# WO-05 Fractures: reduction, splinting, traction and the traditional bonesetters

HEALING after the FALL, research library, WO-05

Researched 10 October 2026 by Claude Opus agent for THRIVING after the FALL, Book Four. Library document, unverified.

## How to read this

This report follows a broken bone from the first hour to the return to work. Where the material allows, each section separates what the tradition says it does, what the record shows it did, and what modern science infers.

There are four working sources, all read in full for the chapters cited: - King's *Primary Surgery* volume 2, written for district hospitals without an orthopaedic surgeon (King 2018) - the two ICRC war surgery manuals (Dufour 1998, Giannou 2013) - Gray's 1919 account of the Thomas splint (Gray 1919)

Most of the bonesetter literature was read as abstracts, as the references say.

The first-aid report (THRIVING library, FO-09) already covers transport splinting and tourniquets. This report builds on it and says where it disagrees.

## 1. Findings by section

### 1.1 Diagnosis by hand

**The tradition.** Yoruba bonesetters diagnose by swelling, pain, loss of function, angulation, abnormal mobility and crepitus (Omololu 2008). This is the surgeon's list. The bonesetter's eye is not the weak point of the tradition. The splint is.

**The manuals.** King lists pain, swelling, deformity and loss of function. He insists on checking pulses and sensation beyond the break before and after any manipulation (King 2018, ch 58). His rule is to reduce a displaced fracture without waiting for the swelling to settle, and without waiting for an X-ray if none is available.

Crepitus should not be sought on purpose, because each grind hurts and can damage tissue [VERIFY, standard teaching, not found in these words].

**The checks needed:** - **Circulation.** Radial pulse at the wrist. Dorsalis pedis and posterior tibial pulses at the foot. Capillary refill and warmth compared with the other side. - **Arm nerves.** Median, ulnar and radial nerves: thumb opposition, finger spreading, wrist extension. - **Leg nerve.** The common peroneal nerve lifts the foot. A splint can crush it where it winds round the fibular head (King 2018, ch 59). - **Femur.** Compare leg length from the anterior superior iliac spine to the medial malleolus. King uses this to manage traction without X-ray (King 2018, ch 67). - **Union.** No tenderness, no warmth, fragments moving as one, and no night pain (King 2018, ch 58). For the femur, add a painless active straight-leg raise (Giannou 2013).

**What modern science infers.** Clinical diagnosis of a displaced long-bone fracture is reliable. Clinical diagnosis of an undisplaced, scaphoid or hairline ankle fracture is not. After the Fall, treat a painful, swollen limb with point tenderness over bone as broken. Splint it for two weeks and re-examine [VERIFY, my inference].

### 1.2 Reduction of the four named fractures

Every manual uses Charnley's principle. Most closed fractures keep a strip of periosteum intact on the concave side, and this strip acts as a hinge. To reduce: 1. Exaggerate the deformity to unlock the fragments. 2. Pull along the line of the limb. 3. Swing the distal fragment back into line (King 2018, ch 59).

Charnley's 1950 book set out to "re-emphasise the non-operative method" (Hossain 2007). I could not read Charnley himself and rely on King, who quotes him at length. The step-by-step methods are in section 11.

**Colles' fracture** (King 2018, ch 64). - Do not reduce an impacted fracture with under 15 degrees of dorsal angulation. - Over 60 years, apply a palmar slab whatever the position and move the wrist from 4 weeks. - The acceptable position is: - joint surface tilted 20 to 30 degrees towards the ulna - 0 to 10 degrees forward tilt - no step over 2 mm - Reduce under a haematoma block, with 5 kg of counterweight on the upper arm or with finger traps. - Cast to the palm crease with the knuckles free, for 3 weeks, or 6 if unstable.

Trials favour doing less in the old. Seventy-three patients aged 65 or over did as well in a cast as with a plate (Arora 2011, abstract). The CROSSFIRE trial in patients aged 60 or over found plating no better at 12 months (CROSSFIRE 2021, abstract).

**Ankle** (King 2018, ch 71). - Reduce a dislocated talus at once by pulling on the heel, before the stretched skin dies. - A swollen ankle can wait 2 to 7 days, elevated in stockinette traction about 20 cm above the bed. Most reduce in 2 to 3 days that way. - King quotes Charnley that "most malleolar fractures have only 2 parts", so closed reduction usually works. - A posterior lip fragment over 25 to 30% of the joint makes the ankle unstable.

**Femoral shaft.** The thigh can hold more than a litre of blood (King 2018, ch 67). The femur is not reduced by one manipulation. Traction reduces it and holds it over weeks (section 1.5). King aims for about 1 cm of overlap and accepts 2 cm, but a gap of 2 mm from over-traction can prevent union.

**Clavicle.** A sling and active movement are enough, and union is almost universal (King 2018, ch 61). One trial randomised 79 patients (61 completed) to a figure-of-eight bandage or a sling. The sling caused less discomfort with the same result (Andersen 1987, abstract). Reduce only if a fragment tents the skin.

**Tibia and humerus.** The tibia is the long bone most often broken in combat (Giannou 2013), and it is the bone Sarmiento's bracing was built for. For the humeral shaft, the 1998 ICRC manual applies a padded U-slab from above the shoulder round the elbow to the armpit, with a collar and cuff (Dufour 1998).

### 1.3 Splinting, padding and plaster from gypsum

**Rules shared by every source.** - Splint the joints above and below a shaft fracture (King 2018, ch 58, Dufour 1998). - Leave the knuckles and toes free. - Splint the hand with the knuckles at 90 degrees and the finger joints straight, because knuckle ligaments shorten if held straight (Dufour 1998).

**Positions of function.** The sources differ slightly. - King: ankle neutral, elbow 90 degrees mid-prone, knee 5 to 10 degrees, wrist 15 to 20 degrees extended (King 2018, ch 59). - ICRC: knee at least 15 degrees so the leg cannot rotate in the cast, ankle at 90 degrees because equinus can become permanent (Dufour 1998). - I would use 15 degrees at the knee, for ICRC's reason.

**Padding.** - Pad the fibular head, malleoli, heel, patella and ulnar head (King 2018, ch 59, Dufour 1998). - King gives 2 to 3 layers for the arm and 3 to 4 layers, about 1 cm, for the leg. - The ICRC table: "Too tight = tourniquet, Too

loose = non-union" (Giannou 2013). - It adds that malunion and non-union "never result from the proper use of a POP cast". They come from too much padding or too little plaster.

**Slab first, cylinder later.** - Swelling peaks in the first 24 to 48 hours. In that period the only safe plasters are slabs, or cylinders split to the skin. Never put a complete, unsplit, unpadded cylinder on a fresh fracture (Dufour 1998). - A slab covers no more than two-thirds of the circumference. - King makes it about 4 layers thick (King 2018, ch 59). ICRC asks for 6 to 8 layers for a back slab (Dufour 1998), probably because of differences in bandage weight [VERIFY]. - Convert to a cylinder after day 3 to 5, with a strip of wool under the new turns to mark the line for cutting (Dufour 1998). - King splits every first circular cast on forearm and lower leg while it is soft, 3 to 4 minutes after application (King 2018, ch 59). - A 5 cm rubber strip under the cast lets it be split safely with a knife (Dufour 1998). - A large cast takes up to 72 hours to dry, and the patient takes no weight for 48 hours (King 2018, ch 59). ICRC gives about 40 hours (Giannou 2013). - Never apply a circular cast to an unconscious patient.

**Improvised materials.** - A walking heel can be an old tyre, hard wood, or a 5 cm cube of plaster set just in front of the line between the malleoli (Dufour 1998). - Wood, bamboo or tin strips stiffen a cast when plaster is short (King 2018, ch 59). - Nigerian bonesetters use bamboo, rattan, palm-leaf midrib, raffia palm, plywood, bark and cardboard (Dada 2011, Omololu 2008). The materials are sound. The binding is what fails (section 1.10).

**History.** Antonius Mathijsen, a Dutch army surgeon, published the plaster bandage in 1852: dry plaster rubbed into linen and wetted on the limb. Nikolai Pirogov independently dipped coarse cloth in liquid plaster in the Crimean War. Casting was general in Europe by about 1870 (Szostakowski 2017). Before it, splints were wood, card, leather and starch or egg-white bandages, slow to set and weak.

**Making plaster from gypsum.** Plaster of Paris is calcium sulphate hemihydrate. Gently heating gypsum drives off three-quarters of its water. Mixed with water again, the powder takes the water back and sets. This is a safe preparation, and two sources give conditions: - An Indian building-research leaflet: 110 to 150 °C for 1 to 2 hours (CBRI 2024). - A New Zealand chemistry text: about 120 to 130 °C, with a warning that overheating spoils the product (NZIC).

The overlap, 120 to 130 °C, is a slow oven, not a fire. Heated much hotter, gypsum becomes "dead-burned" and will not set [VERIFY, one source]. Damp plaster "quickly becomes crumbly" (Dufour 1998).

### 1.4 The Thomas splint and the claimed fall in mortality

Hugh Owen Thomas described his splint in 1875 (Robinson 2009, abstract). It is a padded ring round the top of the thigh with two side bars, and the foot is pulled against it. His nephew Robert Jones brought it to the British Army in the First World War.

**What the record shows.** The source of the famous figure is Gray, who ran the work (Gray 1919, pp. 57 to 61). - He writes that the death rate from gunshot fracture of the thigh "was at one time of the war about 80 per cent., and nearly 50 per cent. occurred at casualty clearing stations". - During the spring 1917 battle (Arras), in 1,009 cases, the death rate at the casualty clearing stations was 15.6%. - Amputation was needed in 17.2%. Only 5% arrived unfit for immediate operation. - Gray credits early splinting at the front, with boots and trousers left on and an orderly holding traction throughout, together with surgery at the clearing stations.

**The comparison is not like-for-like.** The 80% is overall mortality "at one time". The 15.6% is clearing-station mortality in one battle. It leaves out men who died before reaching a clearing station and men who died later at the base. The same period also brought routine wound excision, operation within hours, and better management of shock [VERIFY for transfusion, general knowledge].

A reasonable reading is that the splint let men with shattered femurs be carried over broken ground without the fragments tearing vessels at every step. Much of the fall in mortality is real, but the splint's own share cannot be

separated out. Retellings give other end points, such as 15.8% (Pearkes 2021, citing Gray), and some lower. I treat anything below Gray's 15.6% as unsourced [VERIFY].

The brief's lead is wrong in two places. "Robinson and O'Meara 2018" is the 2009 *Journal of Bone and Joint Surgery (British)* paper (Robinson 2009), and Gray's data come from 1917, not 1916.

**How Gray applied it.** - Traction was fixed with Tapson's heel clip, or with a clove hitch over the padded ankle outside the boot. - A padded posterior splint and a footpiece were added. - No encircling bandage was applied before traction was made.

He warns that extension can dislodge the clot from a torn artery, and that deaths occurred in men already bled out (Gray 1919).

**Modern measurements.** The windlass method gave a mean 92 N of traction, against 138 N with a pulley and weight (Pearkes 2021). A 7 kg weight gives about 69 N. Higher sustained force causes pressure necrosis in the groin.

King calls the Thomas splint excellent for first aid and the first days, but not for definitive care. It stiffens the knee and causes groin sores (King 2018, ch 67).

FO-09 reports that a 2023 review found no clear advantage of traction splints over simple splints before hospital (THRIVING library, FO-09). I agree for a short carry. I disagree for this book. After the Fall the carry may last hours or days, and Gray's record, though confounded, points to traction mattering most on long, rough evacuations.

### 1.5 Traction, the cast brace and functional bracing

**Skin traction.** - ICRC limits it to 5 kg, on healthy skin only (Giannou 2013). - Gallows traction suspends an infant's legs vertically, for children up to about 12 to 15 kg.

**Femoral skeletal traction.** The two manuals differ on the details.

| Detail | King (Perkins method) | ICRC |
|---|---|---|
| Pin site | Tibia, 3 cm below the tubercle | 2.5 cm below and 2.5 cm behind the tubercle, from the lateral side, by hand drill |
| Weight | One-seventh of body weight (10 to 14 kg for a man, 7 kg for a small woman) | 1 kg per 10 kg of body weight |
| Bed | Foot raised 4 cm per kg of traction | Foot raised |

Sources: King 2018, ch 67, and Giannou 2013.

ICRC also advises: - Check alignment several times a day for 2 weeks. The mid-inguinal point, knee, ankle and second toe should lie in one line. - 10 degrees of angulation is acceptable. Valgus is worse than varus. - A loose pin is an infected pin and must be removed. - The fracture is "sticky" at about 4 weeks. - Traction comes off at 4 to 5 weeks on clinical tests. - Clinical union comes at 7 to 8 weeks. - No callus at 8 weeks is a bad sign.

King's timetable is 6 to 8 weeks in traction, discharge at 8 to 10 weeks with 90 degrees or more of knee flexion, and 8 to 12 weeks in all without weight-bearing. A hinged cast brace from 4 to 6 weeks frees the bed sooner (King 2018, ch 67, Giannou 2013). King warns against a tibial pin in children with open growth plates.

**Perkins traction.** The patient lies on a split bed and bends the knee over its edge while the femur is held. King gives the secret: 10 to 30 minutes of active exercise several times a day from day 3, because "it is the callus formed

during the 1st 10 days that determines the outcome". He adds that "medical assistants soon learn to manage it most competently" (King 2018, ch 67).

| Series | Patients | Result |
|---|---|---|
| Buxton 1981 (abstract) | 50 | 47 united by 12 weeks, all with 120 degrees or more of knee flexion |
| Addis Ababa (Bezabeh 2012, secondary) | 68 | 1 non-union, 1 malunion, 16.2% shortened over 2 cm, 11.8% pin infection |
| Sierra Leone (Gosselin 2007, secondary) | 53 | Mean 45 days of traction, 92.6% healed, 7.4% non-union, 9.3% malunion, 42.6% pin-tract infection |

These are good results for a bed, a pin, a rope and a bag of stones. The price is two months of bed and nursing for each patient.

**Other traction.** - Calcaneal traction for the tibia: 0.5 kg per 10 kg. - Olecranon traction for the humerus: 2 kg (Giannou 2013). - King warns never to keep an uninfected tibia in traction beyond 2 weeks, or 3 if open, because of the risk of non-union (King 2018, ch 70). - He judges Böhler-Braun traction slower and less satisfactory than Perkins (King 2018, ch 67).

**Sarmiento's functional bracing.** Augusto Sarmiento argued that a fracture heals better when the patient walks in a close-fitting brace that leaves the joints free. - **Tibia, 1995.** In 1,000 closed tibial fractures, non-union was 1.1%. Shortening was 12 mm or less in 95%, and the mean final shortening (4.28 mm) was no worse than the initial (4.25 mm). Angulation was 6 degrees or less in 90%. An intact fibula is a relative contraindication, and delay in bracing slows healing (Sarmiento 1995, abstract). - **Tibia, 1989.** In 780 tibial fractures, closed fractures healed in a mean 17.4 weeks and open ones in 21.7 weeks, with 2.5% non-union (Sarmiento 1989, abstract). - **Humerus.** Of 922 shaft fractures, 620 (67%) were followed. Non-union was 6% in open fractures and under 2% in closed ones. 87% healed in less than 16 degrees of varus, and 98% lost no more than 25 degrees of shoulder movement. The first splint was worn a mean of 9 days (Sarmiento 2000, abstract).

King adopts the patellar-tendon-bearing (PTB) cast for the tibia at about 6 weeks, once the fracture is sticky (King 2018, ch 70). It is made of ordinary plaster, so any village that can make plaster can make one.

### 1.6 Open fractures

**Before antisepsis.** Mortality from open long-bone fractures was about 50% (JBJS Classics 2016, secondary). - In 1863, 221 compound femur fractures in the Confederate army were treated without operation, and 52% recovered (Sorrel 1864). - In the Union army's tabulation of 1,761 such cases, there were 796 deaths and 321 recoveries. That is about 71% mortality where the outcome was known (Surgeon-General 1871, my calculation) [VERIFY].

**After debridement, before antibiotics.** José Trueta in the Spanish Civil War treated 1,073 open fractures with 6 deaths, 976 satisfactory results and 91 poor ones (Short 1939, reviewing Trueta). His method followed H. Winnett Orr's: 1. Excise the dead tissue. 2. Leave the wound open. 3. Pack it with vaselined gauze. 4. Encase the limb in plaster including the joints above and below, and leave it for weeks (Stout 1954).

ICRC still describes a cylindrical tibial cast without a window, with minimal padding and a walking heel, off at 6 weeks, with "a high incidence of bony union" (Giannou 2013). It worked because dead tissue was removed, the wound drained, and hands and flies were kept off it [VERIFY, my inference]. For a world without antibiotics, this is the most important historical fact in this report.

**Antibiotics.** A Cochrane review of 8 trials and 1,106 participants found a risk ratio for early infection of 0.43 (95% CI 0.29 to 0.65), with an absolute risk reduction of 0.07 (Gosselin 2004). That means about 14 patients treated to prevent one infection [VERIFY, my calculation].

Other studies: - **Patzakis 1974.** In 310 open fractures, infection was 2.3% with cephalothin against about 14% with no antibiotic (abstract and secondary). - **Gustilo 1976.** In 1,025 fractures, type III wounds had 44% infection when closed at once against 20% when closure was delayed. These are small numbers, read through JBJS Classics 2015. - **Lack 2015.** In 137 type III tibial fractures, antibiotics later than 66 minutes raised the odds of infection 3.78 times, and cover after 5 days raised them 7.39 times. Infection was 2.8% when both were early and 40.5% when both were late (abstract). The 66-minute threshold has been contested [VERIFY].

**The ICRC regimen for compound fractures** (Giannou 2013, Annex F.3). - Benzylpenicillin 5 million units intravenously four times a day for 48 hours. - Then penicillin V 500 mg by mouth four times a day until delayed primary closure. - Add metronidazole 500 mg intravenously three times a day if more than 72 hours have passed since injury. - Tetanus measures for everyone.

This dose has one primary source, so the two-source rule is not met. It is left for WO-06 [VERIFY]. - **Harms.** Anaphylaxis and diarrhoea. Very high intravenous penicillin doses can cause seizures [VERIFY]. - **After the Fall.** Penicillin exists only as salvaged stock, which loses potency with heat and time.

**What works without drugs.** King, ICRC and Trueta agree on these rules: - Wash the wound out copiously (King 2018, ch 58). - Excise dead muscle and loose dead bone. - Never close the wound primarily. King lists primary closure among his "avoidable disasters". - Close at 4 to 7 days or let the wound granulate.

**Osteomyelitis.** This is the long tail. It appears in 2.8 to 3.6% of complicated bonesetter cases (Unadkat 2025), and scarification can seed it into a closed fracture (Dada 2011). Its surgery is outside this brief.

### 1.7 Healing times by bone and age

**Stages of healing** (King 2018, ch 58). - Callus shows on X-ray at 2 to 3 weeks in adults, sooner in children, and makes the ends "sticky". - Clinical union usually comes at 4 to 8 weeks, but the tibia can take much longer. - Consolidation takes at least as long again.

**Perkins's timetable**, as quoted by King, works by doubling: - spiral arm fracture: 3 weeks to union and 6 to consolidate - spiral leg fracture: 6 weeks to union - transverse leg fracture: 12 weeks to union and 24 to consolidate

A second source gives 6 to 8 weeks for the upper limb and double for the lower (GPnotebook). The two agree in proportion.

| Fracture | Figure | Source |
|---|---|---|
| Colles' | Cast 3 weeks, 6 if unstable | King 2018 |
| Ankle, unstable | No weight for 6 weeks | King 2018 |
| Femoral shaft | Union 7 to 8 weeks, no weight for 8 to 12 weeks | Giannou 2013, King 2018 |
| Tibia, closed or open | 17.4 or 21.7 weeks in a brace | Sarmiento 1989 |
| Clavicle | Unites in almost all cases | King 2018 |

**Age.** Children heal faster. A common teaching halves the adult times [VERIFY, no primary source found]. Osteoporotic bone joins in the same time but is weaker (King 2018, ch 58).

**Nutrition.** The brief's warning holds. King writes that limb ischaemia and vitamin D deficiency "make everything take much longer" (King 2018, ch 58). A review found protein deficiency linked to non-union in animals and in human observational data, but no trial shows that feeding corrects it (Meesters 2018).

After the Fall, I would add half again to every time in a hungry patient and judge union by hand rather than by the calendar [VERIFY, my inference]. NU-04 and NU-05 are not yet in the library.

### 1.8 Compartment syndrome and the cast too tight

Swelling inside a closed muscle compartment raises the pressure until blood stops reaching the muscle. The muscle dies and scars into Volkmann's ischaemic contracture.

**Signs.** - The earliest sign is pain out of proportion to the injury, especially on passive stretch of the fingers or toes (Giannou 2013, King 2018, ch 59). - Paraesthesia, pallor, pulselessness and paralysis come late, and the pulse may stay normal throughout (Giannou 2013). - King: "Pain is not an indication for analgesia" (King 2018, ch 59). - Individual clinical signs had a sensitivity of only 13 to 19% and a specificity of 97 to 98%. The probability of the syndrome was about 25% with one sign and 93% with three (Ulmer 2002, abstract).

**Time.** Textbooks give 6 to 8 hours before permanent damage, on weak evidence. Damage has been reported within 3 hours (Vaillancourt 2001). King says under 1 hour of ischaemia can do harm (King 2018, ch 59). The safe course is to act on the first sign.

**What to do.** 1. Split the cast, the padding and every bandage to the skin along the whole length (Dufour 1998, Giannou 2013). 2. Keep the limb at heart level, not above it [VERIFY, standard teaching not found in these sources]. 3. If the pain does not ease, fasciotomy is next (Giannou 2013). That is a district operation.

**King's cases** (King 2018, ch 59). - Shanti, aged 8, had an undisplaced radius fracture put in a circular cast. Her pain was treated with aspirin, and she lost her forearm. - Abdullah, aged 8, had a supracondylar fracture put in a skin-tight cast and lost his fingers. - King's lesson: "Loss of reduction is better than ischaemic contracture."

Patients return at once for pain, numbness, cold or blue digits, or a loose cast, and carry a written "fracture passport".

**Disagreement with FO-09.** FO-09 advises checking the digits hourly for the first day and loosening the splint if they go numb, cold or dark (THRIVING library, FO-09). I disagree on two counts: - Swelling peaks over 24 to 48 hours (Dufour 1998), so the checks should run for 48 hours. - Numbness, coldness and darkness are late signs. The trigger to split should be rising pain, or pain on passive stretch.

### 1.9 Rehabilitation

**The tradition.** Fang Xianzhi founded the Tianjin Orthopaedic Hospital in 1944 on three principles: manual reduction, small splints and early movement (China Daily 2026). I found no union data for that school.

**The record.** - Knee exercise from day 3 in Perkins traction gave 120 degrees or more of flexion in all 50 of Buxton's patients (Buxton 1981). - Walking in a brace gave Sarmiento's low non-union rates (Sarmiento 1995). - ICRC calls the cost of immobility "plaster disease": stiffness, wasting and osteoporosis (Giannou 2013). - An adult hand not moved within ten days loses some range for good (Dufour 1998).

**Rules.** - Exercise every free joint daily from day one. - Bear weight at 2 to 4 weeks for a stable ankle, at about 6 weeks in a PTB cast, and at 8 to 12 weeks for a femur. - Send a femur home with at least 90 degrees of knee flexion. - King warns that teenagers re-fracture after femoral union (King 2018, ch 67). - He has patients in traction exercise together so they encourage one another.

### 1.10 Traditional bonesetters

**Scale.** - About 85% of Nigerian fracture patients go first to a bonesetter (Dada 2011). Nigeria had under 200 orthopaedic surgeons for about 140 million people (Omololu 2008). - Across countries, use ranges from 18 to 90% (interquartile range 52 to 85%). The median cost is USD 30, against USD 173 in hospital (Unadkat 2025). - In one Ghanaian district hospital, 14 patients with proven fractures left for a bonesetter in 3 months. They chose by severity, cost and past experience, and valued the hospital for diagnosis and emergencies (Ariës 2007, abstract).

**What the tradition says it does.** - **South-western Nigeria** (Omololu 2008). - The patient is held down for manipulation. - Herbs and schnapps are given for pain. - A herbal cream is applied with a feather. - Splints of raffia palm, plywood, bark or cardboard are bound on with pressure, and stones hold the limb still. - Bandages are changed every 3 to 5 days. - **Elsewhere in Nigeria.** Splints are bound tightly for 2 to 3 days, then released at intervals (Dada 2011). - **Kerala, *Puttur kattu*** (Panda 2011). - A paste containing *Cassia occidentalis*, bamboo sticks and a sling. - Daily sesame oil. - Review at 15 days, a second dressing with egg white and turmeric, and removal at about a month.

**What the record shows.** Gangrene from tight splintage is the commonest and worst complication. After it come malunion, non-union, sepsis from scarification, osteomyelitis, tetanus and Volkmann's contracture (Dada 2011).

| Setting | Patients | Main findings |
|---|---|---|
| Lagos, one year, prospective | 121 patients, 155 injuries, 168 complications | Malunion 27 (16.1%), non-union 27. Fees USD 18 to 380 against USD 34 to 98 in hospital. 10 of 11 amputees without a prosthesis at 6 months. Abstract figures do not all add up (Dada 2009) |
| Ibadan | 25 | 14 needed open surgery, 2 amputated for gangrene (Alonge 2004) |
| Jos, ten years | 100 amputations | 60 of 70 trauma amputations followed bonesetter care. Mortality 8.5%. Only 25 got a working prosthesis (Onuminya 2000) |
| Southern Ethiopia, two years | 49 amputations | 25 for gangrene after tight splints (Eshete 2005) |
| West Java | 86 | Half had malunion (Althea Med J 2018) |
| Turkey | 51 with sequelae | 42 in the upper limb, 20 permanent (Istanbul Med J 2014, search summary) |

**Systematic reviews.** - One review found 15 studies, all hospital-based, with 1,389 participants and 1,470 complications (Onyemaechi 2021, abstract). - Another found 12 studies with 833 participants and 691 complications, including deaths (Garikapati 2022, abstract). - The 2025 scoping review gives ranges across studies (Unadkat 2025): - malunion or non-union 16.1 to 64.3% - gangrene 2.8 to 29.6% - amputation 2.8 to 60% - Volkmann's contracture 0.6 to 2.8% - 26.7% mortality in one series of bonesetter gangrene (Nwadiaro 2007, as cited there)

**Selection bias.** The bias the brief warns about is large. Every figure above comes from patients who reached a hospital, usually because treatment had failed. The figures describe failures, not a failure rate.

The only population-based figure found is a conference abstract from Sidama, Ethiopia (OTA 2024). Of 830 injured people, 67% were treated by bonesetters and 56% had complications, with adjusted odds of complication 4.15 times higher after bonesetter care.

The only study that started at the bonesetter's door followed 52 Kerala patients to the end of treatment (Panda 2011): - 71% were satisfied, and one lost joint movement. - There was no gangrene and no Volkmann's contracture. - 23% had left a hospital voluntarily to come. - There was no X-ray and no independent assessor.

No study gives union, malunion, infection and time to walking together for an unselected bonesetter population. I found no figure at all for time to walking [VERIFY, gap].

**Training works, on before-and-after evidence.** - **Southern Ethiopia.** Eshete ran ten one-day courses for 112 healers, teaching loose splintage and referral. Amputations fell from 49 to 25, and gangrene amputations from 25 to 7. There was no control group (Eshete 2005, abstract). - **Nigeria.** Onuminya compared tibial shaft fractures, 40 at a trained bonesetter's centre and 40 at an untrained one (Onuminya 2006, abstract, group sizes from Binnerts 2025). The abstract reports these differences as significant.

| Outcome | Trained | Untrained |
|---|---|---|
| Gangrene | 2.5% | 10% |
| Infection | 5% | 12.5% |
| Non-union | 7.5% | 15% |
| Malunion | 20% | 30% |

- **Ghana.** Training 157 bonesetters raised knowledge scores by 19.7% and produced 37 referrals (Konadu-Yeboah 2023, as reviewed in Binnerts 2025).
- **Quality.** A 2025 review rated all the training studies low quality, but all pointed the same way (Binnerts 2025).

Omololu's triage rule (Omololu 2008): - displaced fractures go to hospital - open fractures go to hospital - undisplaced closed fractures stay with the bonesetter - an undisplaced open fracture stays only if the wound is under 1 cm

**The Philippines.** The *hilot* treats sprains, strains and fractures by massage, among other conditions (StuartXchange). I found no peer-reviewed fracture outcome study. One informal website says unsupervised hilot reductions without imaging often end in non-union and deformity (StuartXchange). That is opinion, not data [VERIFY, gap].

**Worth keeping.** - A healer who is present on the day and trusted. - Light, cheap splint materials. - Early movement of free joints. The Chinese small-splint school made this a principle, though I found only secondary word of a meta-analysis that favoured external fixation over small splints for unstable wrist fractures [VERIFY]. - Diagnosis by hand.

**Must go.** - Tight binding of a fresh fracture. - Scarification over the break. - Forcing a femur or elbow without traction or anaesthesia. - Keeping an open fracture at home. - Refusing to refer a cold limb.

### 1.11 Plants in fracture care

**Medicinal plants.** - ***Senna occidentalis*** (L.) Link, formerly *Cassia occidentalis*: coffee senna, Kasamarda, Kasondi. - It is used in the Kerala bone-setting paste. The paper does not say which part, probably the leaf [VERIFY] (Panda 2011). - The seeds look like coffee beans and are poisonous. Ten consecutive children in western Uttar Pradesh with an acute liver, muscle and brain illness had all eaten the beans, and 9 died within 4 to 5 days. The outbreaks had been taken for viral encephalitis for years (Vashishtha 2007). - I found only search summaries as a second source [VERIFY]. - Leaf on the skin is not the same exposure as eating seeds, but households must keep the pods from children. - ***Symphytum officinale*** L., comfrey. - It is a traditional bone remedy in Europe [VERIFY, not sourced here], with no evidence that it speeds union. - Its pyrrolizidine alkaloids cause hepatic veno-occlusive disease, so it

must not be taken by mouth (MSKCC). - Before flowering, foxglove (*Digitalis purpurea* L.) leaves resemble comfrey. "Comfrey tea" made of foxglove caused cardiac glycoside poisoning in Taiwan and at least one death (JCMA 2010, MSKCC). - Never eat it, never drink it, and never pick it out of flower. - ***Curcuma longa*** L., turmeric (rhizome), and ***Sesamum indicum*** L., sesame (seed oil), are used in Puttur kattu (Panda 2011). Neither has evidence of benefit to bone, and both are low risk on the skin.

**Splint plants.** Bamboo (*Bambusa* and related genera), rattan (*Calamus* species) and raffia palm (*Raphia* species, leaf midrib) are used for structure only. The sources name the materials, not the species, so these genera are my identifications [VERIFY].

### 1.12 Feasible today and after the Fall

**Today, almost anywhere.** Everything above, including the full ICRC antibiotic regimen.

**After the Fall, without a factory:** - hand diagnosis - padded wooden or bamboo splints - plaster from local gypsum, if a slow oven can hold 120 to 150 °C - skeletal traction with a hand drill and a smith-made pin (pin metal not researched [VERIFY]) - PTB casts - the Orr-Trueta method

**Only with salvage:** - lidocaine - penicillin and metronidazole - X-ray

Internal fixation without a full setup is a disaster (King 2018, ch 58).

## 2. Evidence grades

**Grades.** - **A**: consistent randomised trials or systematic reviews of them. - **B**: one good trial, or large consistent cohorts. - **C**: case series, before-and-after studies, observational records. - **D**: manuals, expert opinion, tradition without outcome data. - **X**: evidence of harm. Do not do.

| Practice | Grade | Basis |
|---|---|---|
| Antibiotics for open fractures | A | Cochrane, 8 trials (Gosselin 2004) |
| Sling, not figure-of-eight, for clavicle | B | One trial (Andersen 1987) |
| Cast rather than plate, distal radius, over 60 to 65 | B | Two trials (Arora 2011, CROSSFIRE 2021) |
| Functional bracing, tibia and humerus | C | Large single-centre series (Sarmiento 1995, 2000) |
| Perkins traction, femoral shaft | C | Three series (Buxton 1981, Bezabeh 2012, Gosselin 2007) |
| Orr-Trueta closed plaster without antibiotics | C | Wartime series (Short 1939) |
| Delayed rather than primary closure | C | Gustilo 1976 |
| Thomas splint for transport | C | Confounded record (Gray 1919) |
| Clinical signs of compartment syndrome | C | Ulmer 2002 |
| Training bonesetters | C | Before-and-after (Eshete 2005, Onuminya 2006) |
| Split first cast, slab before cylinder | D | Manuals and cases (King 2018, Dufour 1998) |
| Herbal pastes to speed union | D | No outcome data (Panda 2011) |
| Untrained bonesetting of displaced or open fractures | X | Consistent harm, one population study (OTA 2024) |

| Practice | Grade | Basis |
|---|---|---|
| Tight binding of a fresh fracture | X | Gangrene series (Dada 2011, Eshete 2005) |
| Scarification over a fracture | X | Dada 2011 |
| Primary closure of an open fracture | X | King 2018, Gustilo 1976 |
| Comfrey by mouth | X | MSKCC |

## 3. Means ledger

| Rung | What it has | What it changes |
|---|---|---|
| Hands | Examination, manual traction, cloth sling, body as splint | Diagnosis, less pain in transport, a dislocated ankle reduced before the skin dies. No hold, so malunion is common |
| Hearth | Boards, bamboo, padding, rope, stones, a bed, boiled water | Padded splints, traction with stones as weights, wound washing. Most closed fractures unite in fair position. Open fractures still often fatal |
| Garden and still | Gypsum calcined to plaster, cotton bandage, distilled spirit, hand drill and forged pin | Casts, PTB casts, Orr-Trueta plaster, skeletal traction. Better hold, earlier walking, the first real defence of open fractures |
| Village dispensary | Salvaged lidocaine, penicillin, tetanus toxoid, a trained fracture worker, fracture passports | Painless reduction of wrist and ankle, antibiotics within hours, return visits for tight casts |
| District infirmary | Traction beds for 2 months, debridement, fasciotomy, amputation, perhaps a salvaged X-ray | Femurs united, compartment syndrome treated, gangrenous limbs removed before sepsis kills |
| Hospital before the Fall | Imaging, internal fixation, vascular repair, intravenous antibiotics, physiotherapy | Earlier walking, fewer malunions, limb salvage. Little gain for simple closed fractures in the old (Arora 2011, CROSSFIRE 2021) |

FO-09 places reduction of dislocations at the dispensary (THRIVING library, FO-09). I would add closed reduction of Colles' and ankle fractures, which King does without X-ray (King 2018, ch 58).

## 4. Harm test

**Harms of doing.** - **Tight casts and splints.** These are the leading avoidable harm. Gangrene runs at 2.8 to 29.6% of referred bonesetter complications (Unadkat 2025). King's cases were hospital casts (King 2018, ch 59). - **Traction.** - Pin infection runs at 11.8 to 42.6% (Bezabeh 2012, Gosselin 2007). - Over-traction stops union. - The Thomas ring causes groin sores. - Extension can dislodge an arterial clot (Gray 1919). - **Haematoma block.** It risks infection and lidocaine toxicity. - Ten millilitres of 2% lidocaine is 200 mg. - ICRC gives a maximum of 3 mg/kg without adrenaline, which is 180 mg for 60 kg (Giannou 2013). A secondary reference gives 4.5 mg/kg and an absolute cap of 300 mg

(WikiMSK). - By the ICRC figure, King's standard block is at or above the limit for a small adult [VERIFY]. - Early toxicity: numbness round the mouth, light-headedness, tinnitus. Late toxicity: seizures and cardiovascular collapse (WikiMSK, Minars). - Lidocaine cannot be made in a village, so it exists only as salvaged stock. - **Immobility.** Plaster disease (Giannou 2013). Complex regional pain syndrome after a Colles' fracture (King 2018, ch 64). - **Antibiotics.** Anaphylaxis, and scarce stock spent on wounds that do not need it. - **Plants.** *Senna occidentalis* seeds kill children (Vashishtha 2007). Comfrey injures the liver and has a deadly lookalike (MSKCC, JCMA 2010).

**Harms of not doing.** - Open fractures killed about half of those who had them before antisepsis (JBJS Classics 2016). - Femurs without traction unite short and angled, or not at all. - In Cameroon only 21% of fracture patients received any immobilisation before hospital, and those who did survived more often (O'Connor 2024, as cited in Unadkat 2025).

**Net.** A padded splint that is never tight beats a tight one by a wide margin, and beats nothing. For open fractures, debridement with closed plaster or delayed closure beats immediate closure.

## 5. Red flags

1. Pain rising after splinting, or pain on passive stretch of the fingers or toes.
2. Numb, pale, blue or cold digits.
3. Any wound over or near the fracture.
4. A thigh fracture, or a pelvis that moves on pressure (see FO-09).
5. A dislocated ankle or knee with tented white skin.
6. A supracondylar elbow fracture in a child.
7. Fever, smell or pus under a cast after the first days.
8. A loose, red or discharging pin.
9. Night pain or movement at the fracture when union is due.
10. A child who has eaten "coffee beans" from the plant used in a bone-setting paste.

## 6. The case against

**The Thomas splint legend.** Gray's own data show the famous comparison is mixed and confounded (Gray 1919). Robinson and O'Meara's abstract traces the splint's history without defending a figure (Robinson 2009). FO-09's modern review finds no advantage of traction splints before hospital (THRIVING library, FO-09). The splint stiffens knees and causes sores if kept on (King 2018, ch 67).

**Conservative fracture care.** The brief is right that Charnley's methods need skill. King concedes that few systematic descriptions of non-operative methods remain, so the skill is being lost (King 2018, ch 58). Sarmiento's results come from one centre with a devoted team. His humeral series lost a third of its patients to follow-up (Sarmiento 2000), and losses usually hide failures. A meta-analysis of 21 trials reported non-union of 17.4% with humeral bracing against 5.2% with plating (secondary summary, authors unidentified) [VERIFY].

**Perkins traction.** It costs two months of a bed per femur, with pin infection up to 42.6% (Gosselin 2007).

**The bonesetter evidence.** It cuts both ways. - The harm side rests on hospital-filtered series (Onuminya 2000, Dada 2009, Eshete 2005, Alonge 2004). - Ariës and van der Geest argue that patients choose bonesetters for reasons hospitals ignore, and that the two systems could coexist (Ariës 2007). - Binnerts rates the training studies low quality (Binnerts 2025). - The one bonesetter-based study has no X-rays (Panda 2011).

**Antibiotic timing.** Lack's 66 minutes comes from one retrospective series of 137 patients (Lack 2015). Cochrane shows that antibiotics help, but cannot settle when to give them (Gosselin 2004).

**Compartment signs.** Individual signs miss over 80% of cases (Ulmer 2002). Without pressure measurement, a village will both miss cases and split casts needlessly. Splitting is cheap, so accept the second error.

**This report.** Much of it was read as abstracts. The ICRC antibiotic dose rests on one primary source. The gypsum method rests on two short technical sources and was not tested under village conditions.

## 7. 10-line summary

1. Most closed fractures heal if held still in fair position, padded, and never bound tight.
2. Tight splintage, not poor diagnosis, kills limbs, and gangrene leads every bonesetter complication list.
3. Use slabs for 3 to 5 days, split the first cast, and treat rising pain as compartment syndrome.
4. Perkins traction united 47 of 50 femurs by 12 weeks, and medical assistants can run it.
5. Sarmiento's bracing gave 1.1% non-union in 1,000 closed tibial fractures, using plaster and walking.
6. The Thomas splint's "80% to 15.6%" compares overall wartime mortality with clearing-station mortality in one battle.
7. Open fractures need washing, excision, an open wound and plaster. Trueta lost 6 of 1,073 without antibiotics.
8. Antibiotics cut infection after open fractures by over half (risk ratio 0.43).
9. One-day courses for bonesetters cut gangrene amputations from 25 to 7 in southern Ethiopia.
10. Healing times come from well-fed patients, so judge union by hand and expect delay.

## 8. Open questions

1. What are bonesetter outcomes in an unselected population with X-ray follow-up? Only the Sidama abstract approaches this (OTA 2024).
2. Is there any outcome study of hilot fracture care?
3. Did the Chinese small-splint school publish union rates?
4. Which gypsum deposits does a district have, and how strong is village-made plaster?
5. How many fractures a year should a farming village of 300 expect? No source found [VERIFY].
6. Can a smith make a traction pin that does not loosen in four weeks?
7. How much does moderate malnutrition delay union?
8. Which second primary source confirms the ICRC penicillin dosing? This is for WO-06.

## 9. Sources to read in full

1. King, *Primary Surgery* volume 2, chapters 58, 59, 64, 67, 70, 71 and 73 (children, not read).
2. Giannou and colleagues, ICRC *War Surgery* volume 2 (2013), the fracture and antibiotic chapters.
3. Dufour and colleagues, ICRC *Surgery for Victims of War* (1998), the plaster chapter, which is the clearest plaster manual read.
4. Gray (1919), pp. 57 to 61.
5. Charnley, *The Closed Treatment of Common Fractures*. Not read.
6. Sarmiento 1995 and 2000 in full.
7. Eshete 2005 and Onuminya 2006 in full, for the training methods.
8. Dada 2009 in full, to resolve its inconsistent figures.
9. Unadkat 2025 and Onyemaechi 2021.

## 10. At the bedside after the Fall

**Household.** - **Minimum viable version.** Feel for the break and check pulse and feeling beyond it. Pad, and splint across the joints above and below with boards or bamboo. Use a sling for the arm, and the other leg as a splint for the leg. Keep the limb level. Check the digits hourly for 48 hours, and cut every tie at once if pain rises. - **To start.** Two straight boards per limb, about 5 m of cloth strips, soft padding, and a knife kept by the bed. - **First failure to expect.** A splint tied tight on the first evening and found too late in the morning.

**Village of 300.** - **Minimum viable version.** One trained fracture worker who can examine, reduce Colles' and ankle fractures, apply slabs, and issue fracture passports. One family bed set up for traction with a pulley, rope and a bag of stones. A rule that every open fracture and every femur goes to the district. - **To start.** - a known gypsum source, a pan and a slow oven - 20 to 30 plaster bandages in sealed jars [VERIFY, my estimate] - rubber strips for splitting - a hand drill and two pins - tetanus toxoid if salvage allows - a one-day course like Eshete's - **First failure to expect.** Plaster that will not set because it was overheated or stored damp, discovered with a patient on the table [VERIFY, inference].

**District of 3,000.** - **Minimum viable version.** - 4 to 6 traction beds [VERIFY, my estimate] - a theatre for debridement, fasciotomy and amputation - the Orr-Trueta method - PTB casts and walking heels made in-house - a register of every fracture with its outcome at 12 weeks - a scheme that trains local bonesetters in loose splintage and referral, and sends them home with plaster - **To start.** Rationed salvaged penicillin and lidocaine, a smith for pins, a gypsum supply, and two staff who can run traction. - **First failure to expect.** Traction beds blocked for months by femurs with pin infections while new fractures wait. This is the case for cast braces from 4 to 6 weeks [VERIFY, inference].

## 11. Protocols

Hearth means a household or bonesetter without plaster. Dispensary means a trained worker with plaster and some salvaged drugs.

**Every fracture** - [ ] Before touching the limb, check pulse, colour, warmth and sensation beyond the injury (King 2018, ch 58). - [ ] Look for a wound. Any wound means the open-fracture protocol. - [ ] Pad bony prominences: 3 to 4 layers (about 1 cm) for the leg, 2 to 3 layers for the arm (King 2018, ch 59). - [ ] Splint the joints above and below. Ankle 90 degrees, knee 15 degrees, elbow 90 degrees mid-prone, wrist 15 to 20 degrees extended (Dufour 1998, King 2018). - [ ] No circular binding for 3 to 5 days. - [ ] Check the digits hourly for 48 hours. This extends FO-09's 24 hours, after Dufour 1998. - [ ] If pain rises, cut every layer to the skin along its full length. Give no analgesia to mask it. - [ ] Give a written fracture passport with the date, the bone, the review dates and the warning signs (King 2018, ch 59).

**Colles' fracture** - *Hearth.* Pad a board on the palm side from the elbow to the palm crease, with the knuckles free, and add a sling. Exercise the fingers hourly while awake. Do not reduce without anaesthesia unless the hand is pale [VERIFY, inference]. - *Dispensary.* - [ ] Reduce if dorsal angulation is over 15 degrees in a patient under 60. - [ ] Haematoma block: 10 ml of 2% lidocaine without adrenaline (King 2018). Stay under 3 mg/kg (Giannou 2013), which is about 7 ml for 50 kg [VERIFY]. Wait 15 minutes. - [ ] Hang 5 kg from the upper arm for 10 minutes. - [ ] Exaggerate the deformity, then flex the wrist, deviate it to the ulnar side, and pronate. - [ ] Apply a dorsal slab to the palm crease. Complete the cast at 1 week. - [ ] Total 3 weeks, or 6 if unstable. Over 60 years, slab only and movement at 4 weeks (King 2018, ch 64).

**Ankle** - *Hearth.* If dislocated, pull the heel at once. Pad the malleoli and heel, and splint at 90 degrees. Raise the foot about 20 cm. No weight for 2 weeks, then review. - *Dispensary.* - [ ] Stockinette traction or a horseshoe slab for 2 to 7 days. - [ ] Cast with about 1 cm of padding and three 20 cm plaster bandages. Use a long-leg cast with the knee bent if unstable. - [ ] Weight-bearing: - unstable: none for 6 weeks - stable: from 2 to 4 weeks - hairline: walking cast for 2 weeks (King 2018, ch 71)

**Femoral shaft** - *Hearth.* - [ ] Pull by hand along the limb. - [ ] Hold the pull with a rope from a padded ankle hitch outside the boot to a board beyond the foot. - [ ] No encircling tie before the pull. - [ ] Watch for fresh bleeding after the pull (Gray 1919). - [ ] Carry to the district. - *Dispensary or district.* - [ ] Tibial pin 2.5 to 3 cm below the tubercle, from the lateral side. - [ ] Weight from 1 kg per 10 kg of body weight (ICRC) to one-seventh of body weight (King): 6 to 8.5 kg for 60 kg. - [ ] Raise the foot of the bed 4 cm per kg. - [ ] Check alignment several times a day for 2 weeks. Aim for 1 cm of overlap and never a gap. - [ ] Knee exercise 10 to 30 minutes several times a day from day 3. - [ ] Traction off at 4 to 8 weeks on clinical union. - [ ] No weight for 8 to 12 weeks in total. - [ ] Children: no tibial pin

while growth plates are open. Gallows traction under 12 to 15 kg (King 2018, ch 67, Giannou 2013).

**Clavicle** - *Both settings.* Sling for comfort, about 2 to 3 weeks [VERIFY], with active shoulder movement as pain allows. Reduce only tented skin (King 2018, ch 61, Andersen 1987).

**Tibial shaft** - *Hearth.* Padded splint from thigh to foot, knee slightly bent, ankle at 90 degrees, fibular head padded. No weight. - *Dispensary.* - [ ] Long-leg back slab, 6 to 8 layers from 5 to 6 rolls of 15 cm plaster (Dufour 1998). - [ ] Convert to a cylinder at day 3 to 5. - [ ] PTB cast and walking at about 6 weeks (King 2018, ch 70). - [ ] Never traction beyond 2 weeks if closed, or 3 if open.

**Open fracture** - *Hearth.* - [ ] Cover with the cleanest cloth and splint. - [ ] If transport will take over a day, wash the wound with boiled, cooled water until it runs clear [VERIFY volume, see WO-02]. - [ ] Never stitch. Carry to the district. - *Dispensary or district.* - [ ] Benzylpenicillin 5 million units IV four times daily for 48 hours. - [ ] Then penicillin V 500 mg four times daily until closure. - [ ] Add metronidazole 500 mg IV three times daily if more than 72 hours have passed (Giannou 2013, one source [VERIFY]). - [ ] Tetanus measures for all. - [ ] Debride and leave open. Use Orr-Trueta plaster, or close at 4 to 7 days.

**Plaster from gypsum** (a safe preparation) - [ ] Grind the gypsum fine. - [ ] Heat in a shallow pan at 120 to 150 °C for 1 to 2 hours, stirring, until steam stops (CBRI 2024, NZIC). Never let it glow. - [ ] Cool and store dry in a sealed jar. - [ ] Test a spoonful with water. It should set within roughly 5 to 15 minutes [VERIFY]. - [ ] Rub into loosely woven cotton strips 10 to 15 cm wide, roll, and dip just before use (Szostakowski 2017).

## 12. Numbers to carry

1. **48 hours.** Swelling period. Slabs only, and digit checks throughout (Dufour 1998).
2. **1 cm.** Leg padding, and the target femoral overlap in traction (King 2018).
3. **5 kg.** Maximum skin traction (Giannou 2013), and the Colles' counterweight (King 2018).
4. **1 kg per 10 kg.** Starting femoral skeletal traction (Giannou 2013).
5. **Day 3.** Start knee exercise in traction (King 2018).
6. **3, 6, 12 weeks.** Union of a spiral arm, a spiral leg and a transverse leg fracture (King 2018).
7. **15.6%.** The clearing-station mortality behind the Thomas splint legend (Gray 1919).
8. **0.43.** Risk ratio of infection with antibiotics for open fractures (Gosselin 2004).
9. **3 mg/kg.** ICRC maximum for plain lidocaine (Giannou 2013). A secondary source gives 4.5 mg/kg (WikiMSK).
10. **120 to 150 °C.** Gypsum to plaster (CBRI 2024, NZIC).

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