

The History of Spinal Deformity

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Abstract

The description and history of the treatment of spinal disorders have evolved from very early Grecian and Hindu times through to today's complex techniques. An emphasis on renowned figures from throughout the world who have contributed greatly to our understanding and care of spinal deformities is provided. Knowledge of the past provides significant input to our understanding of the current problems and enhances the development of future modalities of care.

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Keywords: History; Spinal Deformity; Scoliosis

Introduction

This brief history of spinal deformity outlines what transpired from the days of ancient Egypt to the current techniques of complex derotation, translation, distraction, compression, and resection. This is not meant to be an exhaustive description but instead a chronological progression of the treatment of scoliosis. As Billroth, a famous surgeon from Zurich, Switzerland, once stated, “Only the man who is familiar with the art and science of the past is competent to aid in its progress in the future” [1].

Antiquity Writings, 3000 BC–AD 1000

Smith, in his explorations of Egypt, discovered papyrus papers from 1550 BC describing 48 cases of injury, diagnosis, and treatment, including closing with sutures [2].

The *Edwin Smith Papyrus* is a textbook on surgery that details anatomical observations and the “examination, diagnosis, treatment, and prognosis” of numerous ailments. It was probably written around 1600 BC but is regarded as a copy of several earlier texts. Medical information in it dates from as early as 3000 BC. Imhotep in the third dynasty is credited as the original author of the papyrus text and founder of ancient Egyptian medicine. The earliest known surgery was performed in Egypt around 2750 BC [3].

In 1910, the Egyptologist Ruffer described tuberculosis of the spine in the mummy of Nesperehan with all of the

indications of Pott's disease, including angular kyphosis caused by the collapse of the thoracic vertebrae [4]. Although Aristotle (4th century BC) is credited with founding the basis of comparative anatomy, it is apparent that Ancient Greek physicians read these Egyptian works and traveled to Egypt to study its medical techniques.

Hippocrates is considered the father of spinal deformity treatment. Through acute observation and logical reasoning,

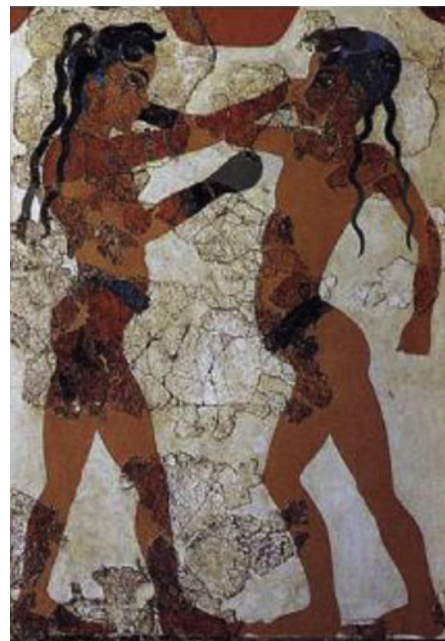


Figure 1. This illustration of the “Boxing Boys” from 1600 BC clearly reflects rigid abnormalities, the likely cause being spinal deformity [5].

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Figure 2. A drawing from the 16th century displaying the correction of a spinal deformity using a Hippocratic board [5].

he was led to accurate conclusions for the structure of the spine and for its diseases (Fig. 1) [5]. Hippocrates was the first to describe the use of corrective casts. Patients were immobilized in casts formed by blood-soaked bandages [6]. Figure 2 clearly shows the correction of what was probably a tuberculous kyphosis using his traction table, which is not all that dissimilar from that used during my early years of practice. Hippocrates also introduced the words kyphosis and scoliosis, as well as performed trepanation. He described the blood supply to the spine and described normal spinal curvatures [5,6].

In his book *On Nature of Bones*, Hippocrates describes that the function of the bones, and particularly of the spine, is to maintain the erect position of man and to form the shape of the human body [7]. He describes the anatomy and the diseases of the spine and suggests treatments for patients with spinal deformities. This is the first systematic presentation of anatomy and pathology of the spine in medical history. He realized that the spine was held together by means of intervertebral discs, ligaments, and muscles, permitting him to describe the normal curvatures of the spine [5]. This remarkable knowledge of anatomy derived from cadavers in battlefields, from observations of athletes exercising in the gymnasiums, and from dissections of animals, because dissection of human bodies was prohibited.

Galen, also a Greek, described scoliosis, lordosis, and kyphosis in depth, and provided etiologic implications. He employed the same principles as Hippocrates for their management, while his studies shaped the treatment of spinal deformities for more than 1,000 years. He also described the exiting nerve roots and experiments on animals on spinal cord transection [8]. Galen's dedication to the human anatomy and treatment of diseases led to the production of a voluminous collection that became the foundation of the Galenic system of medicine. This system relied more on logical theories than observation and experience, and remained the accepted method of medicine until the Renaissance [9].

From the time of Hippocrates to the Middle Ages, a somewhat clouded period in history, surgery consisted of bloodletting, bone setting, and trephining. In the bright days of the Middle East, including the Arab world, Persia and Turkey contributed. Abbas in Persia, more than 1,000 years ago, talked of spinal trauma. Ibn Seru (980 BC–AD 5) discussed axial traction as did Somuncuoglu (1385–1468) [10].

Early “Modern” Spinal Knowledge, 1600–1900

Leonardo DaVinci (1452–1519) was the first to describe anatomy of the spine and its biomechanics in any detail [11]. He detailed the number of vertebrae as well as the relationship of various curvatures and articulations between the vertebrae. Giovanni Alfonso Borelli (1608–1679) wrote the first text on biomechanics entitled *De Motu Animalium* [12].

Bracing

Nicolas Andry de Bois-Regard (1658–1759), a French physician, is credited with using the term *orthopedics*, which literally means “straight child” and is known for his illustration of a crooked tree strapped to a straight stake [13]. The line diagram is intended to show backbone deformities and now is the symbol of orthopedic surgery. Andry believed that skeletal deformities were caused by an imbalance of the vertebral muscles and/or poor sitting posture.

Jacques Mathieu Delpech (1777–1832) published a two-volume atlas titled *De L'orthomorphie*. He described the different ideologies of scoliosis and introduced subcutaneous tenotomy in 1818 [14]. He founded a rehabilitation facility that emphasized exercise in the treatment of postural back pain and deformity [15].

Traction

Francis Glisson (1597–1677) from Britain, a physician and pathologist, introduced the Glisson sling for the correction of scoliosis [16]. This consisted of a bandage strapped from under the axilla, above the head and under the chin. The patient's arms were translated dorsally with a rod placed anteriorly to the arms and pressing against the posterior thoracic spine. The patient would then be suspended in the air. This apparatus attempted to provide corrective forces to the apex of the deformity.

Francois LeVacher later described a skull cap distraction device to correct deformity [17]. This was applied with the patient in the upright position. Jean-Andre Venel (1740–1791), a Swiss, founded the first hospital for crippled children [18]. The hospital specialized in spinal deformity. He advocated the use of braces and appreciated the concept of the three-dimensional balance of the spine.

Surgery

The first recorded spinal surgery is by Paul of Aegina in the late 7th century [19]. He performed a laminectomy on a slave who was struck across the back with a stave. History does not record the outcome, but given that 90% of the soldiers in World War I who were rendered paraplegic died within 1 year, it is unlikely that this victim of the 7th century survived long.

The founder of modern surgery was Ambroise Paré (1510–1590), a barber-surgeon [20] who, during the 1537 siege of Turin, rejected the Galenic system of medicine and

used empirical observations to treat the wounds of his patients. Paré initiated a new era of medicine more focused on minimizing damage to tissue and improving the restorative process [21].

Andreas Vesalius (1514–1564) contributed to the significant understanding of anatomy [20]. His anatomical drawings led him to the discovery that Galen used animal models for his theories on human anatomy [21]. Vesalius corrected many of Galen's anatomical theories and, more importantly, taught his medical students to rely on their own observations instead of those of their elders.

Percival Pott (1717–1789), from London, contributed to the description of spinal disorders in his classic treatise in 1769 of spinal deformity caused by tuberculosis of the spine. The importance of his contribution is recognized by the eponym “Pott's disease” [22]. The tuberculous nature of spinal deformity had been surmised by Hippocrates, but it was Pott's classic description that finally brought the condition to crystal clarity for the practitioner of the time [23].

Early scoliosis surgery consisted primarily of myotomies described by Guerin in 1839, who also described posterior spinal surgery. The myotomies were performed percutaneously as an adjunct to straightening with a specially designed brace. Guerin was violently criticized by Malgaigne and Velpeau. Malgaigne is better known for the description of pelvic fractures and Velpeau for the technique of shoulder immobilization. Among a total of 24 cases that were reviewed, 20 had one or more myotomies, 13 were described as having slightly improved, 7 lost correction, and 6 were worse. Subsequently, Guerin was banned from practicing in France and moved to Belgium [24].

Resections began to be used for the correction of spinal deformities in the late 1800s. Volkmann (Germany) first described thoracoplasty for the treatment of rib hump deformity in 1889 [25]. This technique was further explored in the 20th century in combination with other techniques to treat scoliosis [26]. In 1928, Royle of Great Britain described resection of hemi-vertebrae as did Compere in 1932 from Chicago. Compere described the use of hemi-vertebral excision using a posterior approach in two cases of congenital scoliosis. He also used the ipsilateral side to prevent progression of the deformity. The results were not good, including the development of severe kyphosis. He subsequently did not recommend this treatment because of postoperative complications [27,28].

Lewis Albert Sayre (1820–1900) authored a book titled *Spinal Disease and Spinal Curvature: Their Treatment by Suspension and the Use of Plaster of Paris Bandage*. Using actual traction, a plaster of Paris cast was fitted to the patient with lateral traction applied as well. The principles described by Sayre were practiced until the early twentieth century. Sayre was the first to use plaster of Paris casts [29,30]. Arthur B. LeMesurier from Toronto, Canada, described the fishnet technique for correction of spinal deformity [31].

Treatment of spinal deformity took a turn for the better with the work of Joseph Risser of Los Angeles. He

described localizer and turnbuckle casts, and casts for postoperative ambulation. He advocated early surgery, and described the Risser sign. Surgery was subsequently done after cast correction through a window in the posterior aspect of the cast (Fig. 3A and 3B). Needless to say, the infection rate was somewhat high and casts required change because of their inherent risk of infection due to a lack of hygiene. [33,34].

Early surgery as described consisted of basic forms of traction suspension, myotomies, and muscle transfers. Deformities were generally felt to be due to poliomyelitis, the great orthopedic teacher. Early fixation consisted of the use of silk soaked in carbolic acid, and silver wire. Hadra in 1891 described to the Texas State Medical Association wiring as a means of immobilization in fractures and Pott disease. Silver wire was used between the spinous or transverse process [35,36].

Captain W. F. Wilkins (1848–1935, Fig. 4A), a professor of medicine at the college of physicians and surgeons in Kansas

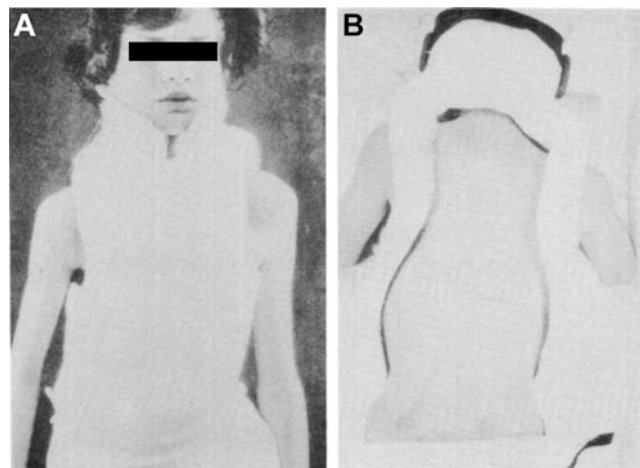


Figure 3. (A) Localizer cast that extends up over the occiput and mandible. (B) Surgery performed through a window in the cast [32].

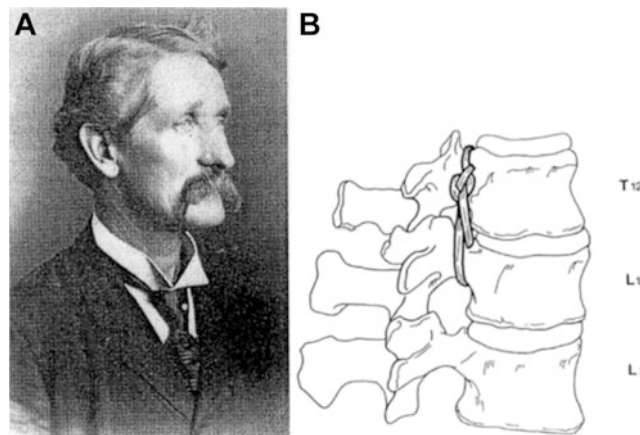


Figure 4. (Left) Captain W. F. Wilkins. (Right) Illustration of the wires used by Wilkins posteriorly on the newborn spine [37].

City, Kansas, is credited with performing the first operation on a spine where internal fixation was used (Fig. 4B). Possibly this could be described as the first use of pedicle fixation. He carried out the surgery in a newborn infant with a fractured dislocation of T12 on L1. The carbolyzed silver wire was passed completely around the pedicles. The canal was dislocated and opened wide so that the fixation could be easily performed without injuring the spinal cord [23].

Edward Bradford established the first scoliosis clinic at the Children's Hospital in Boston in 1897 [38], and in the same year Calot treated tuberculous spines at Berck Plage in France, a well-known institution that recently closed. This was the home of Cotrel and a major site of worldwide spinal education. Calot described plaster cast reduction of kyphosis and posterior arthrodesis by periosteal suture around the lamina and transverse processes. Bone graft was not used [39].

In 1909, Arthur Steindler from Iowa published his works on scoliosis advocating the development of secondary compensatory curves rather than persisting in unsatisfactory attempts of correction of the primary deformity. He advocated prolonged exercise and muscle strengthening, and once he felt the corrected position was achieved, the plaster of Paris cast was applied. Later in his career, operative treatment of scoliosis was introduced. A more detailed biography of Steindler is available elsewhere [40,41].

Lange in 1910 presented a paper to the American Orthopedic Association in Washington, DC, describing support for the spondylolytic spine obtained by healing and attaching steel bars to the vertebrae by silver wires—no arthrodesis was attempted or achieved [42].

Era of Fusion

Techniques of fusion were introduced by Fred Albee and Russell Hibbs. Albee was considered the father of spinal surgery during the early 1900s (Fig. 5A). He was an advocate of using tibial autologous graft inserted between the split spinous processes (Fig. 5B). The operation was described

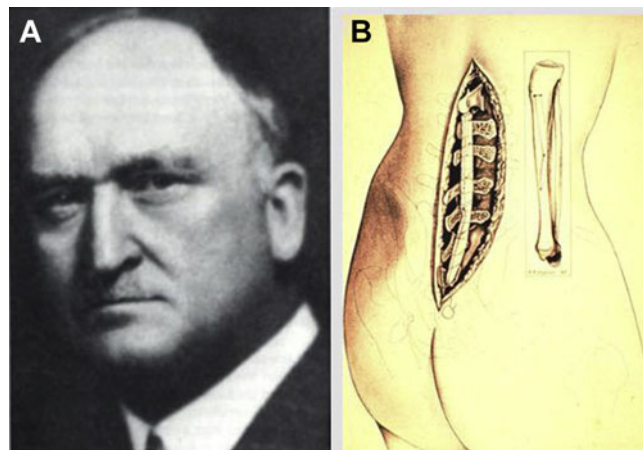


Figure 5. (A) Fred Albee (1876–1945) [43]. (B) During surgery, the tibial graft is shaped to match the kyphosis of the deformity [44].

initially for tuberculosis but its use in scoliosis was predicted [45]. In 1913, Galloway (Winnipeg, Canada) reported on 3 cases of spinal fusion using Albee's graft, the first described case was a 6-year-old boy with a collapsing polio spine [46].

Russell Hibbs recorded operations for scoliosis in 1914 and reported on these in 1923 [47]. Using concepts he had published on an operation for stiffening the knee joint, Hibbs realized the same could be done for the articulating joints of the spine. On January 9, 1911, he performed a landmark and extremely controversial surgery to fuse the “spinous processes, laminae and intervertebral articulations” to prevent the progression of curvature of the spine in a patient with spinal tuberculosis. Describing the procedure in *An Operation for Progressive Spinal Deformities*, Hibbs wrote that he stripped the periosteum from the posterior arches and split the spinous processes to overlap the interspinous spaces. Fragments of bone from the laminae were placed in the interlaminar spaces. In addition, each intervertebral articulation was curetted and denuded of cartilage to form a bleeding bed and thus make the fusion possible. Acquiring enough bone to perform the fusion, especially in pediatric cases, allowed Hibbs to succeed where others failed and stands as a testament to his meticulous operative skills [48].

In spite of the use of fusion, a report to the American Orthopedic Association in 1941 on scoliosis was provided including 425 cases of idiopathic scoliosis. In 214 patients, correction was described as fair to poor in 69% and good to excellent in 31%, but included a 30% incidence of pseudarthrosis [49].

Anterior approaches to the vertebral column were common in the late 1800s in order to access and drain tuberculous abscesses. In 1934, Ito of Japan refined this approach. His work popularized the anterior approach and became the foundation for future, more complex anterior spinal procedures [50].

Mixer and Barr of Boston (a neurosurgeon and an orthopedic surgeon respectively), described the rupture of a vertebral disc with involvement of the spinal canal in the *New England Journal of Medicine* in 1934. This publication fundamentally changed the understanding of sciatica. Though not directly contributing to the treatment of spinal deformity, it was a major advance in spinal surgery. Their work helped clarify the relation between the sciatica and intervertebral disc, as well as change the management of the sciatica in spinal surgery. The initial surgeries were done transdurally, and it wasn't until later that the extradural approach to the disc was developed [51].

Philip Wiles in the early 1940s performed dorsal wedge resection of the vertebra in two patients with congenital scoliosis. Both patients developed severe kyphosis and one developed paraplegia as well. These were the first glimpses of surgical correction of kyphotic deformity. Roaf, another surgeon from England, also conducted wedge resection for kyphotic deformities, but long-term results are unknown [52].

Von Lackum and Allen DeForest-Smith performed the first anterior spinal surgery in the United States in 1924. They

used a two-stage surgery, including an anterior approach, describing excision of vertebral bodies in the treatment of scoliosis. Their first report of 10 cases was in 1933 in the *Journal of Surgery, Gynecology and Obstetrics*. The results were not well recorded, but it is known that kyphosis developed in some [53]. It is of interest that this technique was subsequently popularized by Suk of Korea [54].

Professor J.I.P. James, initially from the Royal National Hospital in London, England, and subsequently in Edinburgh, Scotland, described a radiographic classification of curves and said up to 69 degrees was classified as mild, 70–99 degrees classified as severe, and over 100 degrees as very severe [55].

John Cobb, an orthopedic surgeon from New York, is best known for his methods of measuring scoliosis curvatures. He also advocated a preoperative period of observation to see if and how the patients' curvatures changed over time. His method of measuring curvatures, known as the Cobb angle, remains a fundamental tool despite the great advances in 3D computer imaging and diagnostic tools [56,57]. Cobb also stated in 1952, "From our experience we have been quite pleased with cancellous bone bank bone for supplemental bone in scoliosis fusion. It does not take the place of good surgical technique in doing a fusion operation" [58].

Before the 1970s, only one publication described cases on the surgical treatment of adult spinal deformity. Nilsson of Sweden described a few cases in 1970. A much more significant number including 90 cases were described by Kostuik in 1972 [58,59].

A significant advance in the treatment of rigid deformity was described in the *Journal of Bone and Joint Surgery* in 1968 titled "The halo, a spinal skeletal traction fixation device", by Nickel and Jaqueline Perry. They worked at the famous Rancho Los Amigos in Downey, CA, a suburb of Los Angeles. They described the use of the halo vest using a plaster cast for immobilization attached to the halo (Fig. 6) [60].

DeWald of Chicago first described the use of the halo pelvic device. O'Brien and Hodgson of Hong Kong subsequently popularized this. Patients were often immobilized

and slowly distracted over a number of months. Problems occurred at C1–C2 with this device and it proved to be awkward to operate on the spine with the device on. Its modification subsequently occurred, and today axial traction has assumed an important place in the treatment of severe deformities, often used in an ambulatory fashion [61,62].

John E. Hall of Toronto, and subsequently Boston, as a registrar at the Royal National Orthopedic Hospital (1954–1956), described the treatment of spinal deformity consisting of 200 polio patients, 100 tuberculous patients, 50 idiopathic scoliotics, and 20 with deformity secondary to osteomyelitis. Patients at that time remained in hospital for 1 year. The pseudarthrosis rate was 50%; there was a 35% incidence of infection, and correction was rarely maintained [63].

Spinal stenosis first appeared in medical literature with the description of a laminectomy performed in 1893. Sachs and Frankel again described the condition with their description of lumbar spinal stenosis in 1900. Verbiest of Holland clinically described lumbar spinal stenosis in 1954, and his explanation became the classic description. Intermittent spinal claudication or neurogenic claudication is now called the Verbiest syndrome as a result of his contribution [64,65].

Paul Harrington was educated in Kansas, but operating in Houston, Texas, revolutionized deformity surgery. He introduced the Harrington rods in Houston in the late 1950s because of the excessive humidity in that locale and the difficulty for patients in plaster cast immobilization. Harrington described not only his technique of internal fixation but described the balanced spine, the neutral vertebrae, and also developed morbidity mortality reports. The Harrington system provided distraction and compression with hooks at either end of the distraction system. It thus corrected only the mobile ends of the curve, and if used in the lumbar spine, resulted in a flattened lumbar lordosis. His early instrumentation was simple when compared to current instrumentation and truly began the era of modern instrumentation. It was subsequently used in combination with segmental sublaminar wires or spinous process wires. His work was the greatest stimulus to the development of spinal surgery and led directly to the formation of the Scoliosis Research Society [66,67].

For the same reasons as Harrington, Eduardo Luque of Mexico (Fig. 7A) described sublaminar wiring because of the heat and humidity in Mexico and the wish to avoid plaster cast immobilization (Fig. 7B). This provided a much more rigid fixation and introduced the concept of lordotic contouring for the lumbar spine [69,70]. The passage of sublaminar wires introduced significant fears among many of potential neurologic injury, though this was subsequently partially alleviated by the introduction of spinal cord monitoring as popularized by Brown and Nash [71]. Surgeons from Galveston, Texas, subsequently modified the Luque procedure to include a pelvic fixation system, and this modification is still used today by some in the treatment of paralytic scoliosis patients. A major disadvantage of the Galveston technique was the windshield wiper effect within the pelvis [72,73].

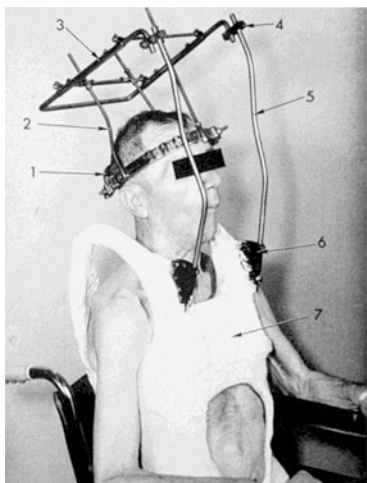


Figure 6. Patient shown in plaster cast attached to a halo device [60].

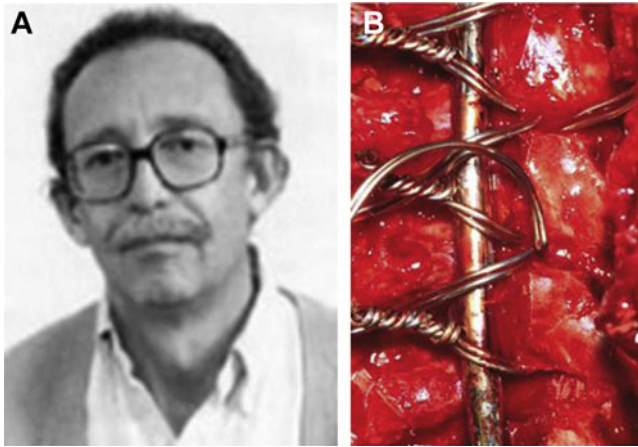


Figure 7. (A) Eduardo Luque [68]. (B) Sublaminar wires.

Up to the 1960s, spinal surgery included development of discography by Hirsch (Sweden) in 1948, electromyography, lipiodol myelograms, posterior lateral fusion, and occasional anterior lumbar surgery as well as anterior cervical surgery [74].

John Moe of Minneapolis is described as the father of modern posterior fusion. He introduced facet joint excision for spinal fusion, which added greatly to the Hibbs technique and helped to convince Paul Harrington to add fusion to rod correction. John Moe was the first president of the Scoliosis Research Society (1966–1969). He described the use of the ambulatory Risser localizer after Harrington instrumentation, halo femoral traction, square-ended rods with square-holed Harrington hooks to prevent rod rotation, and the use of subcutaneous rods without fusion for malignant early-onset deformity [75–77].



Figure 8. A. F. Dwyer [79].

A major influence in the late 1960s included a cable system used anteriorly as described by Alan Dwyer from Australia [78] (Fig. 8). He described the use of an anterior titanium cable system on the convexity of the curve for the correction of deformity, but this unfortunately resulted in kyphosis, particularly in the lumbar spine [80,81]. John Hall of Toronto, and subsequently Boston, described the use of short segment anterior Dwyer fixation for mobile curves in the lumbar and thoracolumbar spine instead of fusing more extensively [82].

Adam Gruca of Poland described the use of springs initially for treatment of fractures of the spine (Fig. 9). This method was used for deformity correction by initially placing the springs laterally on the ribs and gradually moving more medial to the spine. However, because of the tension of the spring, it led to bone erosion and failed in most cases [83].

Pierre Stagnara was also a great surgeon, particularly in France and Europe. He developed the Stagnara distraction



Figure 9. A spinal spring initially used for trauma in Poland.

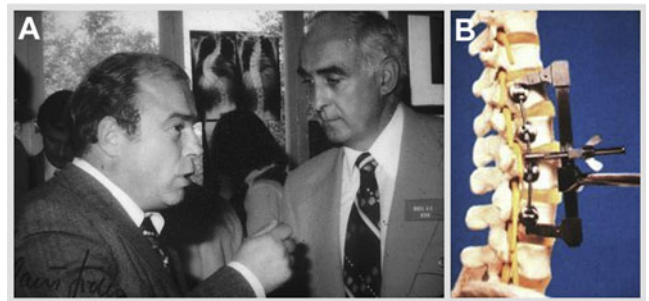


Figure 10. (A) Klaus Zielke and John Hall. (B) Anterior Zielke derotation device.

cast, which is still considered useful for the gradual distraction of the spine. Of more value was the intraoperative wake-up test used during surgery to assess the neurologic status of the patient. This test helps save patients from paraplegia and remains a standard of care today [84].

Klaus Zielke of Germany (Fig. 10A) in the early 1970s described the first derotation maneuvers to correct deformity. He used a semirigid rod with a derotator to correct the spine anteriorly as shown in Figure 10B. This provided a major influence on correction of lumbar and thoracolumbar deformities [85]. A report published in the *Journal of Bone and Joint Surgery* in 1986 by Kostuik et al. described its use in 56 patients with no pseudarthrosis, with loss of lordosis occurring in 11%. Patients older than 50 years had an average correction rate of 60%, with an average 72% correction for those under the age of 30 [86].



Figure 11. Dr. Raymond Roy-Camille (1927–1994) [37].

The 1970s saw significant advances, particularly with the development of pedicle screw fixation. Boucher from Vancouver first described in 1959 pedicle screw fixation with a trans facet pedicle screw for lumbosacral fusions [87]. Roy Camille (Fig. 11) of France first introduced pedicle screws with longitudinal plates in the 1960s,

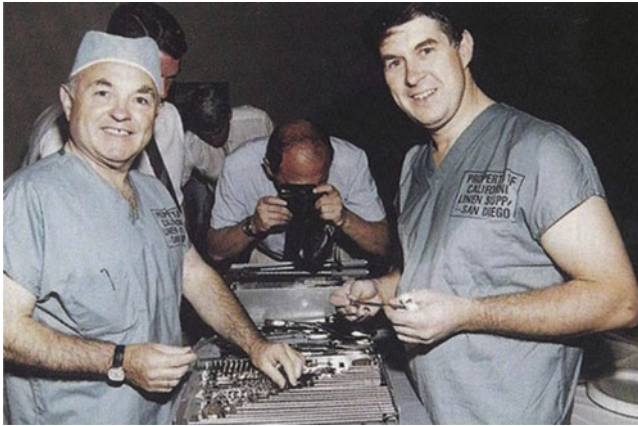


Figure 12. Cotrel and Dubousset [90].

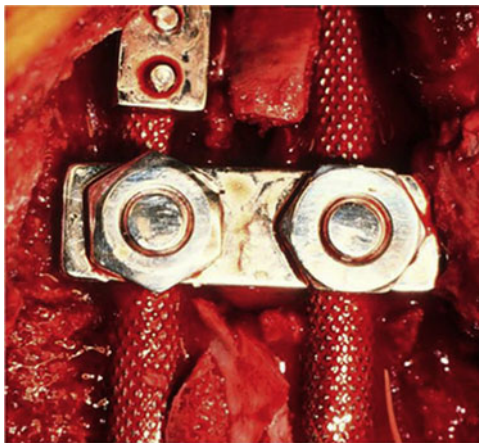


Figure 13. The CD (Cotrel-Dubousset) system using knurled rods designed by Cotrel and Dubousset.

but the technique initially was not known outside of France [88,89]. Camille was a great teacher and a well-loved figure, but unfortunately he died at an early age.

A remarkable new era was introduced in the 1980s by two famous French surgeons, Yves Cotrel and Jean Dubousset (Fig. 12). They were the first to describe posterior derotation of the spine using segmental fixation initially with hooks and subsequently with pedicle screws (Fig. 13) [91,92].

Contributions worldwide have significantly improved the well-being and lifestyle in people with spinal deformities. The explosion of techniques that have evolved today are far more effective in the treatment of spinal deformity, including the use of cantilever, translational, and derotation techniques. Though pedicle screws were first utilized in the 1960s, Suk of South Korea has popularized their use in the treatment of spinal deformities with marked success [54]. The use of vertebrectomies and multiple forms of osteotomies have greatly enhanced the treatment of rigid deformities worldwide. Improved instrumentation together with biologics have enhanced and decreased the

morbidity of spinal fusion. The long, complex history of spinal surgery involves many theories and techniques that are no longer used. However, a common theme throughout the years has been observation, preoperative treatment (such as traction and/or bracing), and surgical correction.

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