Orthopaedic implants

Rahul Upadhyay

Basic terms

- **Implants** : are devices or tissues that are placed inside or on the surface of the body.
- Many implants are prosthetics, intended to replace missing body parts.
- □ **STIFFNESS** – it is the resistance of a structure to deformation.
- □ **RIGIDITY** – it is used in context of fracture fixation describes an implant or of a bone- implant construct physical property of resisting deformation under load.
- □ **ELASTICITY**- it is the ability of a material to recover its original shape after deformation.

- PLASTICITY – the ability of a material to be formed to a new shape without fracture and retain that shape after load removal.
- □ DUCTILITY – the ability of solid material is to be deformed under tensile stress and to be stretched into a wire without fracture. It also bestows capacity to be shaped eg. Construction of bone plates.

- **STAINLESS STEEL 316L (Fe+Cr+Ni+Mo+C+Mn+Si)**
- There are at least 50 alloys and grades of alloys identified as commercial stainless steel. Only a few are useful as implant biomaterial in fracture surgery.
- Stainless steel designated as ASTM(American Society for Testing and Materials) F-55, -56 (grades 316 and 316L) is used extensively for fracture fixation implants.
- Type 316L stainless steel is an iron-based alloy.

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- □ Type 316L stainless steel is an iron-based alloy.

- Alloying with chromium generates a protective, self-regenerating chromium oxide layer which provides a major protection against corrosion.
- □ The addition of molybdenum decreases the rate of slow, passive dissolution of the chromium oxide layer by up to 1,000 times. Molybdenum further protects against pitting corrosion. Nickel imparts further corrosion resistance and facilitates the production process, while limited quantities of manganese and silicon are added to control some manufacturing problems.

Cobalt chromium alloys

- The cobalt-chromium-tungsten-nickel alloy (ASTM F-90) is used for manufacture of fracture fixation implants.
- □ In clinical practice it is used to make wire and internal fixation devices including plates, intramedullary rods, and screws, arthroplasty implants.

Titanium alloys

- Titanium-aluminum-vanadium alloy (ASTM F-136) is commonly referred to as Ti6Al4V. This alloy is widely used to manufacture implants.

FACTORS	STAINLESS	TITANIUM
1. ELASTICITY AND DUCTILITY	LESS	MORE
2.ENDURANCE LIMITS(STRESS LIMITS)	SAME	SAME
3.COST	CHEAP	COSTLY
4.CORROSION RESISTANCE & TOXIC IONS	+VE COZ OF CHROMIUM N NICKEL	-VE
5.ALLERGIC REACTION.	+VE	-VE
6.SECOND OPERATION	MAY REQUIRE	HIGH COST IS OFTEN COMPENSATED COZ IMPLANT CAN BE LEFT INSITU & 2ND SURGERY IS OFTEN UNNECESSARY.

Nickle titanium alloy/ NITINOL

- It is a Shape Memory Alloy (SMA) was discovered in 1965.
- □ Nitinol is an acronym for nickel titanium naval ordnance laboratory, where the alloy's remarkable properties were discovered.
- □ The alloy contains nearly equal numbers of nickel and titanium atoms, leading to its common compositional representation as NiTi.
- □ Shape Memory Alloy can be "trained" to take on a predetermined shape in response to a stimulus such as a change in temperature.

Original AO principles: 1962

Restoration of anatomy

Stable fracture fixation

Preservation of blood supply

Early mobilization of the limb and patient

AO principles : present

Fracture reduction and fixation to restore anatomical relationships. Reduction of long bones may not be anatomical but instead should demonstrate axial alignment with respect to length and torsion in the diaphysis and metaphysis.

Fracture fixation providing absolute or relative stability as the " personality " of the fracture, the patient, and the injury requires.

Preservation of the blood supply to soft tissues and bone by gentle reduction techniques and careful handling.

Early and safe mobilization and rehabilitation of the injured part and the patient as a whole.

Stability of Fixation	Type of Fracture: **Simple** **Small (<2 mm)**	Type of Fracture: **Multifragmentary** **Large (>2 mm)**
Relative	Bone resorption, healing delay, or nonunion	Secondary bone healing (callus)
Absolute	Primary bone healing, osteonal remodeling	Bone resorption, healing delay, or nonunion

Evolution of plates

1961 – Form / T plates : cancellous screws in metaphysial region achieve compression.

1962/63 – Round hole plates (Muller ME) : conical screws head gave a firm fit.

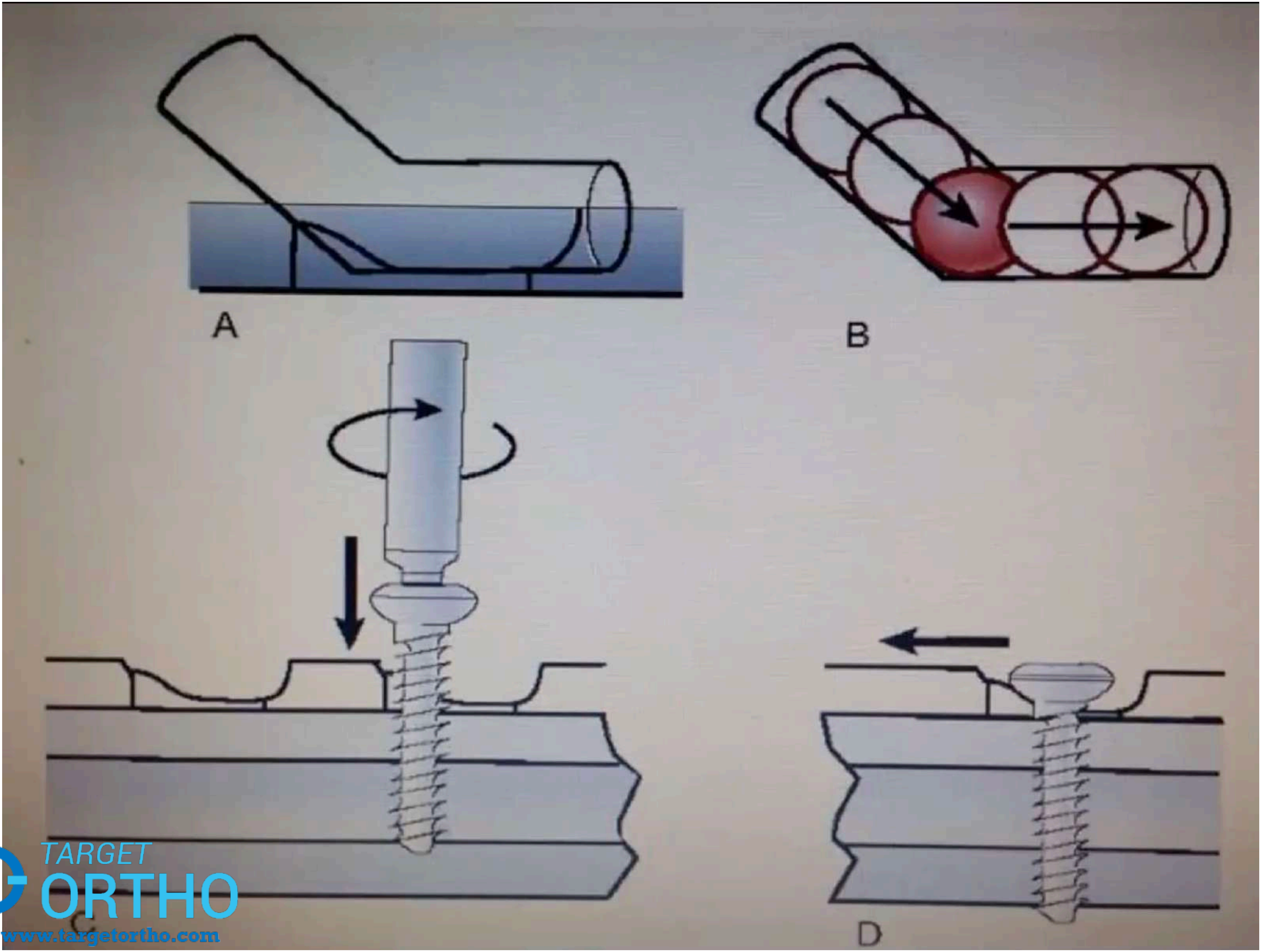
1963 – Semi tubular plate (Muller ME) : acted as self compression plate due to eccentric screw placement.

Dynamic compression plate (DCP)

1967 – Perren

principle - applying axial compression by leveraging the interaction of a spherical screw head and an inclined oval screw hole .

The oval hole also allowed angulations of the screw in different directions.


A
B
C
D

DCP

1980 – modified by Brunner & Webber

Had transverse undercuts in screw heads.

Plates for Splinting

1981/82 – Wave plate (Brunner & Webber)

Concept of biological plating – Ganz & Mast

Concept of indirect reduction - Ganz & Mast

1985 – Bridge plating (Heitemeyer & Hierholzer) : today any plate can be used in bridging mode (DCP, LC-DCP, LCP with cortex and cancellous bone screws)

Limited contact DCP (LCDCP)

1990 – Perren

Studied and found decreased blood supply to underlying cortex.

new design of the under surface reducing the area of contact between the plate and the bone to reduce the adverse effects of pressure and friction on bone vascularity.

Advantages of LCDCP

Uniform material stiffness due to even placement of screw holes from one end of the plate to the other.

Wider angle of screw orientation relative to screw hole (40 degree compared to 20 degree in DCP)

Auto compression from either side of the

Cont:

Grooves in the undersurface of the plate to allow circulation under the plate and formation of callus bridges.

Improved fatigue life (LCDCP titanium)

Decreased stiffness: young’s modulus for steel is twice that of titanium.

Internal fixators: Advantages

ZESPOL – Poland **1976**- first internal fixator.

No requirement for direct contact to the underlying bone, preservation of periosteal blood flow

Improved construct stability in osteopenic bone

Resistance to secondary collapse or screw displacement

No need for precise plate contouring

PC - Fix

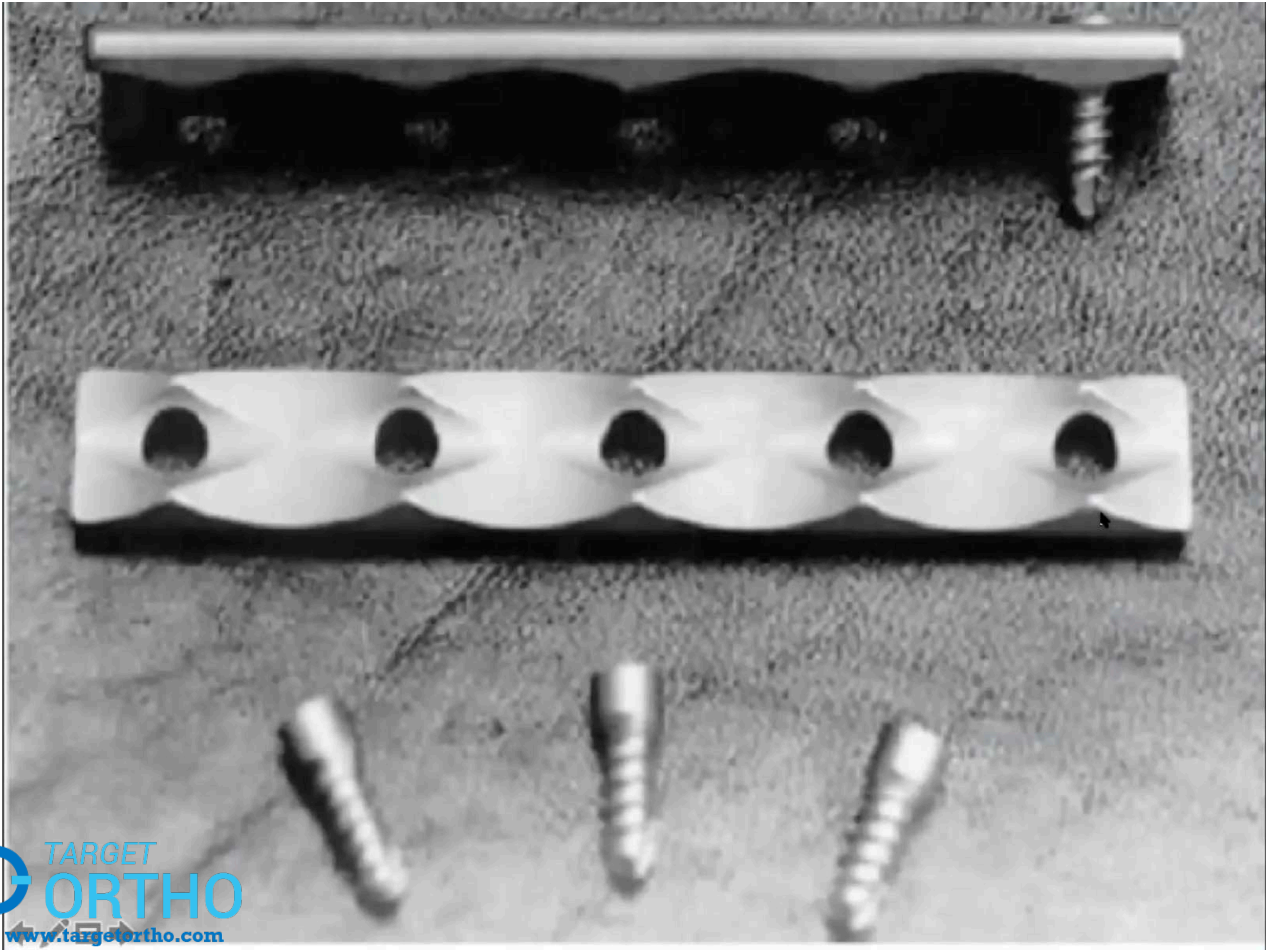
1990 – Perren, Tepic

Point contact fixation plate.

Angular stable screws were used for the first time.

Can be used for submuscular plating.

every screw head was locked in the plate hole through a tight fit between the conical shape of the head and the plate hole .



Less invasive stabilization system- LISS

1994 – Frigg & Schvan

Distal femur.

It combines the fixed angle device with the possibility of a minimally invasive plate insertion technique using a special jig and monocortical and self-drilling and self-tapping screws that are introduced through short stab incisions.

lack torsional control seen with bicortical

Locking compression plate- LCP

2001 – Wagner, Frigg & Schvan

All purpose implant system

Offers great flexibility.

Option of combination holes (commonly called as combi-hole plate)

Different versions of LCP with combi-holes :

a. 4.5/5.0 mm large fragment

b. 3.5 mm small fragment

c. 2.4 & 2.0 mm

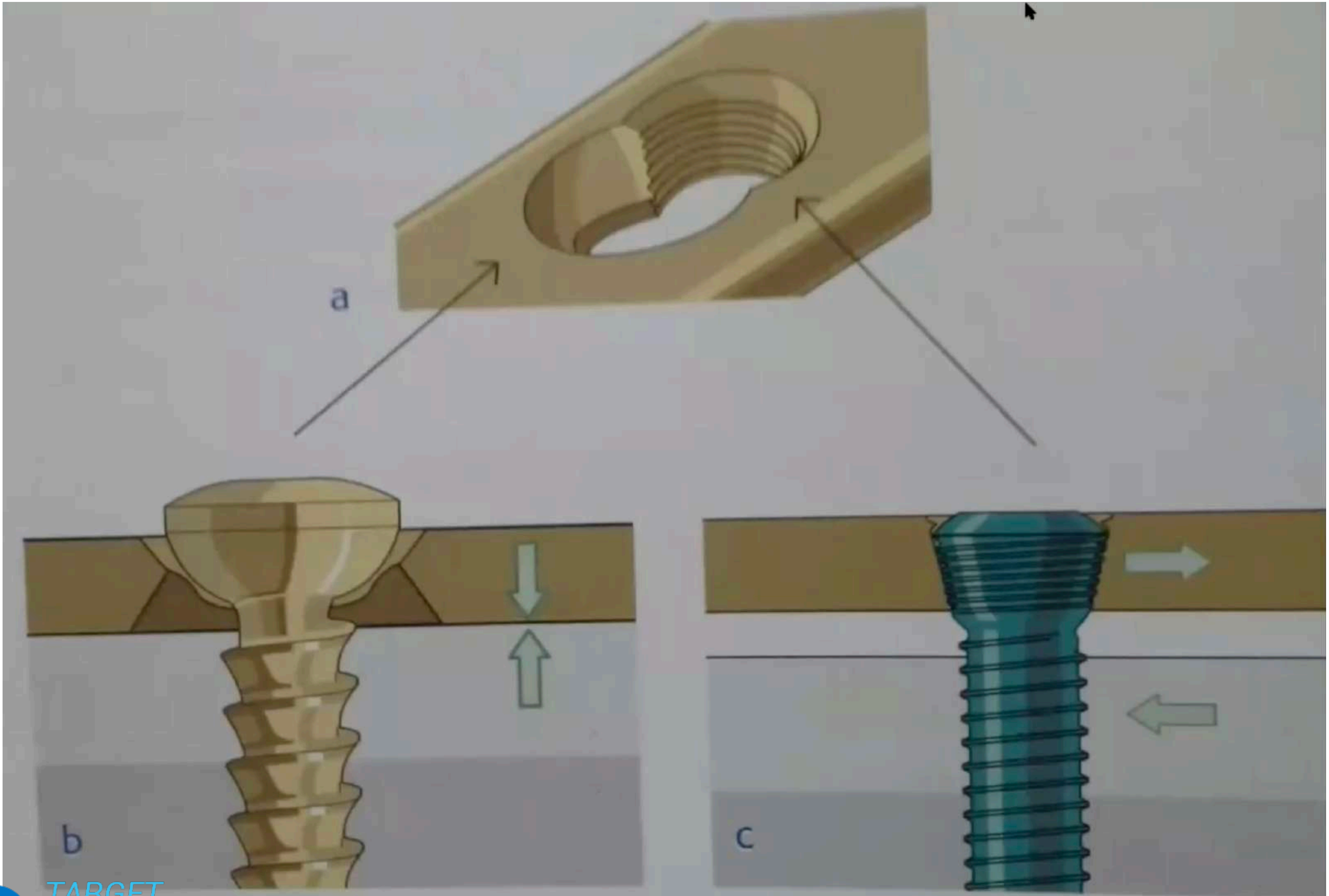
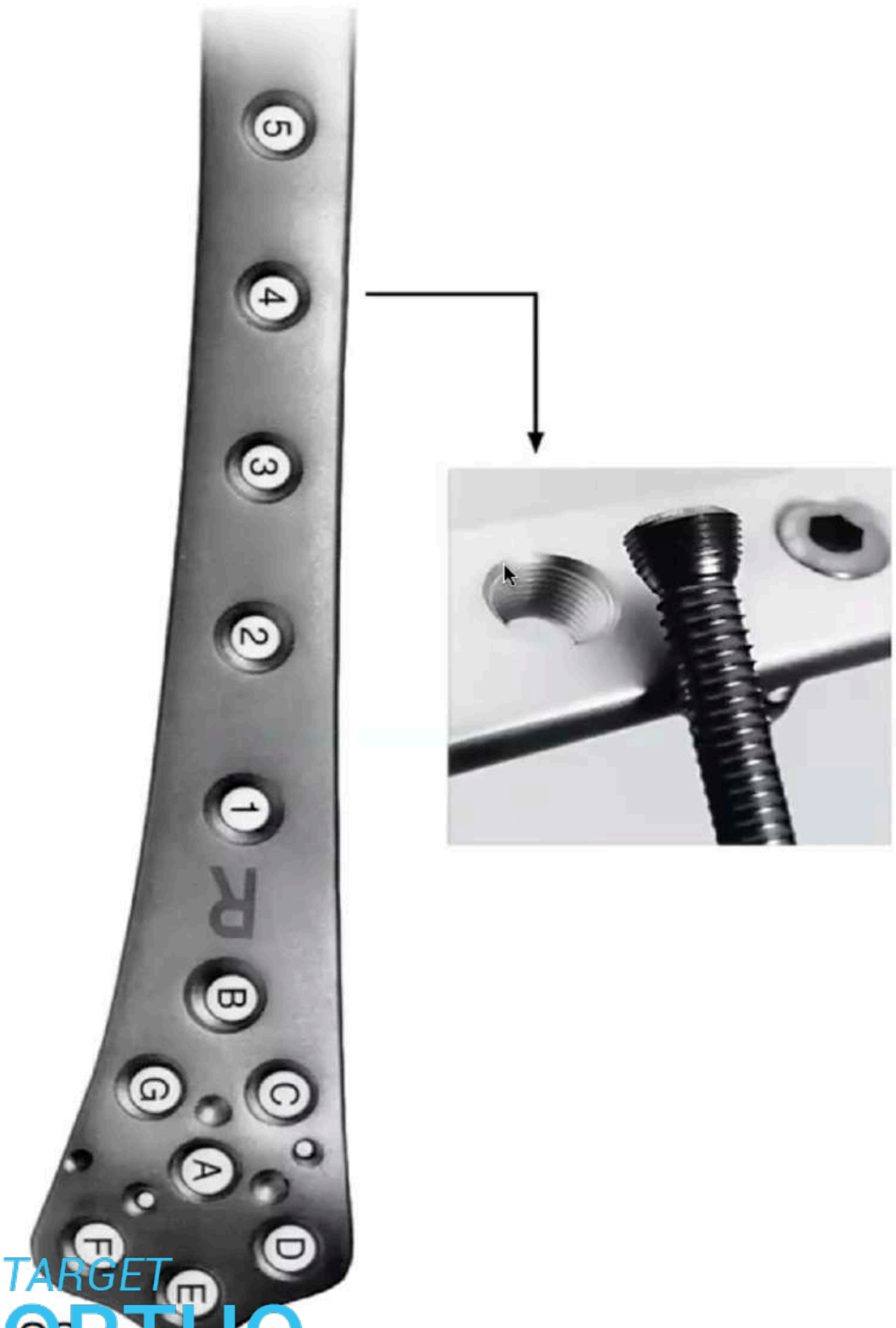
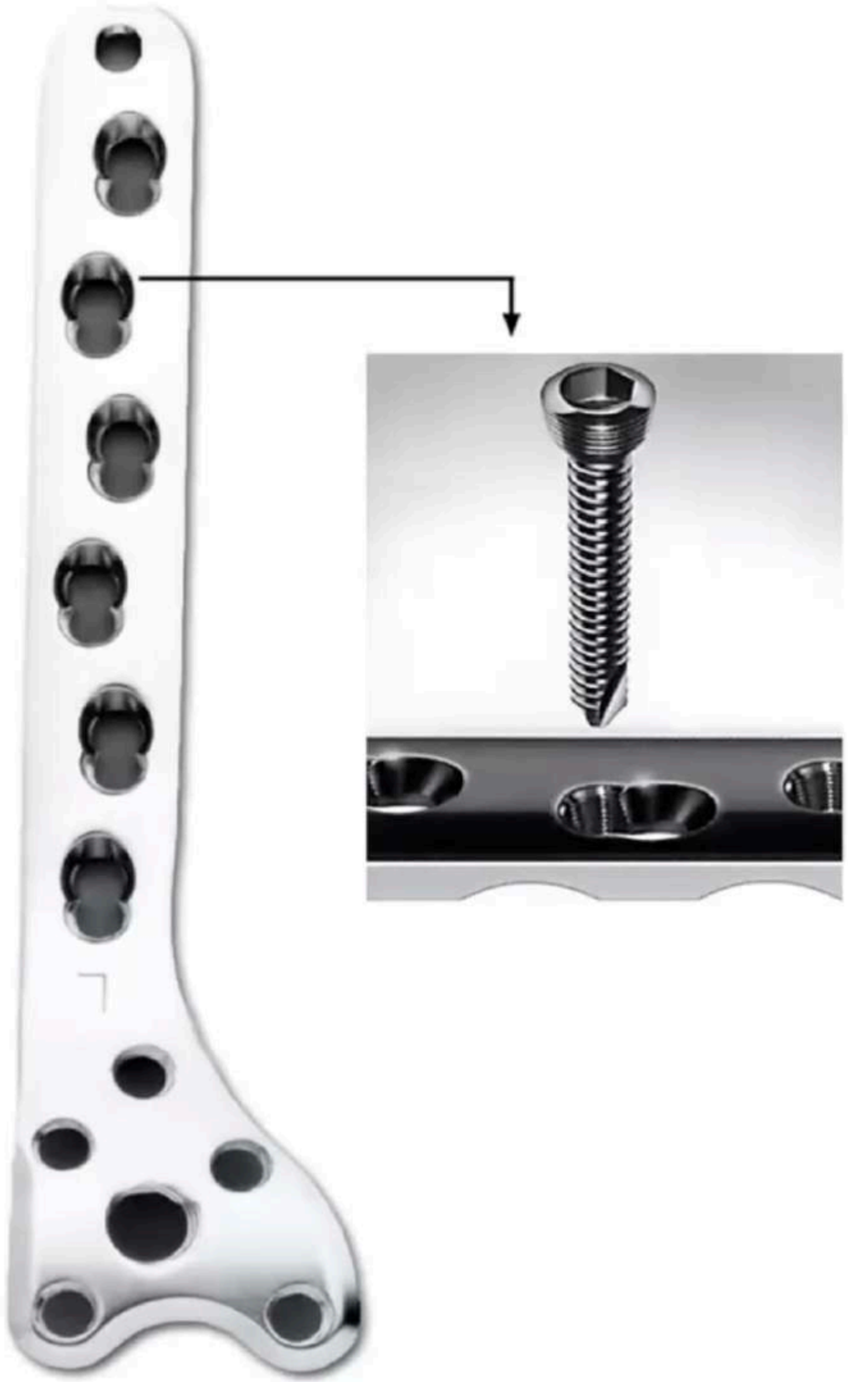


Fig 1-23a–c Locking compression plate with combination hole.



LISS plate

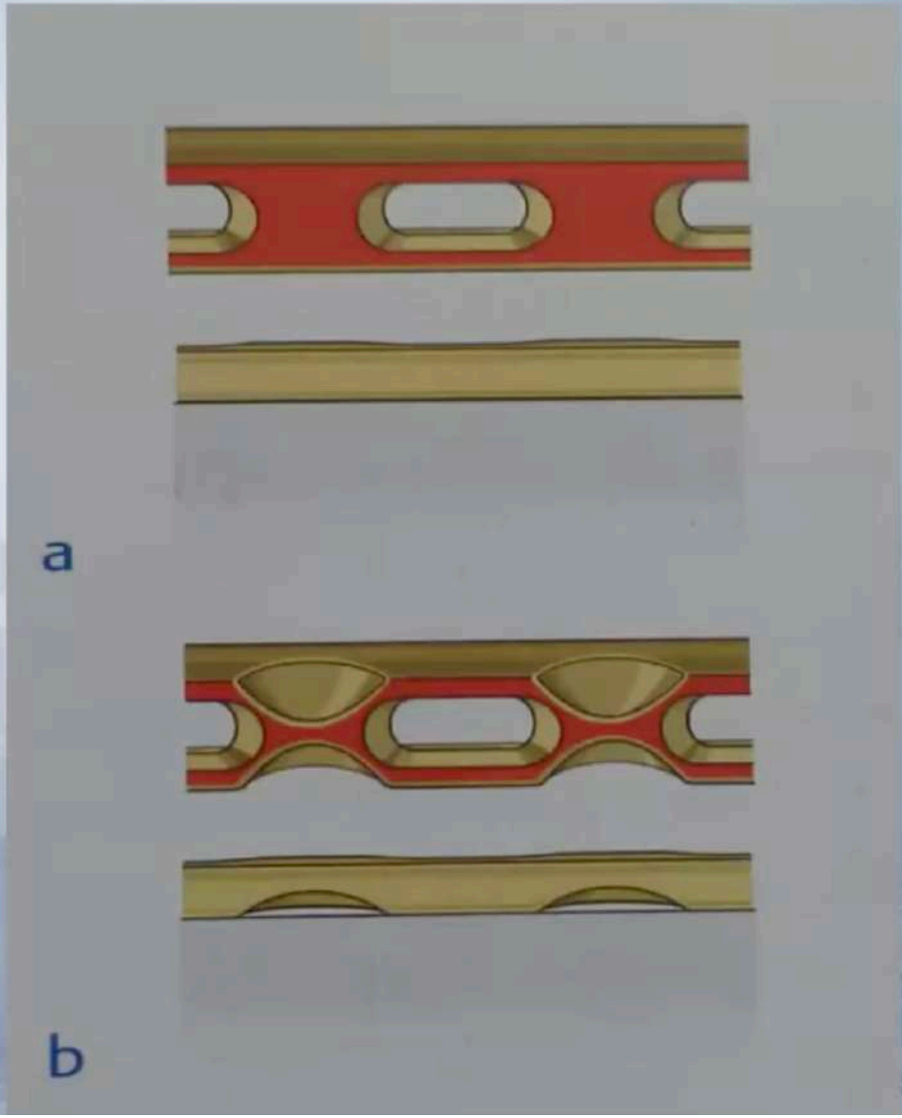


Locking Compression Plate

Comparison of plate contact with bone

A : DCP

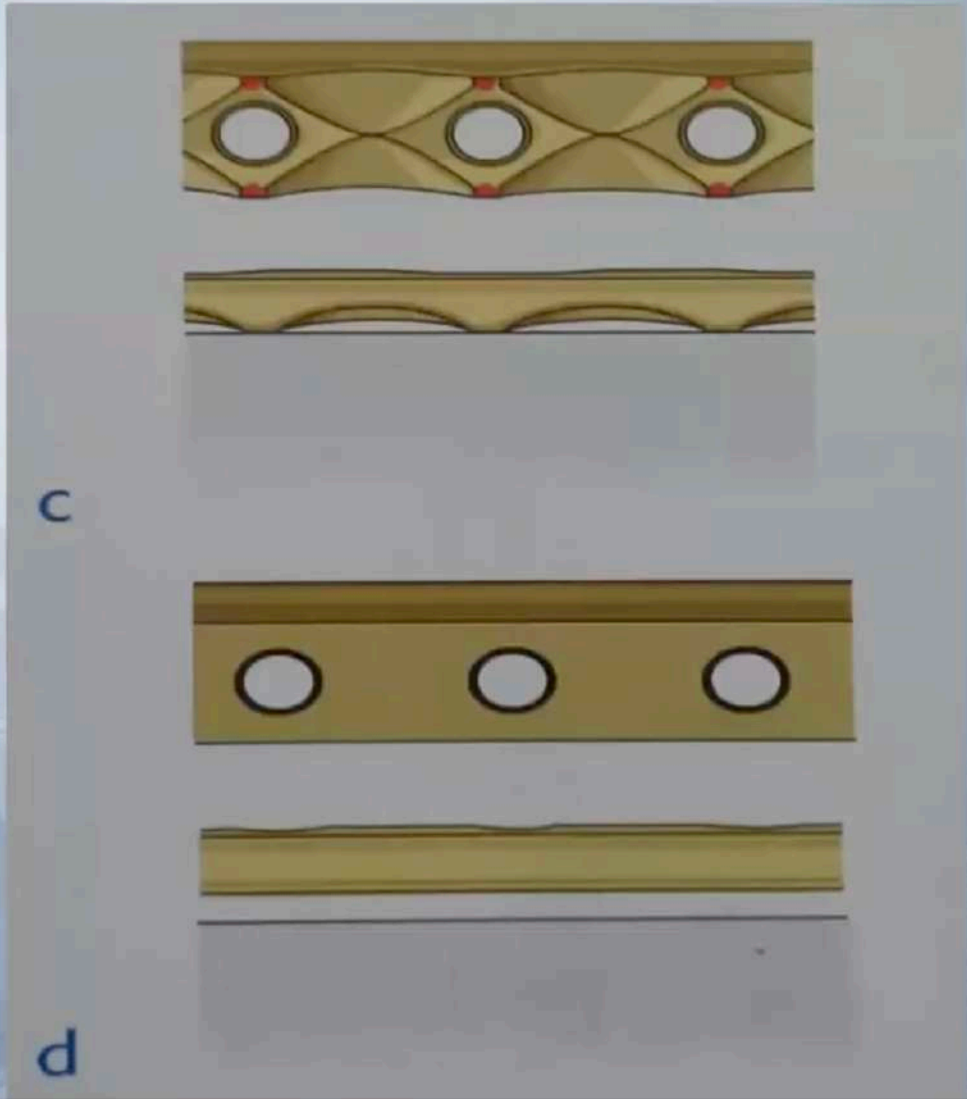
B : LCDCP



Comparison of plate contact with bone

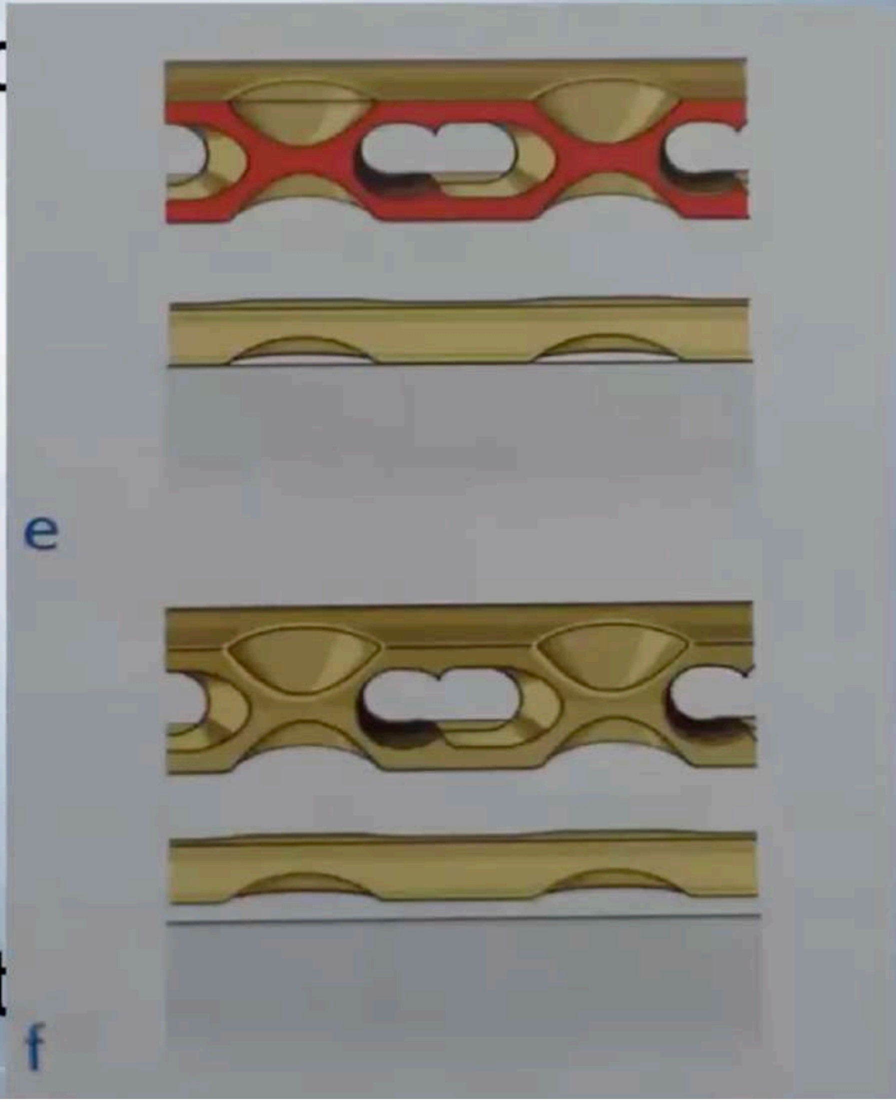
C : PC-Fix

D: LISS



Comparison of plate contact with bone

E : LCP with cortex sc



F : LCP with LHS

(no contact plat

RECONSTRUCTION PLATE

- ACURATE COUNTOURING OF PLATE
- SHOWS DEEP NOTCHES
- USED IN →PELVIC BONE
  ACETABULUM
  CLAVICLE
  OLECRENON
  DISTAL HUMERUS

TUBULAR PLATE

- 3.5 SYSTEM -> 1/3 TUBULAR PLATE
- 4.5 SYSTEM → SEMITUBULAR PLATE
- LESS STABILITY
- USED FOR-> LATERAL MALLEOLUS

  DISTAL ULNA

  OLECRENON

  DISTAL HUMERUS

Plate functions

Neutralization or protection

Compression

Buttressing

Tension band

Bridging

LCP in conventional compression plating

Principle of absolute stability and direct bone healing.

Indications :

1. simple fractures of diaphysis and metaphysis.(precise anatomical reduction needed, little soft tissue compromise, good bone quality)
2. intra-articular fractures. (buttress plate)
3. delayed union or non- union.

Requirements :

Precise reduction of fragments- open & direct reduction.

Precise anatomic preshaping of the plate (If the protection plate is to be fixed with cortex screws)

Good bone quality, to ensure adequate anchorage of cortex or cancellous bone screws.

Minimal soft tissue damage.

Technique

Aim is to achieve absolute stability and interfragmentary compression.

4 ways :

1. absolute stability by a lag screw and protection plate.
2. compression using the tension device.
3. compression by over bending (over contouring) the plate .
4. compression using dynamic compression unit in a plate.

Lag screw and protection plate

Conventional compression principle with DCP

- Precise anatomical reduction (direct, open)
- Absolute stability with interfragmentary compression by lag screws across the plate
- Direct (primary) healing without callus
- Good bone quality is required

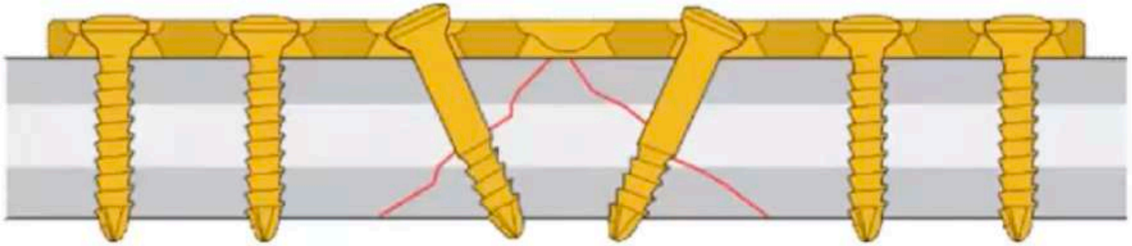


Plate is pressed against the bone > friction

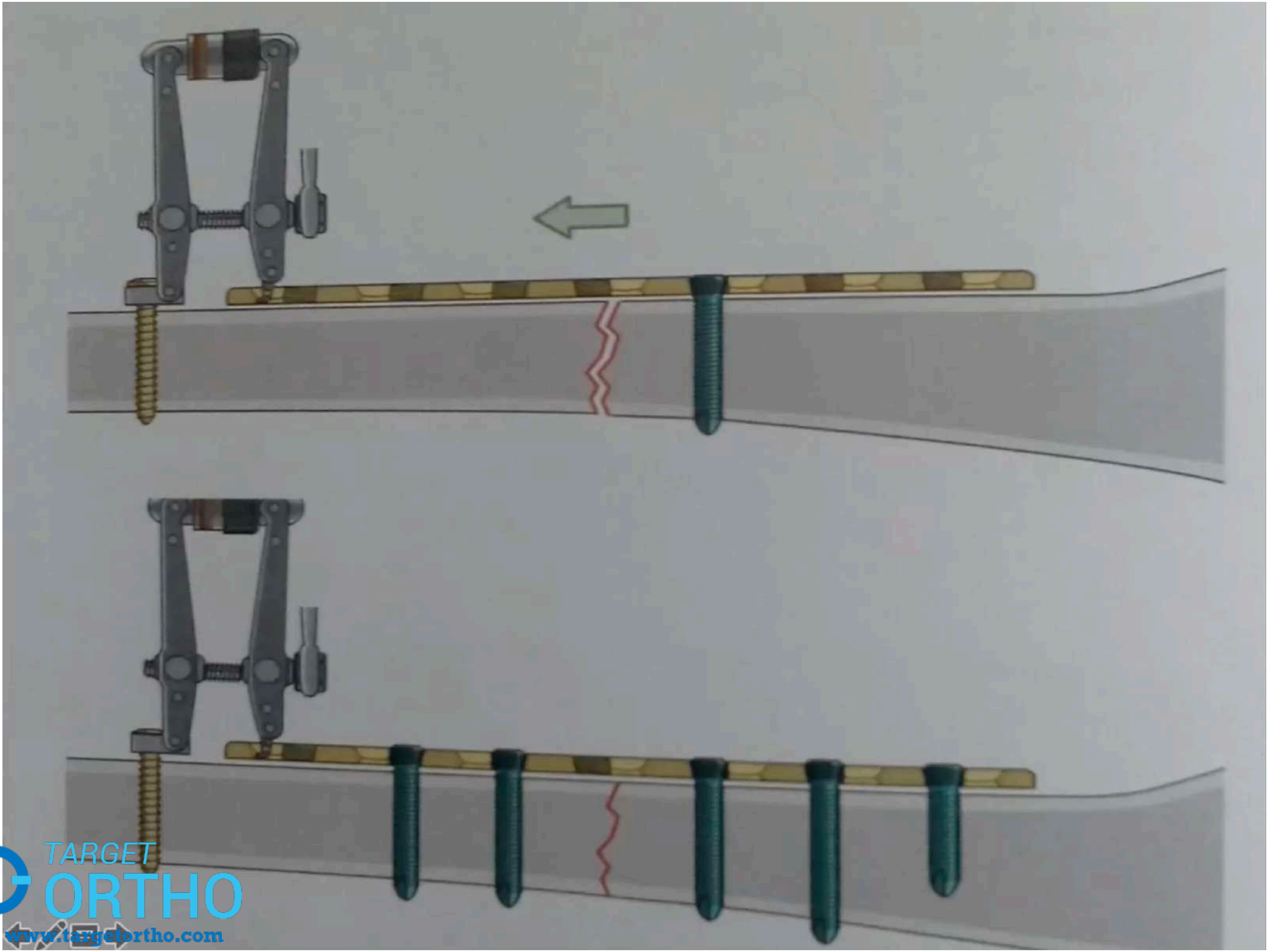
AOTRAUMA

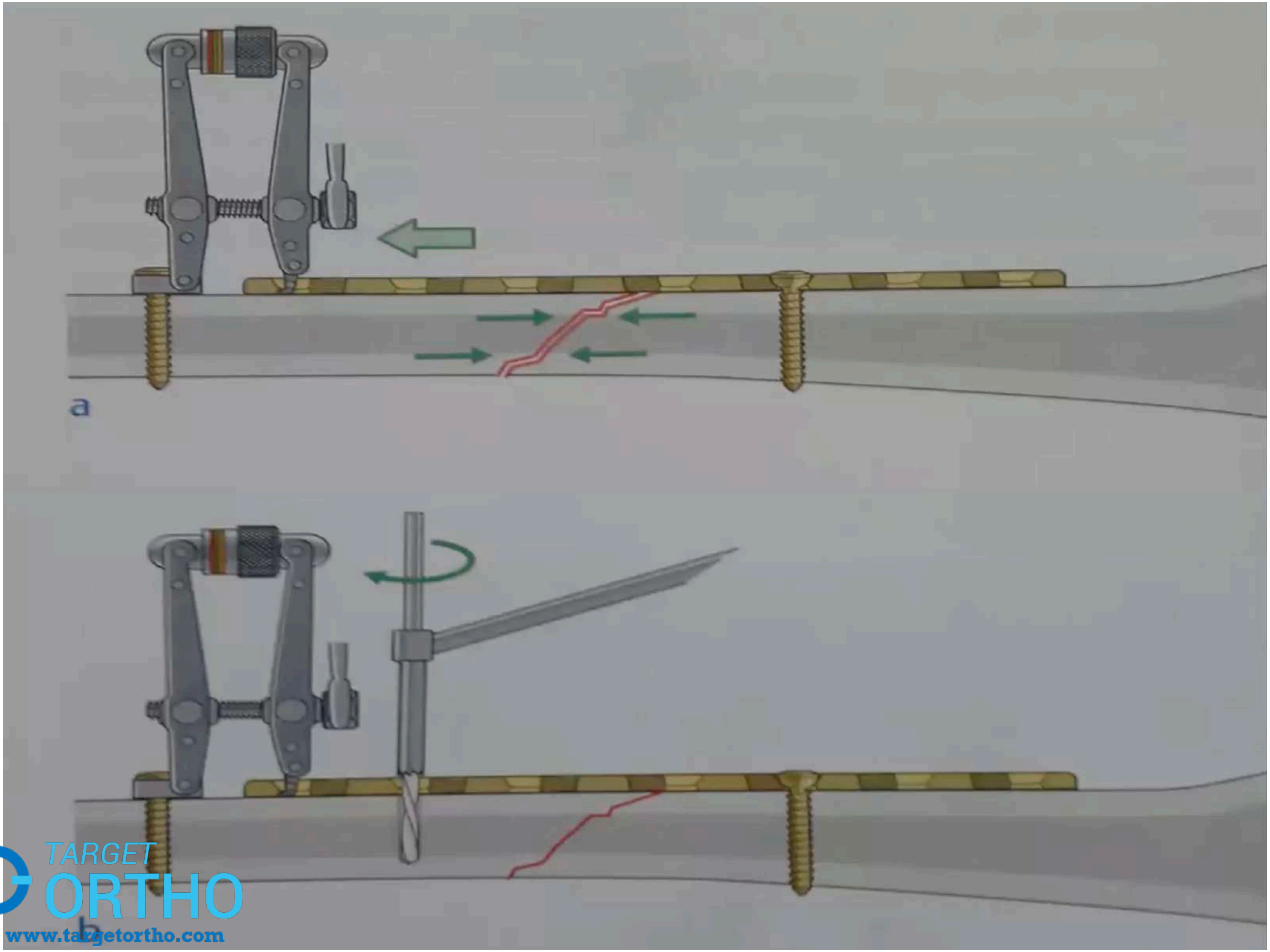
Cont:

Protection plate reduces the load placed on interfragmentary screw and protects it from failure. (bending, rotational or shearing forces).

Correctly placed lag screw generates forces up to 3000 N.

Lag screw can be placed independently or through the plate.




a

Compression by overbending of plate

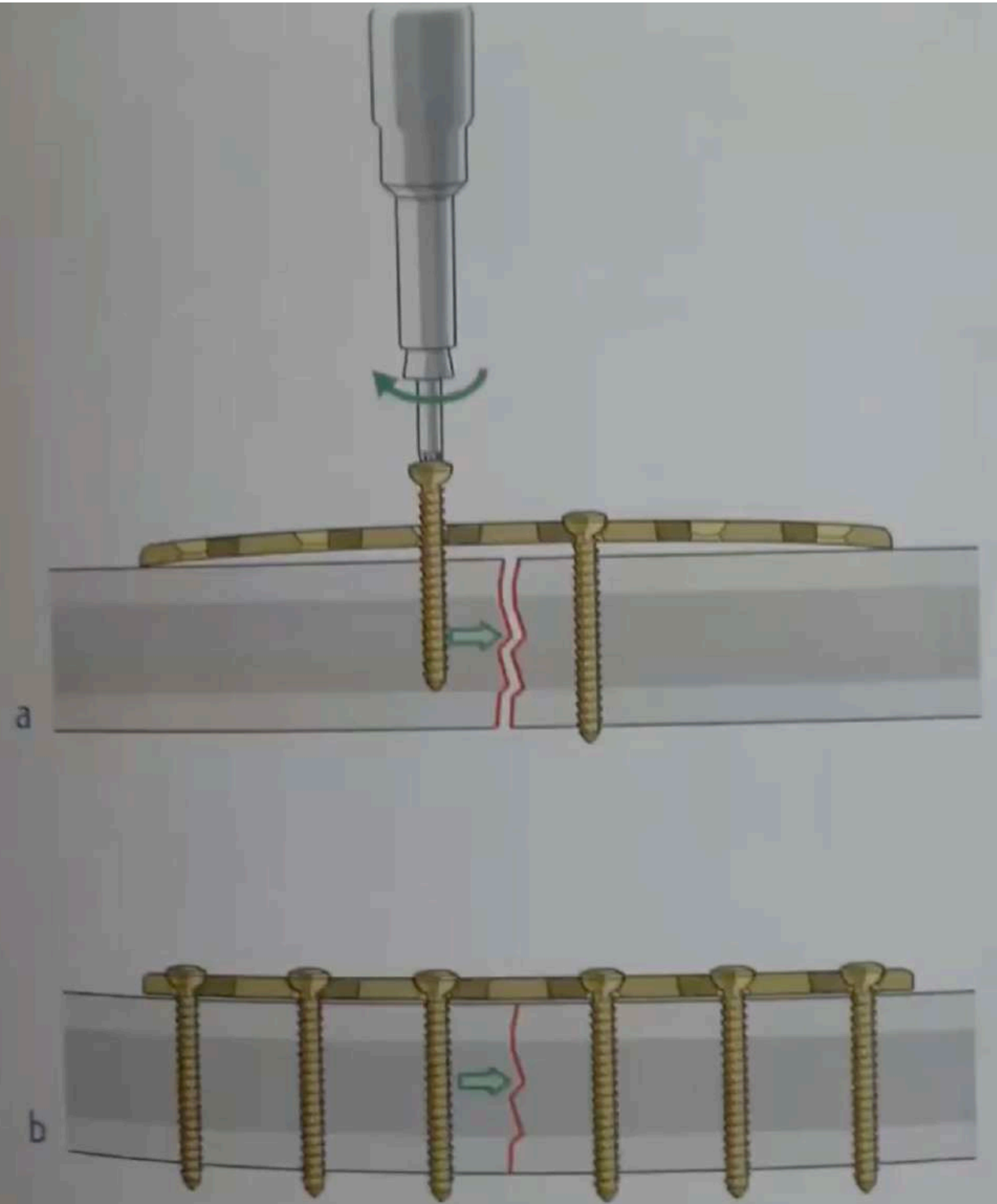
If straight plate is applied to straight bone, compressive forces are greatest directly underneath the plate..

Small gap occurs at far cortex due to tension.

Prevent adequate concentric compression across entire fracture surface.

Pre- bending is essential.

Due to tension- overbent plate straightens – compression of opposite cortex.- stability.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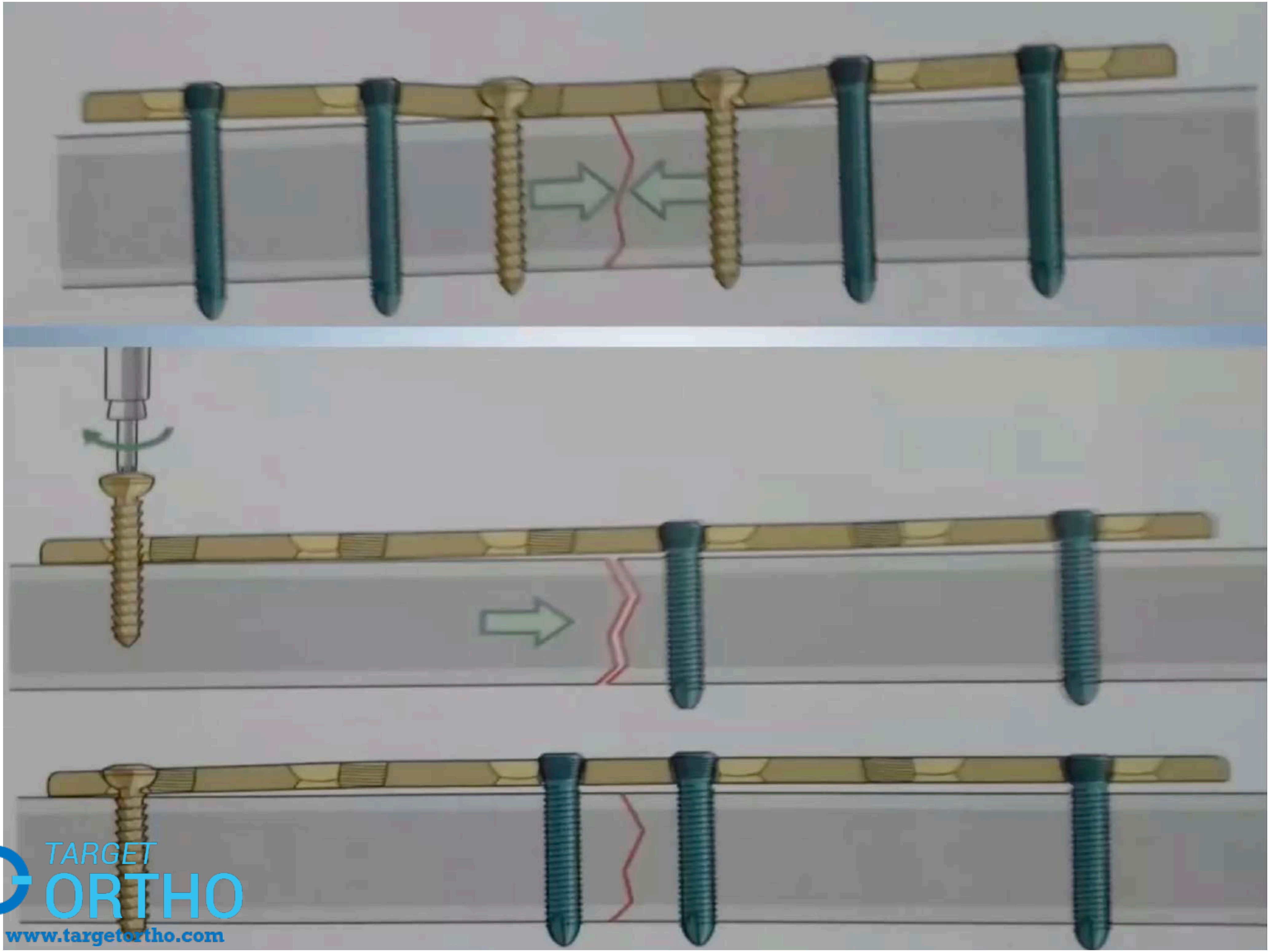


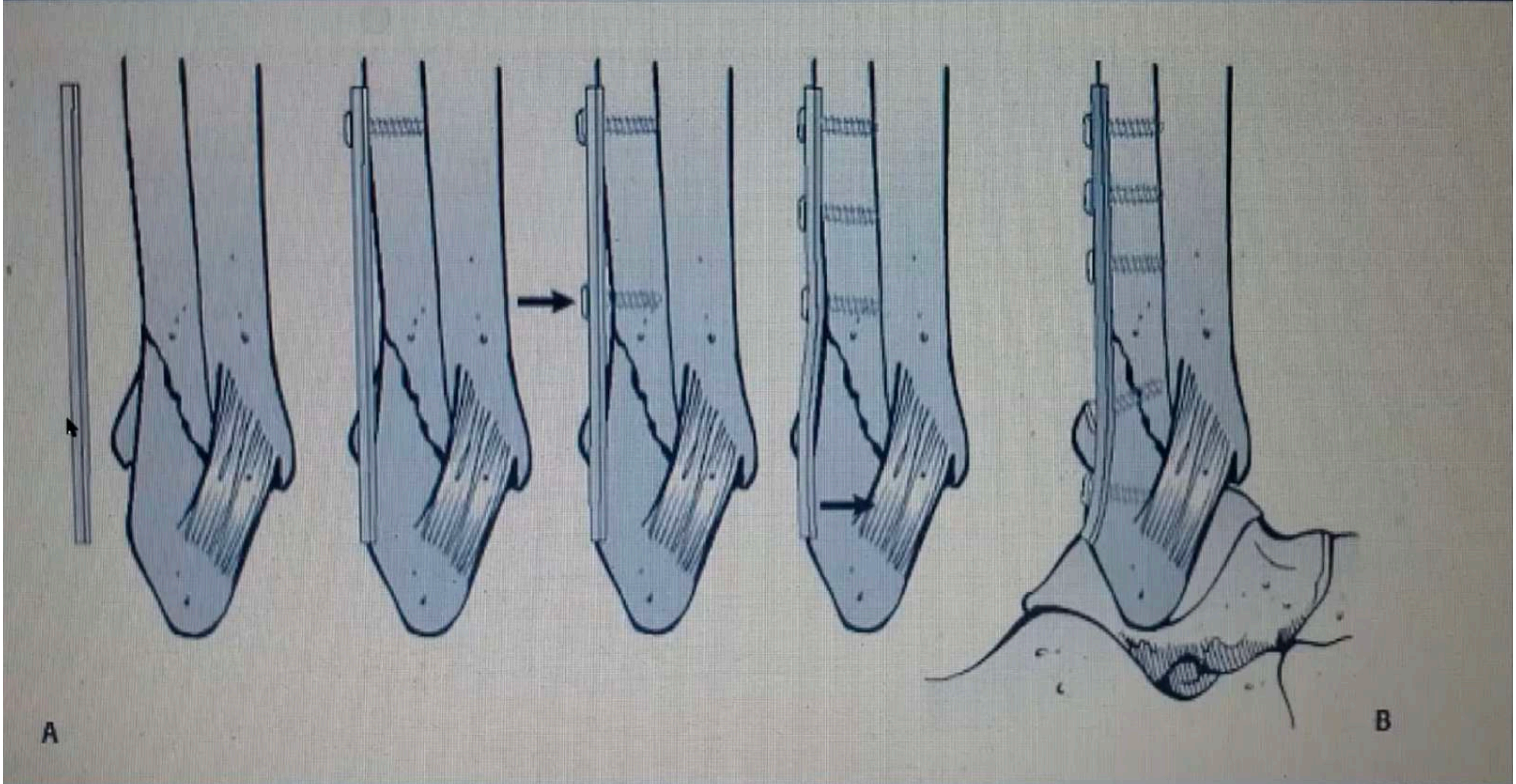
Buttress / Antiglide plate

Buttress is a construction that resists axial load by applying force at 90 degree to the axis of potential deformity.

Meta-/Epiphysial shear or split fractures.

Protect the screw from shear forces across the fracture.

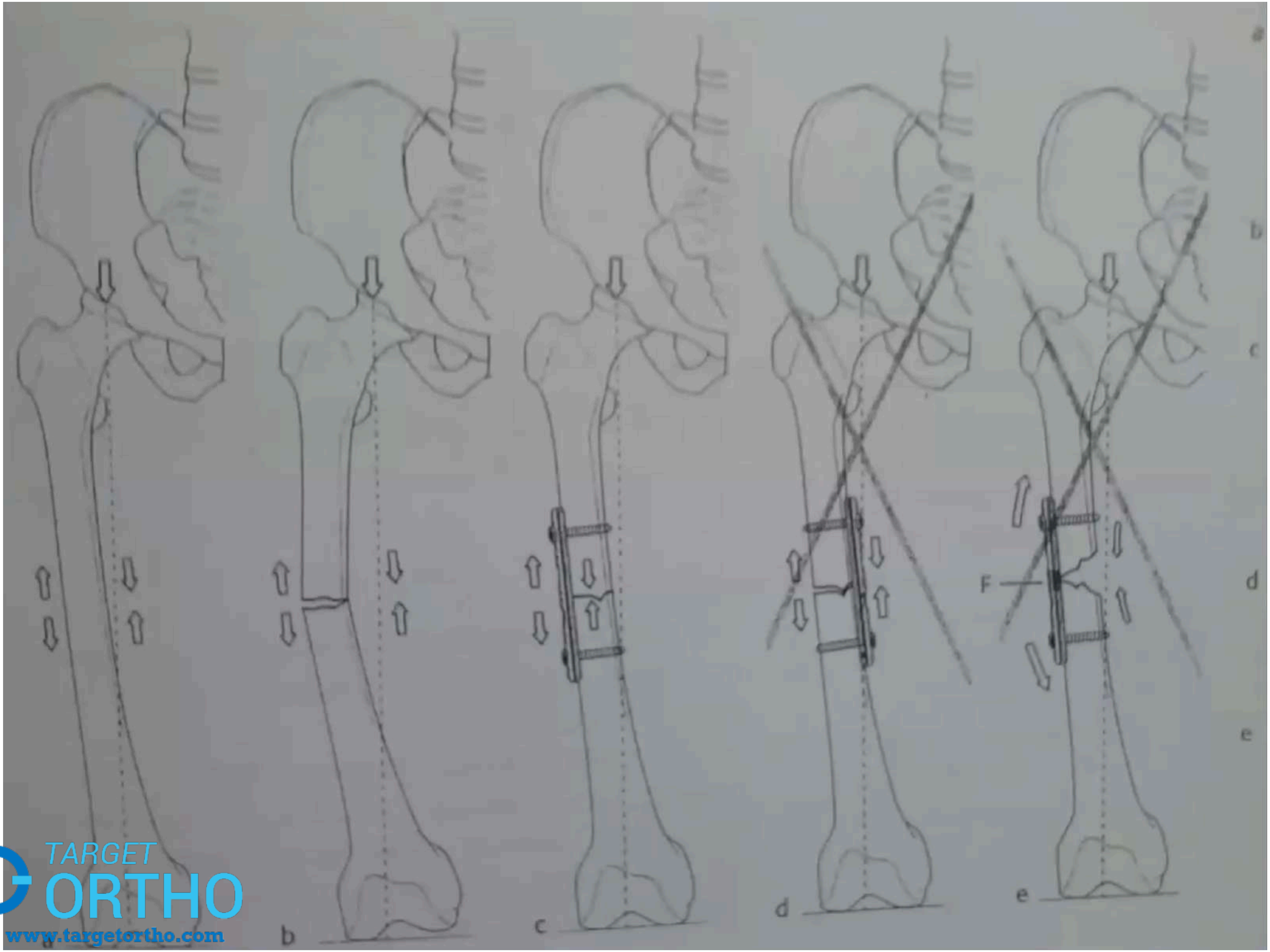
Can be used with or without lag screw.


A
B

Tension band plating

4 criteria:

1. fractures bone must be eccentrically loaded.
2. plate must be placed on the tensile surface.
3. plate must be able to withstand the tensile force.
4. opposite cortex must be able to withstand the compressive force.


b
c
d
e
F

Bridging plate

Relative stability and callus formation.

Multi-fragmentary fractures of diaphysis and metaphysis.

Simple transverse fractures where a short segment of plate will undergo deformation due to high strain on plate and tissue.

Open wedge osteotomies

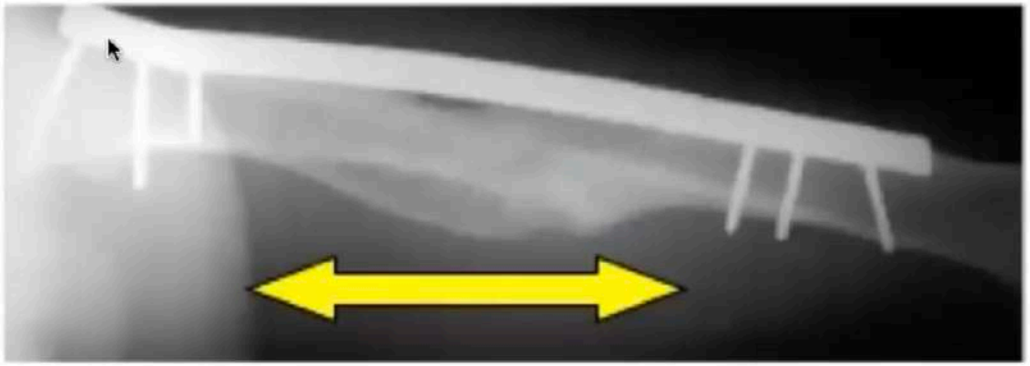
Periprosthetic fractures

Other implants in situ

Bridge Plate

- Fixed to the two main fragments only, leaving the fracture zone untouched.

- Respect the biology of a complex multi-fragmentary fracture and to minimize any additional soft-tissue injury



Technique for bridging

Long plate with few screws- increase the lever arm- distribute the bending forces.

Plate length > 3 times fracture length in comminuted fractures.

Plate length > 8-10 times in simple fractures.

Screw to plate hole ratio : 0.5

Span of 2-3 screws over fracture to be left to prevent stress concentration.

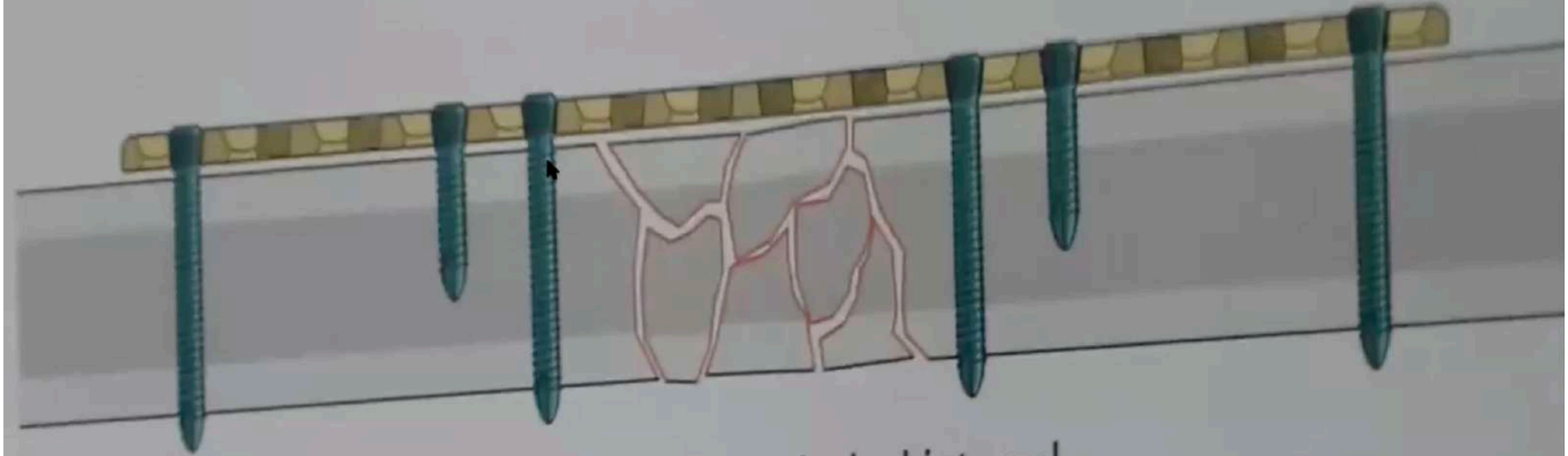


Fig 3-54 Prerequisites for using the LCP as a locked internal fixator: long plate/fixator; adaquate space between the LHS in each main fragment. Avoid stress concentration while leaving out three or four plate holes without screws in the fracture zone.

Monocortical screws

Self drilling, self tapping LHS

Prevent soft tissue and neurovascular injury over opposite cortex

Diaphysial fractures

Good bone quality

Have small working length equal to single cortex, which further decreases in osteoporotic bone, thus should not be used.

Bicortical screws

Self tapping

Weak osteoporotic bone

Thin bone cortex with insufficient working length.

High torque loading in the plated bone segment

Short main fragment that allows only limited number of screws.

Bones with small diameter.

Positioning of the implant

Any bone surface that can be conveniently approached, even with MIPO technique.

Centered over the fracture like standard LCDCP approach.

Length of the implant

Depends on:

1.fracture pattern

2. method and mechanical principle used.

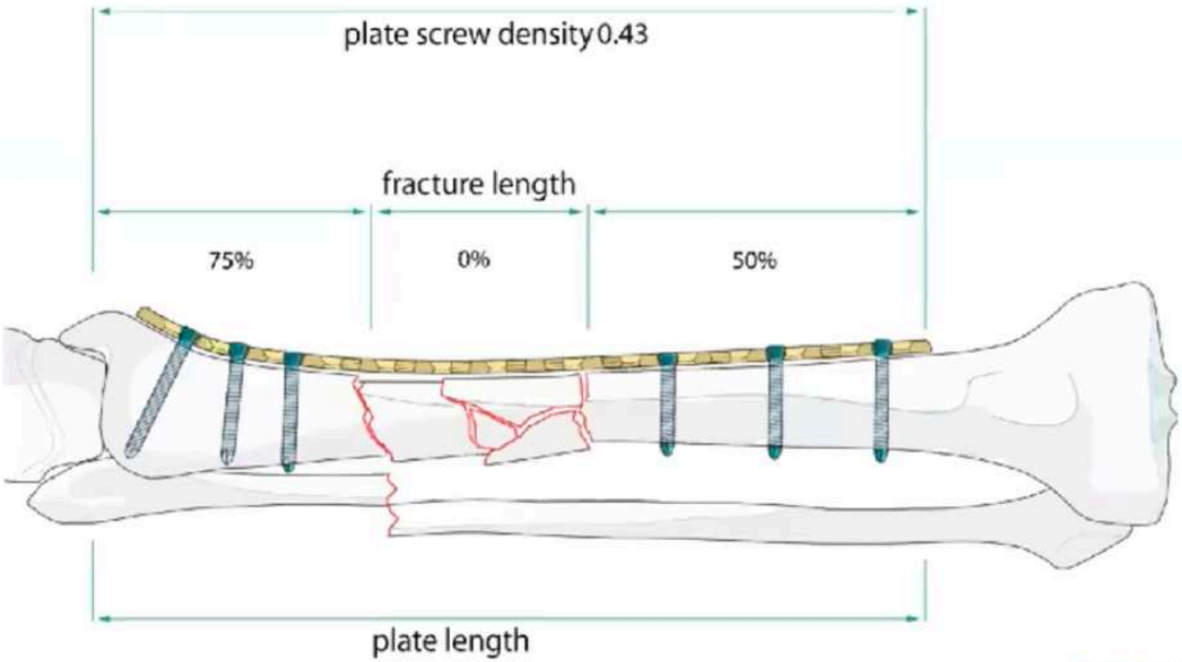
Plate span ratio :

>8-10/1 – simple fracture with interfrag. compression

> 2-3/1 – simple fracture without lag screw

Length of LCP—relative stability

Plate length should be at least 2 or 3 times fracture length
[Gautier E, et al 2003]



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Effect of plate length on screw loading

"end of fragment screws " are maximally loaded.

Bending moment= force * distance

Longer the plate, smaller the pull out force acting on screws.

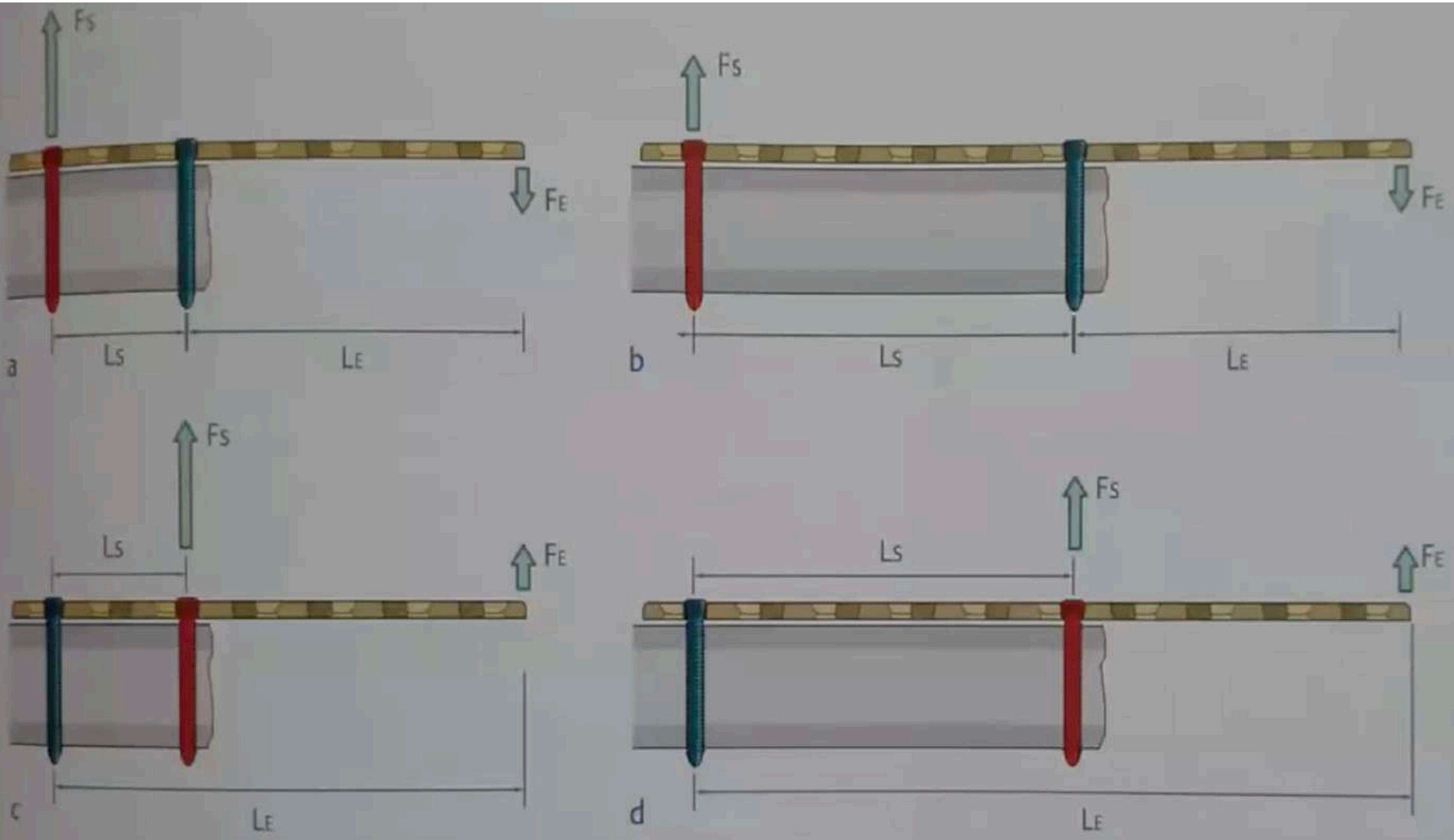


Fig 3-42a–d Pull-out force on screws and working leverage of the plate. When a relatively short plate is used, the screw loading is relatively high due to the short working leverage of the screws in both directions of a bending moment (a, c). Using a longer plate increases the working leverage for each screw. Under a given bending moment the pull-out force of the screws is therefore reduced (c, d).

F_E External force creating a bending moment on the plate.
L_E Lever arm of the external force.
F_S Pull-out force of the screw.
L_S Lever arm of the screw.

Effect of plate length and screw position on plate loading

Bending a plate over short segment enhances the local strain on the implant.

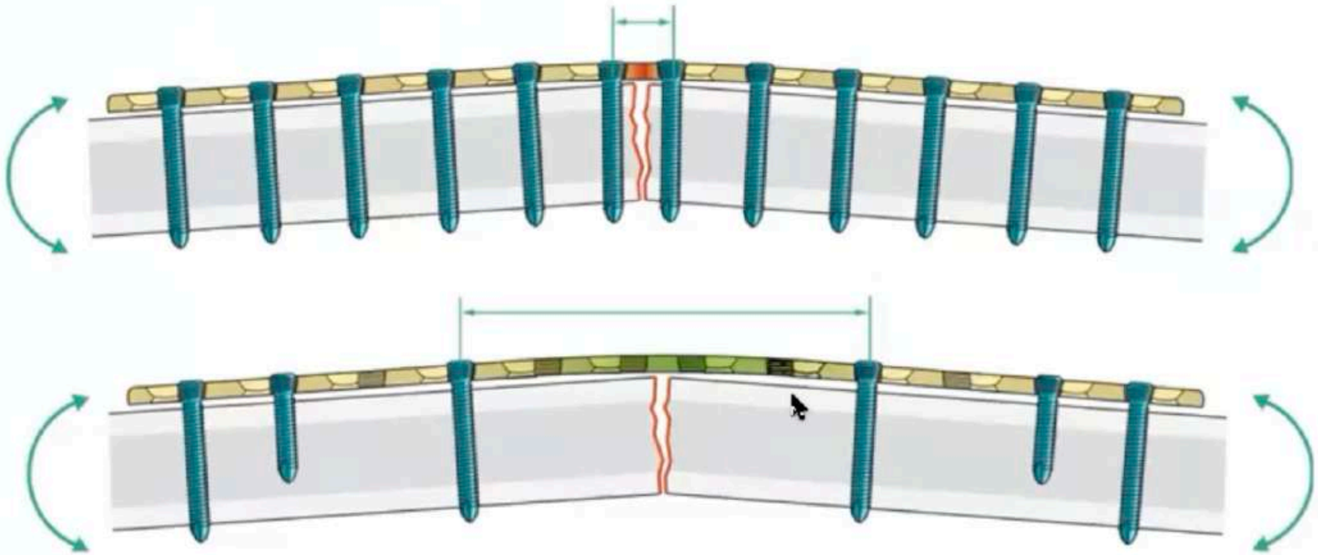
Bending over segment limit deformation and decrease local strain by stress distribution.

Ideal length can be determined by:

1. **plate span ratio**: ratio of plate length to overall fracture length.

2. **plate screw density** : proportion of no. of screws inserted to the no. of holes (< 0.5

Avoid short "middle"



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Number of screws

Earlier AO guidelines recommending specific numbers of screws, mono/bicortical in each fragment- no longer the only decisive factor.

Important to insert few screws with high plate leverage.

Operative steps

Reduce the fracture

Approximate contouring of the plate

LCP application

Insert threaded drill sleeve

Drill the hole and measure length

Insert LHS with torque limiting screw driver

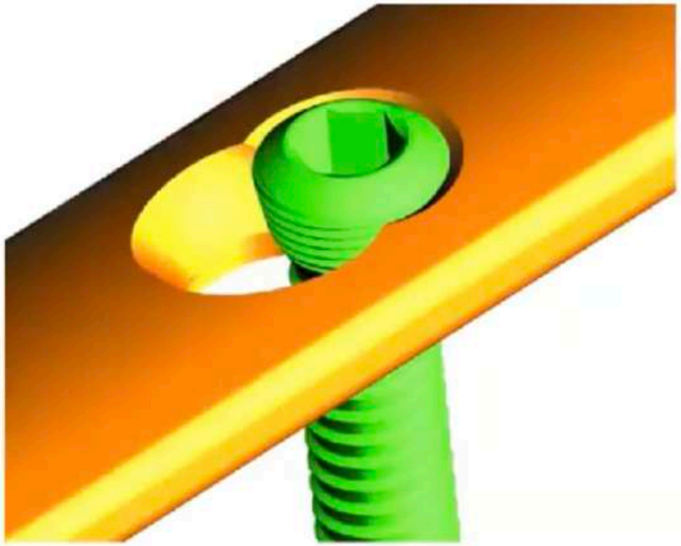
Conventional screw*

- Is used in “smooth” DCU part (dynamic compression unit)
- Can be angulated in hole
- Allows compression

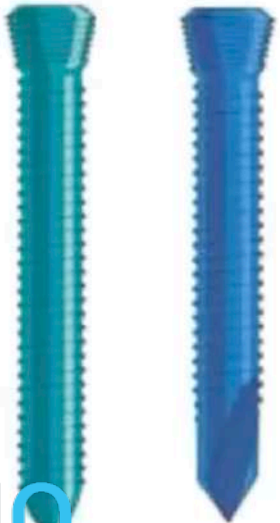
- 3.5 - 4.5mm cortical
- 4.0 - 6.5mm cancellous
- Fully threaded (or shaft)

*** can also be used as independent lag screw**

Locking head screw*



- Is used in the threaded part
- Locks in a fixed angle
- Good purchase in poor bone



- 3.5 - 5.0mm self tapping (green)
- 3.5 - 5.0mm self tapping / self drilling (blue)

*** To be used with a plate**

Drill sleeve for LHS

- With thread - to be screwed into plate hole
  - provides correct direction for drilling
  - its purchase in plate hole must be checked
  - can be used as handle for percutaneous plate insertion

Drill bit

- A drill bit is used prior to screw insertion
- Graduation facilitates measuring

- Table of drill bits

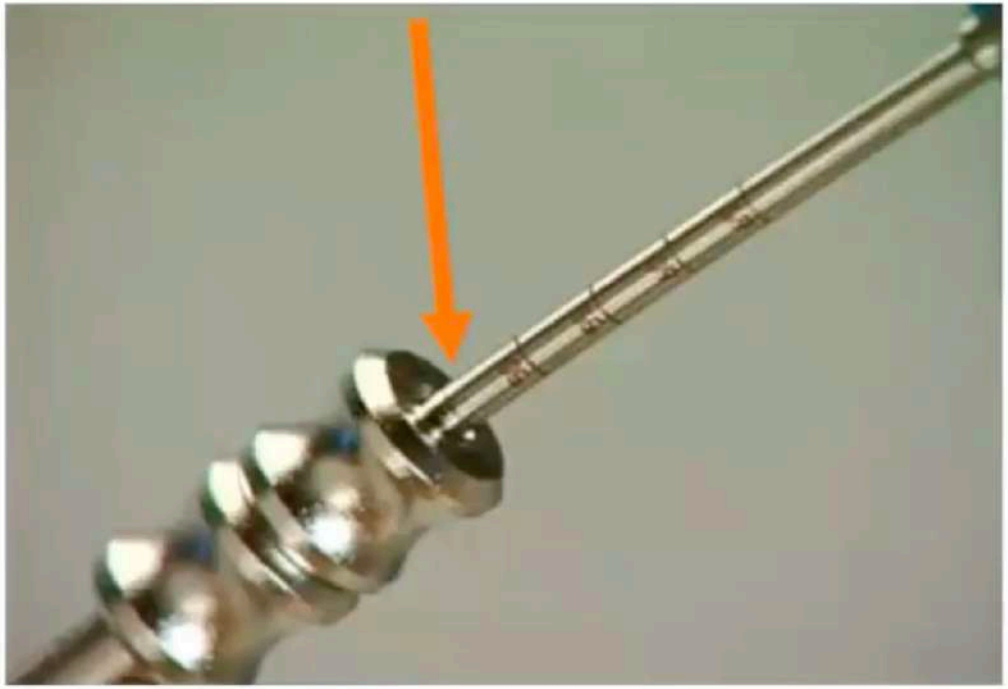
Screw size	Drill bit
3.5	2.8
5.0	4.3

Aiming device for special LCP

- Designed for pre-contoured plates (eg. PHILOS)
- Fix onto plate with central screw
- Facilitates insertion of drill sleeve for different screw angulations
- Must be removed after use

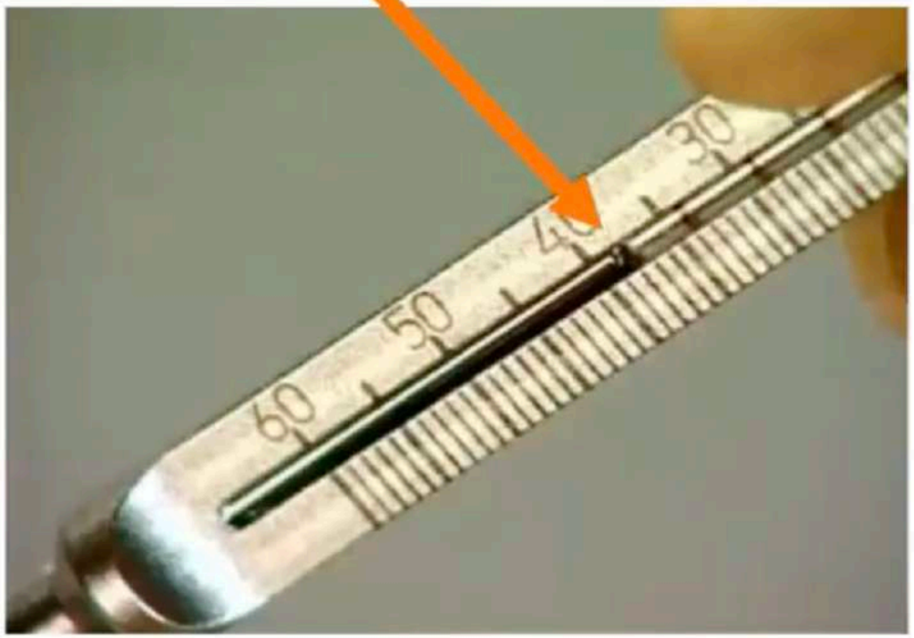
Measuring of screw length 1/2

1. Graduation on drill bit
   - Most commonly used
   - Drill guide indicates the length



Measuring possibilities 2/3

2. Depth gauge
   - Adapted to size of screw
3. Measuring device for guide wire
   - End of K-wire indicates length

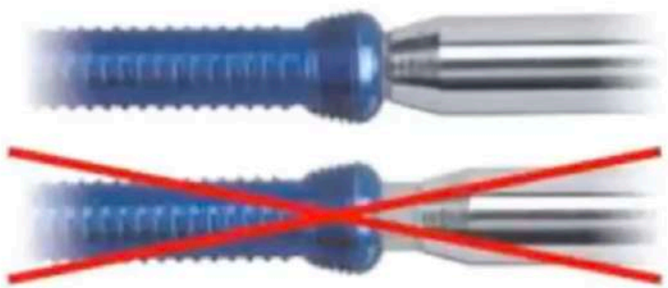


Screwdriver for LCP

- Use of torque limiting screw driver or
- Use of attachment for power drill with shaft
- Limited torque of
  - 3.5mm screw is 1.5Nm
  - 5.0mm screw is 4.0Nm

Insertion—Screwdriver

- Use of corresponding holding sleeve
- Screwdriver must totally inserted into recess



- Insert screw until "click" is heard
- Use of well maintained and undamaged screwdriver

Additional instrument

- Guide to predrill a hole for self-drilling LHS

Conclusion 1/2

Principle	Absolute stability	Relative stability
Method	Compression	Splinting
Function of plate	Fixation with standard screws - neutral / eccentric position - lag screw	Fixation with locking head screws Internal fixator principle
Reduction	Direct	Indirect
Approach	Open Large incision	Less invasive Small incision - no touch
Healing	Primary – No callus	Secondary - Callus

Sizes of DCP

Name of plate	Small	Narrow	Broad
Width	11 mm	13.5 mm	17.5mm
Profile	4 mm	5.4 mm	5.4 mm
Screw	2.7 , 3.5 cortex screw and 4 mm cancellous screw	4.5 mm cortex screw & 6.5mm canellous screw	4.5 mm cortex screw & 6.5mm canellous screw

Sizes of LCDCP

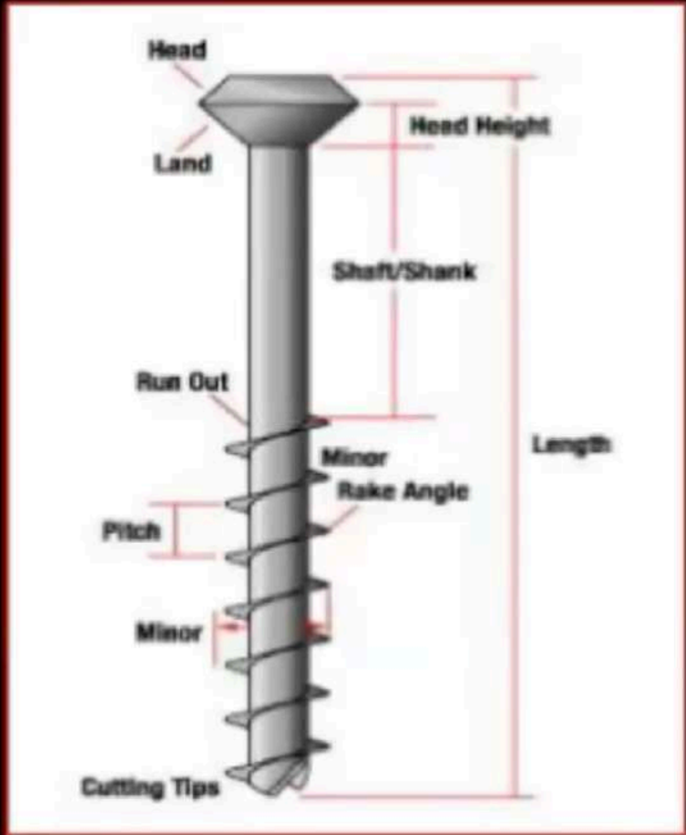
Name of plate	Small	Narrow	Broad
Width	11 mm	13.5 mm	17.5mm
Profile	4 mm	5.4 mm	5.4 mm
Screw	2.7 , 3.5 and 4 mm cancellous screw	4.5 mm & 6.5mm canellous screw	4.5 mm & 6.5mm canellous screw

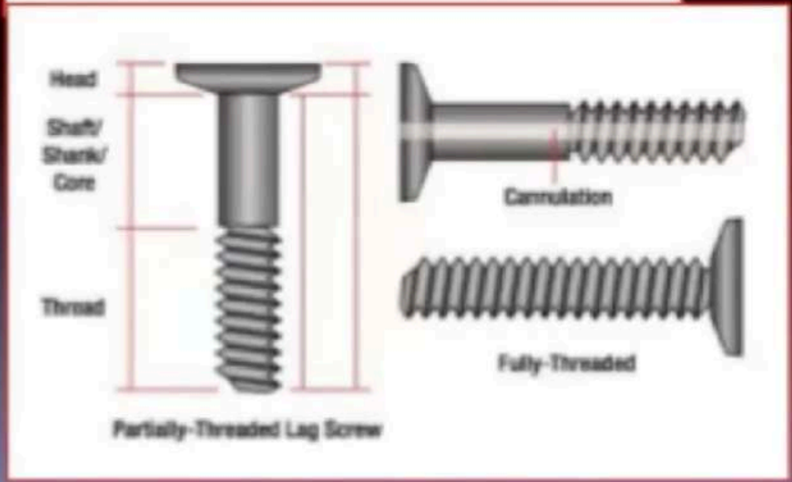
Sizes of LCP

Name of plate	Small	Narrow	Broad
Width	11 mm	13.5 mm	17.5mm
Profile	4 mm	5.0 mm	5.0 mm
Screw	4 mm locking screw	5 mm locking screw	5 mm locking screw

SCREWS

- 4 functional parts
  - Head
  - Shaft\ Shank \Core
  - Thread
  - Tip





Head: Recess Types

- 1. Slotted
- 2. Cruciate
- 3. Philips
- 4. Hex/ Allen
- 5. Torx (eg Stardrive of Synthes)

Screw: Run out

- Transition between shaft and thread
- Site of most stress riser
- Screw break
  - Incorrectly centered hole
  - Hole not perpendicular to the plate

Screw: Thread

- Inclined plane encircling the root
- Single thread
- May have two or more sets of threads

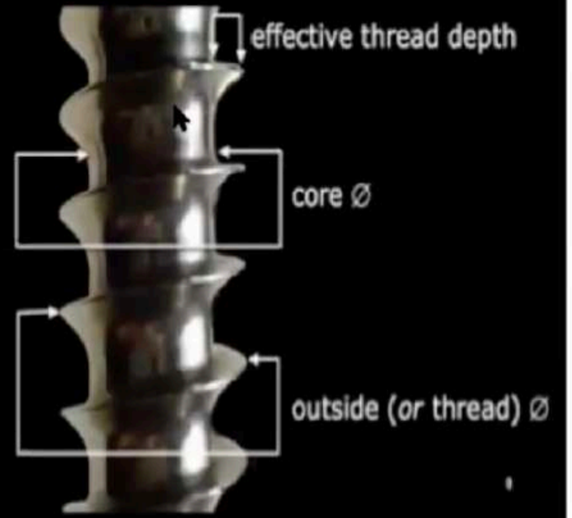
- V-thread profile: more stress at sharp corner
- Buttress thread profile: less stress at the rounded corner

Core

- Solid section from which the threads project out wards. The size of core determines the strength of screw and its fatigue resistance. The size of drill bit used is equal to the core diameter.

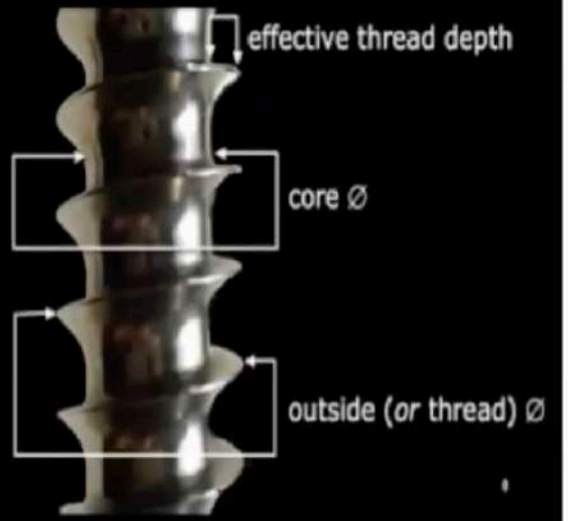
Screw: Core Diameter

- Narrowest diameter across the base of threads
- Also the weakest part
- Smaller root → shear off
- Torsional strength varies with the cube of its root diameter



Screw: Thread Diameter

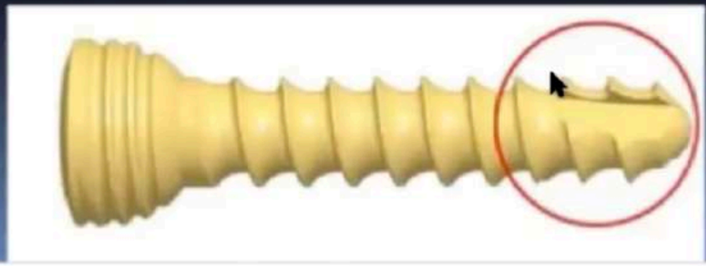
- Diameter across the maximum thread width
- Affects the pull out strength
- Cancellous have larger thread diameter



Screw: Tip Designs

1. Self-tapping tip:

- Flute
- Cuts threads in the bone over which screw advances
- Cutting flutes chisel into the bone and direct the cut chips away from the root



Screw: 2.Non self tapping

- Lacks flutes
- Rounded tip
- Must be pre-cut in the pilot hole by tap
- Pre-tapped threads help to achieve greater effective torque and thus higher inter-fragmental compression
- Better purchase

Screw: 3.Corkscrew tip

- Thread forming tips
- In Cancellous screws which form own threads by compressing the thin walled trabecular bone
- Inadequate for cortical bone

Screw: 4.Trochar Tip

- Like self tapping
- Displaces the bone as it advances
    - Malleolar screw
    - Schanz screws
    - Locking bolts for IMIL

Screw: 5.Self drilling self tapping

- Like a drill bit
- In locked internal fixator plate hole
- Pre-drilling not required
- Flute
- Good purchase in osteoporotic and metaphyseal area

Locking Screws vs Cortical Screws

- MALLEOLAR SCREW:
  - smooth shaft
  - partially threaded
  - trephine tip : no tapping needed
  - was designed as lag screw for malleoli fixation NOW small cancellous screws preffered
  - distal humerus and lesser trochanter
  - size : 25mm – 75 mm

Special Screws

- Locking bolt
- Herbert Screw
- Dynamic Hip Screw
- Malleolar Screw
- Interference screw
- Acutrak screw

- Pedicle screw

- Suture anchor

Headless Screws

Herbert screw bridging a scaphoid fracture

Acutrak screw

Bioabsorbable Screws

The most common materials used are polylactic acid (PLA), poly-L-lactic acid (PLLA), and polyglycolic acid.

TAP

- To cut threads in bone of same size as the screw to facilitate insertion
- Flutes : to clear the bone debris
- Two turns forward and half turn backward recommended to clear debris
- Used with sleeve
- Done manually
- Power tapping NOT recommended
- For cancellous bone : short and wide thread ,
  slightly smaller dia than screw

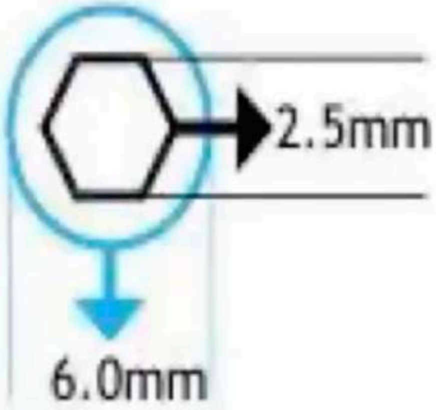
Lag screw principles

Near cortex

Far cortex

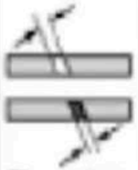
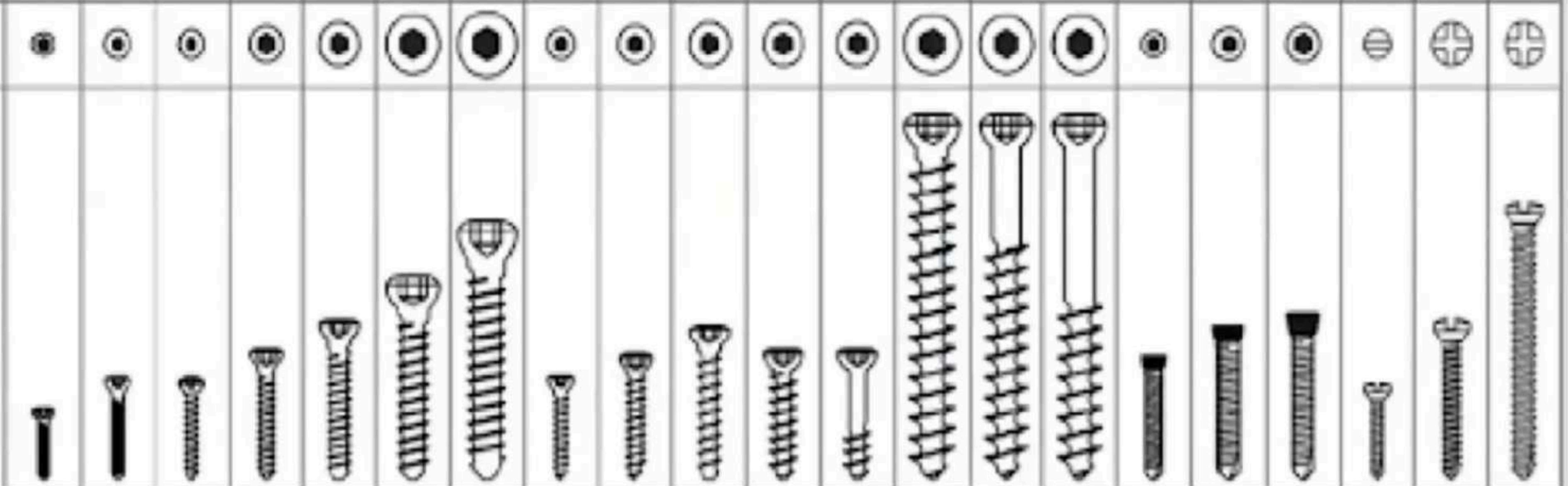
Thread Diameter:	3.5mm
Thread Pitch	1.25mm
Core Diameter	2.4mm
Head Diameter	6.0mm
Hexagonal Socket	2.5mm
Drill bit for:	
Threaded hole	2.5mm
Gliding hole	3.5mm

HEX HEAD



3.5mm Cortex Screw

Standard Screws, Locking Screws, Drill Bits and Taps

Screw Diameter (mm)																					
Thread Diameter	1.5	2.0	2.4	2.7	3.5	4.5	5.5	2.2	3.0	3.5	4.0		6.5			2.4	2.7	3.5	2.0	2.7	3.5
Screw Type	Cortical							Cancellous								Locking Head			Sherman		
								Full thread			Full thread	Partial thread	Full thread	32mm thread	16mm thread						
Drill bit and Tap Diameter (mm)																					
Drill Bit for Gliding Hole	1.5	2.0	2.5	2.7	3.5	4.5	5.5	2.2	3.0	3.5	4.0	2.5	6.5	4.5					2.0	3.0	3.5
Gliding hole  Threaded hole																					
Drill bit for threaded hole	1.1	1.5	1.8	2.0	2.5	3.2	4.0	1.5	2.0	2.5	2.0		3.2			1.8	2.0	2.7	1.5	2.2	2.7
Tap	HA 1.5	HA 2.0	HA 2.4	HA 2.7	HA 3.5	HA 4.5	HA 5.5			HB 3.5	HB 4.0		HB 6.5			LC 2.4	LC 2.7	LC 3.5	LC 2.0	LC 2.9	LC 3.5
Drive Type	1.5mm Hex			2.5mm Hex		3.5mm Hex		1.5mm Hex	2.5mm Hex		2.5mm Hex		3.5mm Hex			1.5mm Hex	1.5mm Hex	2.5mm Hex	Single Slot Recess	Cruciate Recess	

IM NAILING

THE JOURNEY SO FAR.........

- Evolved in the past 70 years
- Gold standard for fractures of the long bones.
- First written record dates back to 1500s – Aztecs used **wooden sticks** for treatment of non union.
- Gluck in 1890 – 1st description of interlocked intramedullary devices
  - **An ivory nail** with holes at the ends thru which ivory interlocking pins was passed
- S.P. nail in 1925 – first successful intramedullary fixation
- Gerhardt Kuntscher : **"father of intramedullary nailing"**
  - Developed principles of nailing
  - Foundation of "1st generation Nailing".
- March 12, 1945 – Time magazine wrote an article "AMAZING THIGH BONE". – which made the United States & the rest of the Europe aware of metallic nail being put in the medullary canal of fractured femur of American soldier.