DEPARTMENT OF BIOMEDICAL ENGINEERING

Unit III

Electrosurgical Units • Prosthetic and Orthotic Devices

No.	Topic	Main subtopics
6	Electrosurgical Units	Principle, types, monopolar and bipolar modes, techniques, block diagram, electrodes, safety
7	Prosthetic and Orthotic Devices	Prosthesis components, power sources, levels of amputation, orthosis classification, lower-limb, spinal and upper-limb orthoses

TOPIC 6
Electrosurgical Units

Electrosurgery (surgical diathermy) uses electric current to cut tissue, destroy abnormal tissue or stop bleeding. An **electrosurgical unit (ESU)** generates the current and the surgeon directs it to the treatment site through an electrode. The resistance of the tissue turns the current into heat; this controlled heat removes unwanted growths, cuts tissue and seals blood vessels, so the damage is deliberate and helps healing. It may be used alone or together with other treatments.

6.1 Principle of operation

Heat is produced by the resistance of tissue to the passage of current (Joule heating, $P = I^2R$). The heat produced depends on the **current density, the tissue resistance and the time** for which current flows. Current density is very high under the small active electrode, so tissue there is heated strongly; at the large return plate the density is low and there is no significant heating.

† ESUs operate at radio frequency (typically 0.3–3 MHz, most units near 500 kHz). At mains and low frequencies, current stimulates nerves and muscles and can cause shock or ventricular fibrillation; above about 100 kHz the neuromuscular response is negligible, so the current can flow through the body and produce only heat.

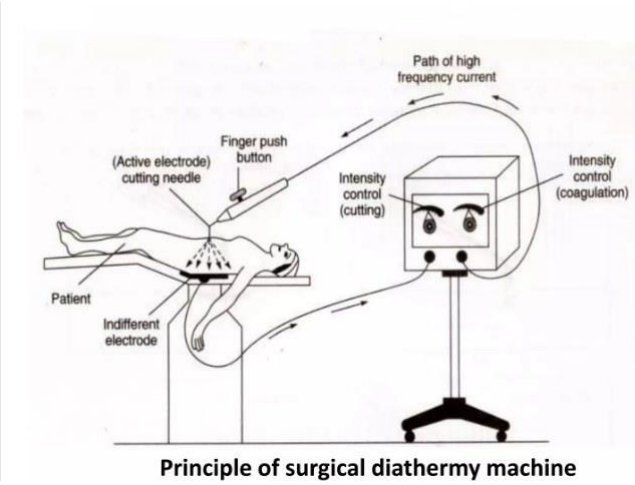

Fig. 6.1 *Principle of a surgical diathermy machine.*

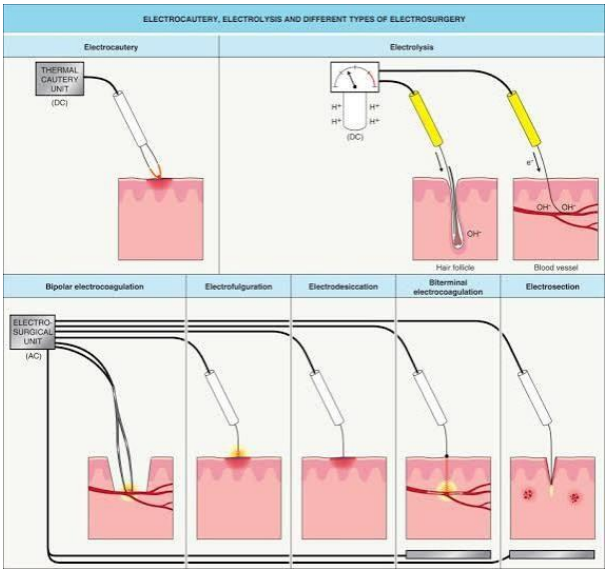

Fig. 6.2 *Electrocautery, electrolysis and types of electrosurgery.*

6.2 Types of electrosurgery

Most types use **alternating current (AC)**, which passes back and forth through the tissue. **Electrocautery** is the exception: it uses **direct current (DC)** that heats a probe tip and does not pass through the tissue.

Type	How it is done	Effect
Electrofulguration	Electrode held a few millimetres above the tissue; a spark jumps the gap. No direct contact.	Changes only the top tissue layer
Electrodessication	Electrode applied directly to the treatment area; current dries out the tissue.	Superficial drying and destruction
Electrocoagulation	Current damages abnormal tissue at deeper layers and promotes blood clotting.	Deeper than fulguration/desiccation; stops bleeding

Type	How it is done	Effect
Electrosection	Current makes precise cuts, described as a warm knife slicing through butter.	Cutting (electrotomy)
Electrocautery (DC)	Current flows through a probe and heats the tip; tip is placed on tissue.	Direct heat breaks down tissue or stops bleeding

6.3 Monopolar and bipolar modes

Monopolar mode (the most common). Only one electrode tip, the **active electrode**, touches the operative site. (1) The ESU sends current to the active electrode. (2) The current passes through the tissue and heats it. (3) It travels to the **dispersive (indifferent/return) electrode**, a grounding pad on the thigh or a plate the patient holds. (4) It returns to the ESU. The current therefore passes through the patient's body, and the plate needs a large contact area (about 300 cm² in the lecture notes) so that skin under it is not burnt.

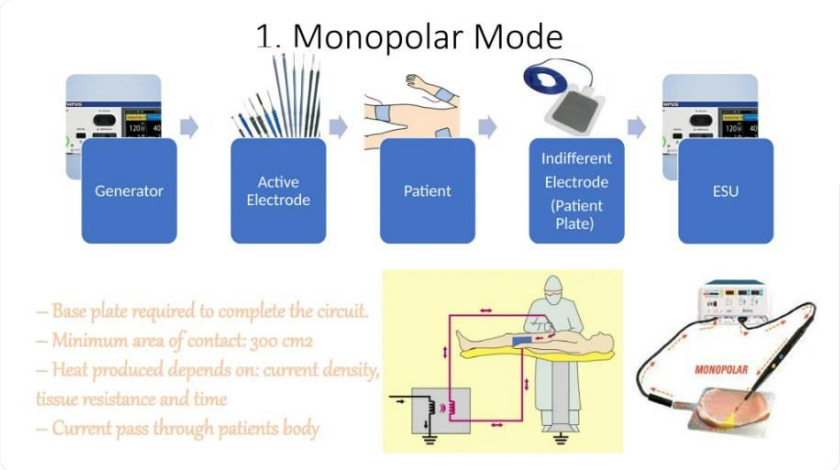

Fig. 6.3 *Monopolar mode: generator, active electrode, patient, indifferent (patient) plate, ESU.*

Bipolar mode. Two electrode tips touch the body, for example the two blades of forceps clasping the tissue: one carries the active current and the other is the return. Current passes only through the tissue between the tips and returns to the ESU, so it **does not pass through the rest of the body** and no return plate is needed.

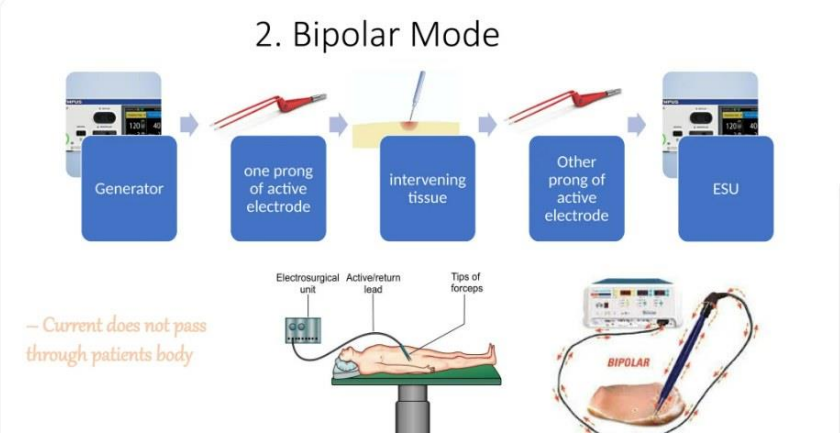

Fig. 6.4 *Bipolar mode: current flows from one prong of the forceps to the other through the tissue.*

Feature	Monopolar	Bipolar
Electrodes at the site	One active electrode	Two tips (e.g. forceps blades)

Feature	Monopolar	Bipolar
Return path	Separate dispersive plate on the patient	Second tip of the same instrument
Current path	Through the body to the plate	Only through tissue between the tips
Main risk†	Burn at plate site if contact is poor	Very low; effect is confined
Typical use†	General cutting and coagulation	Delicate work, small vessels, neurosurgery

Exam tip: some older references call the "cutting electrode + indifferent plate" arrangement "bipolar". By current definition that arrangement is monopolar; use the definitions given above.

6.4 Electrosurgical techniques

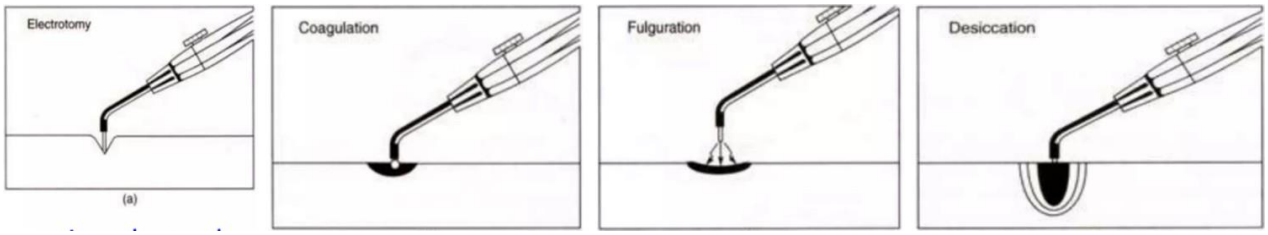

Fig. 6.5 *Tissue effect of (a) cutting/electrotomy, (b) coagulation, (c) fulguration and (d) desiccation.*

- **Cutting (electrotomy):** a fine wire electrode, high RF voltage and high cutting speed confine the destruction to a thin line. Steam bubbles formed in the tissue at the tip continuously rupture it, which is the cutting mechanism. The effect is localised, so it is valuable in microsurgery.
- **Coagulation:** high-frequency current heats the tissue from inside so that it coagulates; a grey-white discolouration appears at the edge of the electrode. It gives better coagulation than a thermocautery because there is no superficial burning.
- **Fulguration:** superficial tissue destruction without affecting deep tissue. Sparks pass from a needle or small ball electrode held near, but not touching, the tissue; the arc dries the surface. Used for fistulas, residual cysts and minor haemorrhage.
- **Desiccation:** needle-point electrodes are stuck into the tissue and held steady; intensity and duration of current decide the local heating, and the tissue changes by drying and limited coagulation.
- **Haemostasis (blend):** continuous RF current for cutting is used together with a burst-wave RF current for coagulation. Cutting current alone often bleeds; blending gives bloodless cutting. The blended waveform has the same frequency as the cutting current.

6.5 Solid-state diathermy machine

The block diagram shows the main sections. In general terms: the **control panel** sets mode and power; the **logic board** is the central controller that produces the cut, coagulate or blend drive; the **power output board** amplifies it to RF power; the **isolator switch board** keeps the patient circuit isolated from the mains and switches outputs; the **audio tone generator** sounds a tone whenever RF

is active; the **footswitch** (or finger switch) lets the surgeon turn the current on and off; and the **power supply** feeds all boards.

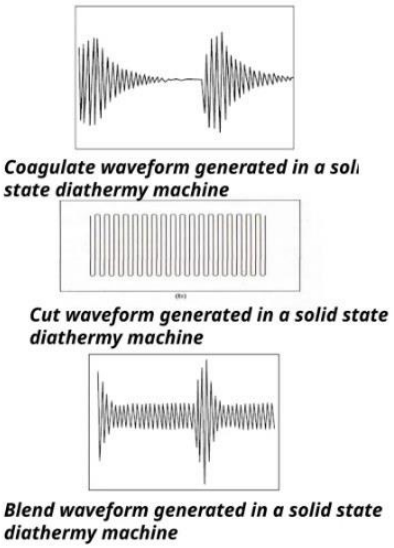

Fig. 6.6 *Coagulate, cut and blend waveforms.*

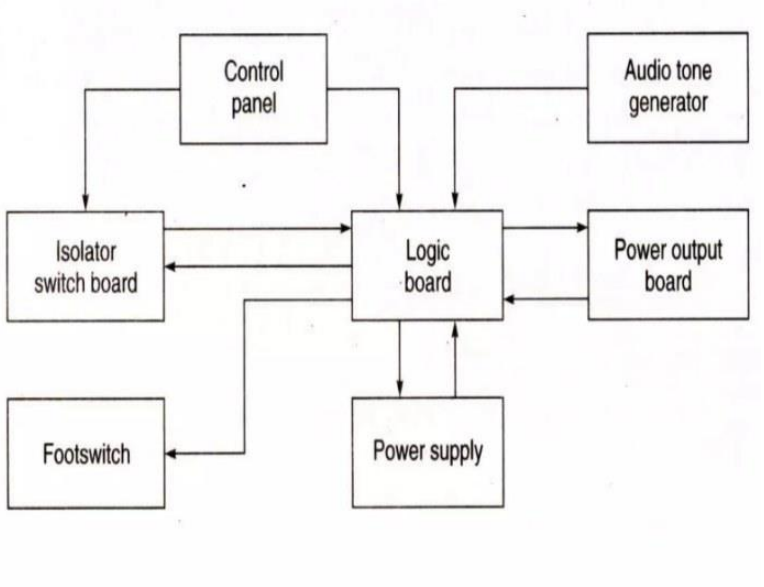

Fig. 6.7 *Block diagram of a solid-state diathermy machine.*

6.6 Electrodes used

- **Lancet electrodes** are normally used for cutting; **needle electrodes** for epilation and desiccation; **loop electrodes** (wire loop, band loop) for excising or opening channels and removing growths.
- Cutting electrodes come in many shapes, chosen by the nature of the application. For coagulation the active electrodes are **ball or plate type**.
- The high-potential terminal of the diathermy is connected to the cutting electrode, which is mounted in an insulated handle. The surgeon switches the current on and off with a **finger-tip switch** in the handle or a **foot switch**.

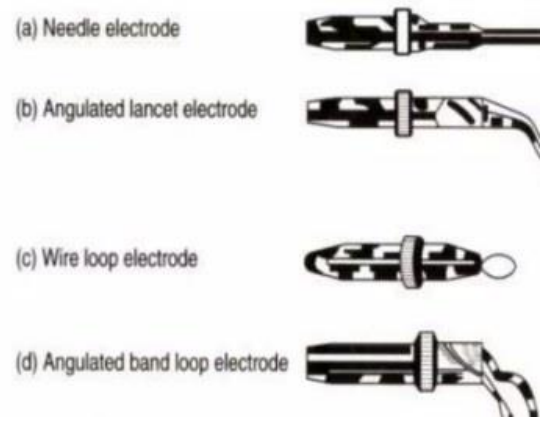

Fig. 6.8 *(a) needle, (b) angulated lancet, (c) wire loop, (d) band loop electrodes.*

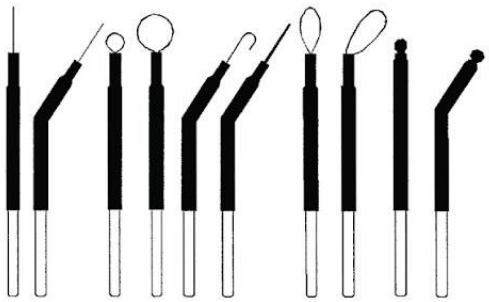

Fig. 6.9 *Common electrode tip shapes.*

6.7 † Safety precautions

- Apply the return plate over a well-perfused, muscular area with full skin contact; poor contact concentrates current and causes burns.
- Keep the patient from touching earthed metal; remove metal jewellery; avoid pooled fluids and alcohol-based skin preparations that can ignite.
- Take care with pacemakers and ICDs (electromagnetic interference) and remove flammable gases or agents from the field.

- Use smoke evacuation and check insulation of cables and handles before each case.

EXAM FOCUS

Short answer (2 marks)

1. Why does an electrosurgical unit operate at radio frequency rather than mains frequency?
2. Distinguish monopolar and bipolar modes of electrosurgery.
3. List the types of electrosurgery and state the effect of each.
4. What is blend (haemostasis) current and why is it used?
5. Name the electrodes used for cutting, coagulation and desiccation.

Long answer (13 / 16 marks)

6. With a neat block diagram explain the working of a solid-state diathermy machine.
7. Discuss the monopolar and bipolar techniques of electrosurgery with diagrams and list the safety precautions.

TOPIC 7
Prosthetic and Orthotic Devices

A **prosthesis** is an artificial replacement for all or part of an upper or lower extremity. It is designed to replace, as far as possible, the function or appearance of a missing limb or body part. An **orthosis** is an externally applied device that supports, aligns, protects or corrects a body segment that is still present. Prostheses and orthoses are designed and fitted by the prosthetist/orthotist as part of the rehabilitation team.

	Prosthesis	Orthosis
Purpose	Replaces a missing limb or part	Supports, protects, corrects or improves function of an existing part
Chosen by	Level of amputation	Body segment affected and the condition

7.1 Prosthesis: purpose and components

A prosthesis gives a person with an amputated limb the chance to carry out functional tasks, particularly **ambulation** (walking) that would not be possible without the limb. The type of prosthesis is determined by the extent of the amputation. The main components are:

- **Socket:** the part into which the stump is inserted; it must give an intimate, comfortable fit between socket and stump. An upper-limb socket has a double-wall framework of resin, lightweight plastic or composite: the inner wall conforms to the stump and the outer wall gives length and contour to replace the forearm. The wrist unit attaches to the distal end of the forearm piece.
- **Body of the prosthesis:** the structure (forearm piece, elbow, pylon, knee) that replaces the missing segment.
- **Harness / suspension system:** attached directly to the socket to (1) give stable support, (2) provide attachment for the control cables and (3) help control the terminal device and/or elbow unit through the cables. A common example is the figure-of-eight harness.
- **Control system and terminal device:** cables, switches or electrodes let the user operate the joints and the **terminal device** (hook, hand or foot) at the end of the prosthesis.

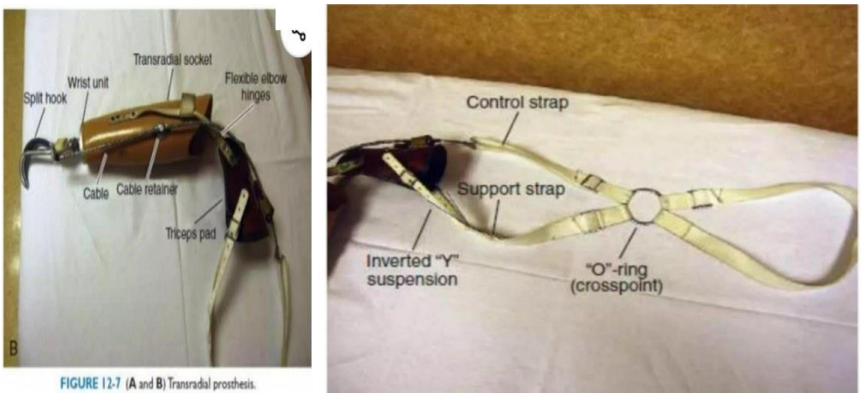

Fig. 7.1 *(a) Transradial prosthesis: split hook, wrist unit, cable, flexible elbow hinges, triceps pad. (b) Figure-of-eight harness with control strap, support strap and O-ring crosspoint.*

7.2 Power sources

	Body-powered	Externally powered
Energy	Body movement transmitted through cables (Bowden cable)	Battery-driven electric motors

	Body-powered	Externally powered
Control	Forward shoulder flexion tensions the cable and opens the terminal device; relaxing closes it	**Myoelectric:** surface electrodes pick up EMG from residual muscles to drive the motors. **Switch-controlled:** small switches in the socket or harness
Features	More durable, lighter and less expensive than myoelectric	Needs no harness force; more cosmetic; costlier and heavier

† In **targeted muscle reinnervation (TMR)** residual nerves are surgically re-routed to spare muscles so that they give extra EMG control sites for a microprocessor-controlled arm.

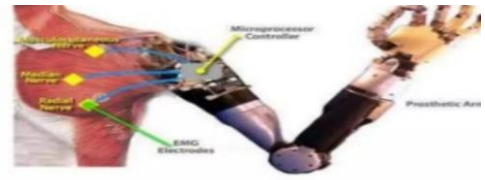

Fig. 7.2 *Myoelectric arm with targeted muscle reinnervation: EMG electrodes, microprocessor controller and prosthetic arm.*

7.3 Types of prostheses by level of amputation

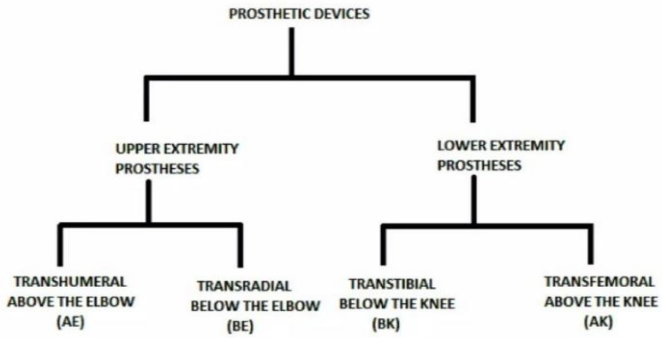

Fig. 7.3 *Classification of prosthetic devices.*

Level	Common name	Key points
Transhumeral	Above elbow (AE)	Replaces the upper arm including a prosthetic elbow. The complexity of elbow movement makes natural motion with an artificial limb very difficult.
Transradial	Below elbow (BE)	Replaces the arm below the elbow. **Cable-operated** limbs use a harness and cable around the opposite shoulder; **myoelectric** arms sense muscle activity in the upper arm through electrodes to open or close the hand.
Transfemoral	Above knee (AK)	Replaces a leg missing above the knee. Regaining normal movement is difficult; the amputee needs about 80% more energy to walk than a person with two whole legs.
Transtibial	Below knee (BK)	Replaces a leg missing below the knee. Because the knee is retained, normal movement is regained more readily than with a transfemoral prosthesis.



Fig. 7.4 *(a) Transhumeral, (b) transradial, (c) transfemoral and (d) transtibial prostheses.*

7.4 Orthoses: classification and functions

An orthosis is named after the body segment it encompasses. Its functions are to **maintain alignment, support a segment, prevent, correct or accommodate deformity, and improve function**.

FO foot; **AFO** ankle-foot; **KO** knee; **KAFO** knee-ankle-foot; **HO** hip; **HKO** hip-knee; **HKAFO** hip-knee-ankle-foot; **SIO** sacroiliac; **LSO** lumbosacral; **TLSO** thoraco-lumbosacral; **CO** cervical; **CTO** cervical-thoracic; **CTLSO** cervical-thoraco-lumbosacral orthosis.

7.5 Lower-limb orthoses

Orthosis	Description	Common indications
Foot orthosis (FO)	Shoe inserts that support the foot and improve posture; maintain alignment and correct or accommodate deformity.	Chronic foot or leg problems that affect foot function
Ankle-foot orthosis (AFO)	Extends above the ankle but below the knee; a mechanical lever arm controls the ankle complex and influences the knee indirectly. Supramalleolar orthoses are shorter versions.	Drop foot, stroke, arthritis, posterior tibial tendon dysfunction, ankle instability, paralysis, ankle fusion, multiple sclerosis
Knee-ankle-foot orthosis (KAFO)	Long-leg orthosis spanning knee, ankle and foot to stabilise joints and assist leg muscles; conventional, modular and modular-with-joints types.	Muscle weakness, lower motor neuron lesions, spinal cord injury, paraplegia, polio
Knee orthosis (KO)	Supports, protects and prevents deformity of the knee joint (push knee splint, single-bar, knee cage).	Osteoarthritis, knee instability, ACL/PCL tear or repair, varus/valgus deformity, MCL/LCL insufficiency, post-operative care, patella dislocation
Hip-knee-ankle-foot orthosis (HKAFO)	Custom-moulded plastic shell with contoured metal uprights and a pelvic band; supports the hip, knee, ankle and foot and improves alignment, posture and independence.	Assist gait, control movement, minimise progression of movement
Hip orthosis (HO)	Supports and protects the hip; prevents excessive flexion or extension and limits abduction (hip stabilising orthosis, SWASH orthosis, Frejka pillow).	Hip fracture or dislocation, post-operative care, osteoarthritis, developmental dysplasia of the hip, coxa valga/vara



Fig. 7.5 *Foot orthotic; supramalleolar orthoses (SMO); conventional, modular and modular-joint KAFOs.*



Fig. 7.6 *Knee orthoses (push knee splint, knee cage); hip orthoses (stabilising, SWASH, Frejka pillow); unilateral and bilateral HKAFO.*

7.6 Spinal and cervical orthoses

- **Corset:** gives abdominal compression, raises intra-abdominal pressure, assists respiration in spinal cord injury and relieves low-back and sacroiliac pain.
- **Lumbosacral orthosis (LSO):** controls or limits lumbosacral motion. The lumbosacral corset gives anterior and lateral trunk containment; steel straps posteriorly restrict flexion and extension. The Knight spinal (LS FEL) has pelvic and thoracic bands, two posterior and two lateral uprights and an anterior corset; a plastic lumbosacral jacket gives maximum support and is more cosmetic but hotter.
- **Cervical orthoses:** soft collar, four-poster, Minerva and halo, in increasing order of immobilisation of the neck.



Fig. 7.7 *Abdominal corset and lumbosacral orthosis.*



Fig. 7.8 *Soft collar, four-poster, halo and Minerva.*

7.7 Upper-extremity orthoses

Categories: finger (FO), hand (HdO), wrist-hand (WHO), wrist-hand-finger (WHFO), elbow (EO), elbow-wrist-hand (EWHO), shoulder (SO), shoulder-elbow (SEO) and shoulder-elbow-wrist-hand (SEWHO) orthoses.

- **Finger splints** immobilise fingers after injury or surgery to prevent contractures. Indications: phalangeal fracture, ligament laxity, swan-neck and boutonnière deformity, rheumatoid arthritis, tendonitis, carpal tunnel and Dupuytren's contracture.

- **Hand orthoses** (functional, resting and dynamic splints) support weak or damaged parts of the forearm, wrist and hand. Indications: radius/ulna fracture, radial nerve palsy (wrist drop), osteoarthritis, carpal tunnel syndrome, stroke.
- **Wrist-hand orthoses** cover the forearm and palm to support weak muscles or limit wrist motion while the fingers move (short opponens splint, thumb spica). Indications: carpal and metacarpal fracture, rheumatoid arthritis, tendonitis.



Fig. 7.9 *Finger splints (Dupuytren, swan-neck, Murphy ring); functional, resting and dynamic hand splints.*



Fig. 7.10 *Short opponens splint and thumb spica.*

EXAM FOCUS

Short answer (2 marks)

1. Define prosthesis and orthosis.
2. Name the main components of a transradial prosthesis.
3. Compare body-powered and myoelectric prostheses.
4. Expand AFO, KAFO, LSO and TLSO.
5. What is targeted muscle reinnervation?

Long answer (13 / 16 marks)

6. Classify prostheses by level of amputation and explain the features of each type.
7. Describe lower-limb orthoses with their functions and indications.
8. Explain spinal, cervical and upper-extremity orthoses with examples.