS



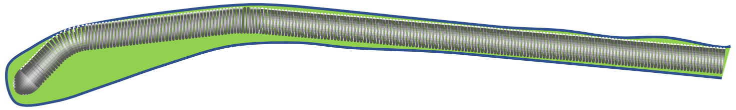
Semi-lunar space in 3D IVUS

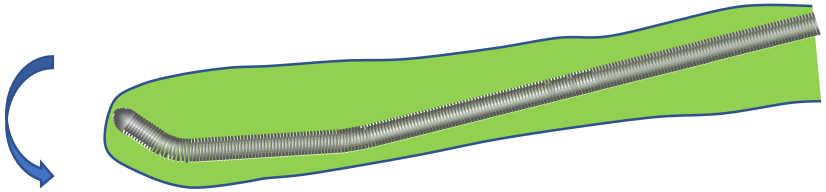


Layered structure of fibrous tissue in CTO lesions



- **As a response to the rotation of CTO wires, semilunar space is created easily due to layered structure of fibrous tissue.**
- **Once a semilunar space is created, the height of the lumen is easily increased with tearing circumferentially.**





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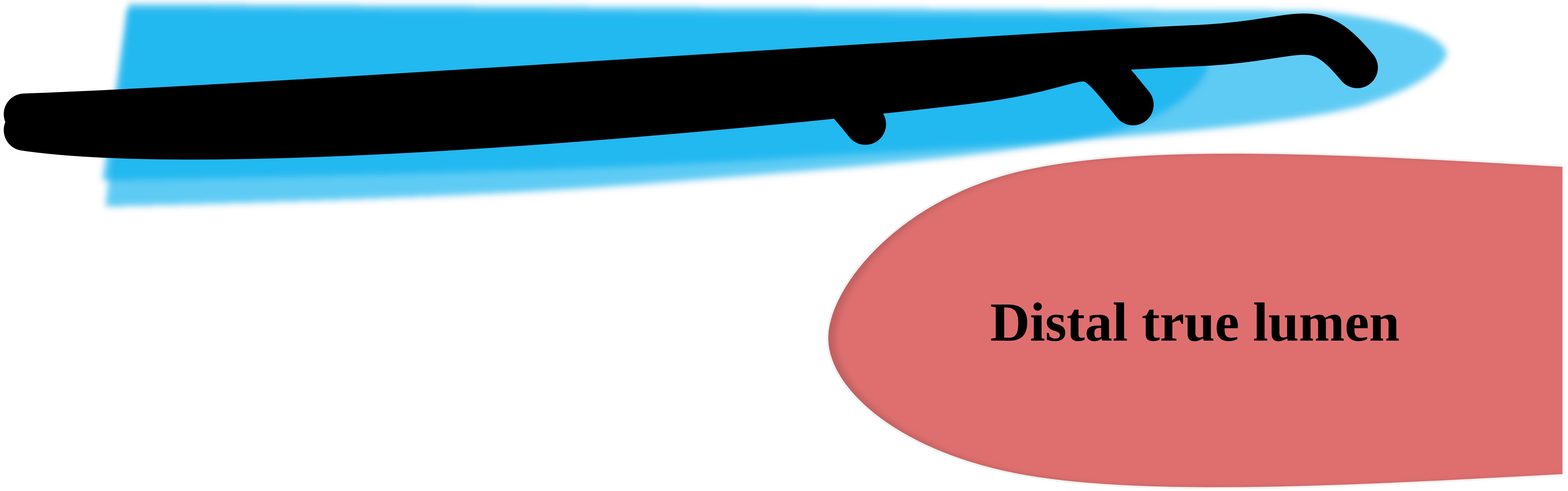

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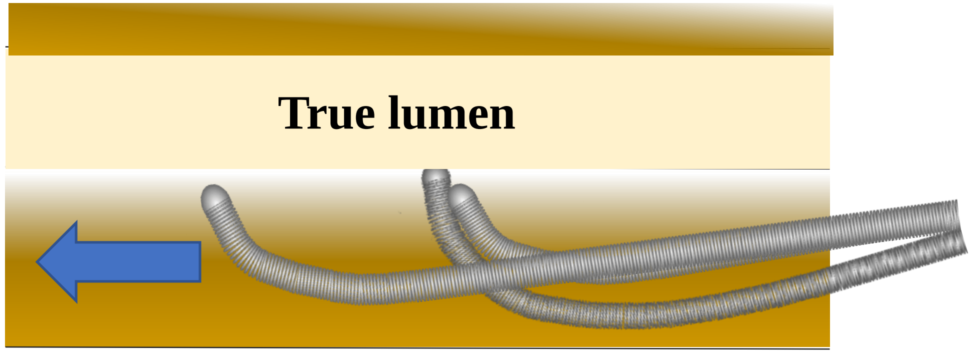

Try re-entry by deflection of GW in big hematoma.
It is more like trial and error.

↓

Newer space is created by whipping when GW is rotated.

↓

Advancement of hematoma