

General

The Orthopedic Splint and Its Origins

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Splints have been used since ancient times. With knowledge and technology, they have continually advanced. This manuscript summarizes the history of splints to elucidate how and why they have changed over time. With this knowledge, readers will be able to value the contributions of previous innovators and imagine future possibilities, and the world of orthopedics continues to evolve.

INTRODUCTION AND BACKGROUND

Casts and splints are orthopedic devices that are used to protect and support fractured or injured bones and joints. Records show that humans have used elements to support extremities after injury since ancient times, and we can trace how practitioners continuously improved their designs and materials into modernity ([Figure 1](#)). The elements of modern splints rely on materials that were first used in construction and insulation, while their structural design resembles the original shape of the supports. Although the core needs of physiology remain unchanged, advanced technology has enabled the creation of more stable, durable, and customizable splints.

REVIEW

ANCIENT TIMES

The first reference to the creation and use of splint bandages appears in 3000 BC. In 1903, members of the British Hearst Expedition unearthed two mummies in the same tomb at Naga-ed-der (Egypt), both buried with splinted, fractured bones (femur and forearm).¹ The ancient Egyptians used wooden splints made of bark wrapped in linen and grass to support broken limbs. Illustrations and hieroglyphics have been found from as early as 2500 BC that depict surgeons working on patients' hands, feet, and knees with various medical apparatuses and splinting devices.¹ In the 10th century BC, Indian surgeon, Sushruta, wrote descriptions for 12 fracture types, 6 dislocation types, and treatment steps for each, including traction, manipulation by local pressure, opposition and stabilization, and immobilization.^{2,3} Ancient records have revealed that Hindus used bamboo sticks similarly to the Egyptians' use of wood for splinting.

The increased flexibility of bamboo was found to heal fractures quicker and more effectively.² Even earlier than these events, Neolithic skeletal remains found with bone fractures revealed advanced bone healing that scientists

suspect required the use of splints,⁴ indicating humans may have been splinting injured bones for even longer than we know.

Hippocrates, often called the father of medicine, built upon the foundation of ancient medicinal practices in his writings, Hippocratic Corpus (circa 440-340 BC). Hippocrates wrote several chapters on orthopedics and detailed instructional treatment information, such as "...splints must be applied along the entire length of the affected limb, including the adjacent joints for safer stabilization." In addition, he recommended splints be made of thin, light wood, placed on the bone shaft, and worn until completely healed.⁵ The bandages used to hold the splints in place were often linen soaked in cerate and oil.⁶

By 30 AD, Romans and Greeks were using splints and bandages to treat fractures. Romans stiffened their bandages with corn starch, and the Greeks used waxes and resins. Beginning around 800 AD,⁷ Arab surgeons used lime derived from seashells and egg whites to harden bandages, creating some of the first iterations of plaster.^{2,7} Starch-based casts remained the standard of care with only minor changes until the beginning of the 19th century.⁸

16TH - 19TH CENTURY

The introduction of gunpowder in battle temporarily displaced armor makers, but their extensive knowledge of exterior anatomy, joint alignment, and metalwork allowed the industry to transition to brace fabrication.⁹ This led to an increase in joint and bone injuries being treated using metal braces or "appliances for crooked arms".⁹ In 1592, surgeon Hieronymus Fabricius wrote and illustrated the first written manual for splints. This one-page manual demonstrated and detailed a variety of armor-based splints to treat contractures of various body parts.⁹ Additionally, Fabricius founded the world's first permanent anatomical theatre in 1595.¹⁰ His written and visual depictions of orthopedic techniques led to his creation of the 'Oplo-mochlion,' or 'armored man'.¹⁰ The image is a collection of all the braces Fabricius used to correct congenital and post-trauma injuries.¹⁰ From the 1750s to 1850s, surgeons and

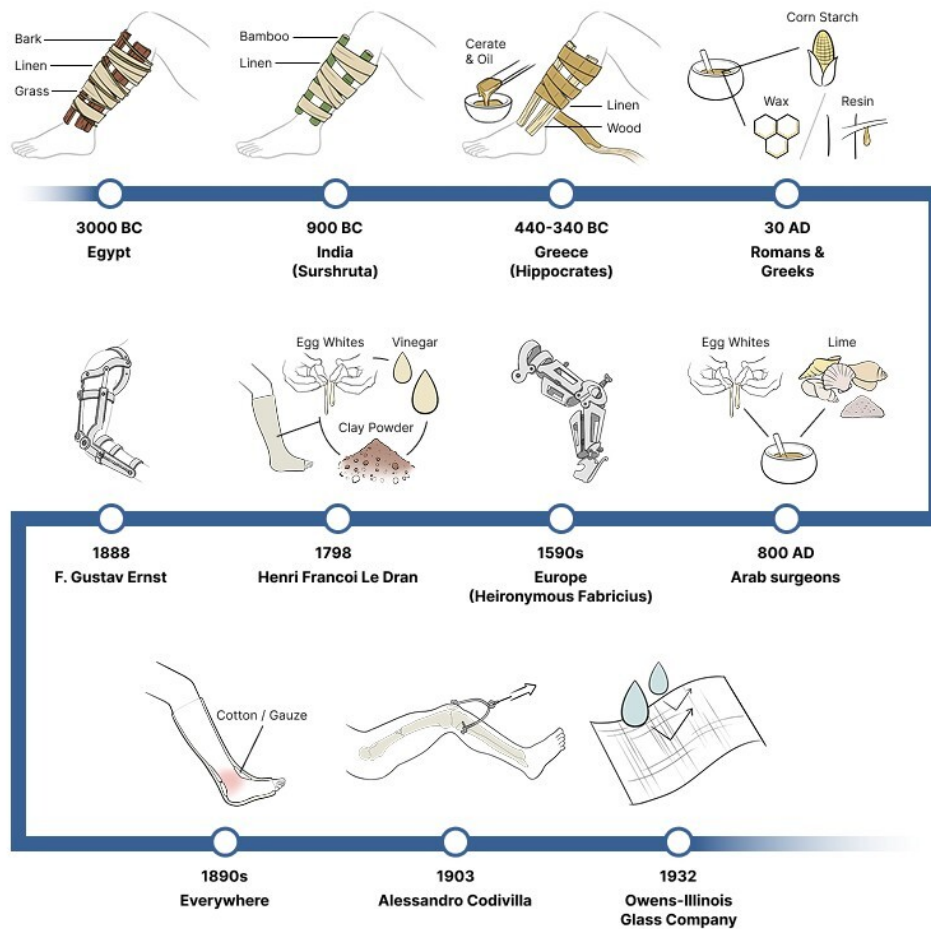


Figure 1.

mechanics worked closely to devise these custom braces and splints.⁹ Fabricius' work was vital to the advancement of orthopedics.

War served as a powerful motivator for the advancement of injury prevention and treatment. In the 18th century, Army surgeon Henri Francois Le Dran used bandages soaked in egg white, vinegar, and clay powder or plaster to treat wounded soldiers in Paris.⁸ Belgian surgeon Baron Louis Joseph G Seutin became infamous for his invention, "La Bandage Immobile," straps of linen or bandages and carton splints soaked in starch.⁸ In 1798, plaster of Paris, or calcium sulfate, was introduced to the world, despite first appearing in Persia as early as 975.⁴ For the majority of the next century, plaster of Paris was very commonly used to treat broken bones. As the field continued to grow, surgeons began to carve out the subspecialty: orthopedics. Jean Andre Venel (1740-1791) founded the first orthopedic institution in Orbe, Switzerland and was later credited with the founding of orthopedic surgery in 1780.¹ French surgery professor Jacques Delpech (1777-1832) published "L'orthomorphie," a complete study of deformities of the bone and joint and opened his own orthopedic institution.¹

By 1883, surgeons and mechanics had become competitive against each other, and a schism formed between the formerly aligned industries.¹ Class issues drove this division, with surgeons wishing mechanics "stayed in their place," only advising on structural components.¹ Mechanics and surgeons stopped working together, but both groups continued to practice brace fabrication, creating two distinct groups of practitioners.¹

In 1888, mechanic F. Gustav Ernst published a book containing elaborate illustrations of sophisticated splints and braces for treating upper extremity problems.⁹ In addition to splints created for post-traumatic injuries, Ernst even devised contractions for paralyzed limbs and contracture conditions (like Dupuytren's disease).⁹ Ernst drew and described elaborate, multi-part metal braces containing sophisticated mechanics like centrifugal springs and parts that could fully extend.⁹ The use of metal in the splint manufacturing allowed them to be easily produced and standardized.¹¹ A little over a decade later, in 1899, Italian surgeon Alessandro Codivilla published articles demonstrating the importance of eliminating contractures prior to rebalancing the tendon transfers.⁹ This discovery was a contributing factor that led to the establishment of post-treat-

ment rehabilitation¹¹ and emphasized the importance of the relationship between surgery and splinting.⁹ Codavilla pursued further orthopedic advances and was the first to apply skeletal traction by means of a pin as early as 1903.¹²

MODERN TIMES

In the early 20th century, plaster of Paris had become the standard material for fracture stabilization.⁹ Before its use as a casting medium, plaster of Paris was a commonly used construction material for centuries.⁸ The best manufacturing technique for casting plaster became standardized by the early 1900s and produced the plaster by removing impurities from mined gypsum and reducing the amount of water crystallization through controlled heating conditions.⁸ Hospital nursing staff was responsible for the creation and maintenance of plaster bandages until the 1930s when the first commercially manufactured bandages became available.⁸ Plaster of Paris was successfully adapted from the construction sphere to the orthopedic field as a casting material because it is affordable, non-toxic, easily malleable to the contours of the human body and rarely causes skin irritation or allergy.⁸ These elements remain true today, which is why it is still so widely used as a splinting material.

However, casts made from plaster of Paris also have downsides. To achieve necessary immobilization, the thick plaster is oftentimes formed into a bulky cast that can become uncomfortable after an extended period of time.¹³ Additionally, plaster of Paris is not water resistant or resistant to moisture; this lack of ventilation can lead to an increased chance of infection.¹³ After a plaster of Paris cast is set, it is impossible to release the moisture accumulation under the cast or provide heat or ice treatment¹³ without compromising the immobilized structure.

Cotton and other synthetic materials are used to line the inside of the cast, providing a soft padding around bony areas like the ankle, wrist, or elbow. Cotton has been commonly used for bandaging since the late 19th century and remains the most readily used and available material today.⁴ Modern-day gauze now often also includes an absorbent coating that prevents the bandage from adhering to the wound.⁴ In 1932, researchers at the Owens-Illinois Glass Company accidentally discovered how to create ultrafine, threadlike glass fibers [14]. Owens-Illinois teamed

up with Corning Glass in upstate New York to create the Owens-Corning Fiberglas Corporation in 1938 [14]. Fiberglass was being used as insulation material for its benefits: “It repels moisture: most acids and alkalis don’t penetrate the filaments; it resists mold and mildew; it doesn’t conduct electricity; and it doesn’t decay, rust, shrink, expand, or burn.” [14]. The orthopedic community saw the potential value of fiberglass in brace fabrication.

The discovery of materials like fiberglass and technology like 3D printing has made the splinting process extremely customizable. 3D printed fiberglass splints are thin and light, fitted to the contours of the wearer, stable, waterproof, easily removable, and prevent infection and muscle atrophy.¹³ Unfortunately, 3D scanned and printed models are very expensive.¹³ Continuous research is being done on more affordable materials that can be used to create models similar to the expensive 3D cast. For example, a study successfully created an affordable cast out of polypropylene that allowed for comfortable immobilization while providing skin exposure to allow for ice/heat pack treatment and better prevention of macerations and infections.¹³

CONCLUSIONS

The evolution of splints over time is due to multiple factors. The first is the material choice. The material choice has changed as different substances have become more readily available and discovered to be suitable for providing the necessary strength and support. As experience and technology have allowed, more durable materials have been used, and comfort has also been incorporated into the design. The shape of splints is largely dictated by the injury location. The design of splints has been influenced by mechanics as well as physicians to ensure that the joints and bones are held in an ideal state for healing.

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