Iranian Journal of Orthopaedic Surgery
Vol. 23, No. 3 (Serial No. 90), Summer 2025, p. 133-152

A Review on the Application and Role of Different Screws in Orthopedic Surgery

(Review Article)

Abstract

Orthopedic screws play a crucial role in internal fixation for fracture stabilization, joint fusion, and osteotomy procedures. Recent advancements in material science and biomechanics have led to the development of various screw designs aimed at optimizing fixation strength and reducing postoperative complications. Understanding the biomechanical properties, classifications, and technological innovations of orthopedic screws is essential for improving surgical outcomes. This study presents a comprehensive review of the classification, design, biomechanical characteristics, and clinical applications of orthopedic screws. A systematic analysis of scientific literature was conducted to evaluate different screw types based on their material composition, mechanical properties, and fixation techniques. Additionally, emerging technologies, including bioabsorbable screws, locking screws, and smart implants, were examined for their potential impact on modern orthopedic surgery. The findings indicate that locking screws provide superior fixation in osteoporotic bone and complex fractures, reducing implant failure risks. Bioabsorbable screws have shown promise in eliminating the need for secondary implant removal surgeries; however, challenges such as degradation rate control remain unresolved. Drug-releasing screws have demonstrated effectiveness in lowering post-surgical infection rates, yet further studies are needed to determine optimal drug dosage and release kinetics. Advancements in orthopedic screw technology, including material innovation and improved mechanical design, have significantly enhanced clinical outcomes. However, challenges remain regarding the long-term stability of bioabsorbable screws, the optimization of mechanical properties, and the reduction of implant-related complications. Future research should focus on developing patient-specific implants and refining biomechanical designs to further improve surgical success rates.

Keywords: Orthopedic fixation devices, Internal fixators, Bone screws, Pedicle screws.

Accepted: 41 days before printing

Saleh Validi, MD, Ehsan Ghadimi, MD, Seyed Pouya Tabatabaei Irani, MD, Erfan Khosravi, MD,
Seyed Hadi Kalantar, MD

Imam Khomeini Hospital Complex, Joint Reconstruction Research Center, Tehran University of Medical Sciences, Tehran, Iran.

Corresponding Author:
Seyed Hadi Kalantar, MD
Email address:
hadikalantar4@gmail.com

Introduction

Orthopedic screws play a fundamental role in modern musculoskeletal surgery by providing stable fixation for bone fractures, osteotomies, and joint fusion procedures. The increasing prevalence of fractures due to aging populations, sports injuries, and trauma-related incidents has led to continuous advancements in screw design and material technology(1). These screws are an essential component of internal fixation, working in conjunction with plates, rods, and intramedullary nails to facilitate bone healing while minimizing complications such as malunion, nonunion, and implant failure(2).

The biomechanical performance of orthopedic screws depends on factors such as thread design, material composition, and the interaction between the screw and bone tissue. Cortical and cancellous screws, locking screws, cannulated screws, and bioabsorbable screws each serve distinct purposes, reflecting the complexity of bone fixation techniques(3). Innovations in 3D-printed implants, smart screws with embedded sensors, and bioactive coatings have further expanded the functional capabilities of orthopedic screws, enhancing their role in patient-specific treatments(4).

The history of orthopedic screws dates back to the early 19th century when metal implants were first introduced for bone fixation. The earliest designs, primarily made of stainless steel, provided limited biocompatibility and were prone to corrosion and fatigue failure(5).

In the mid-20th century, the introduction of titanium alloys revolutionized implant technology due to their superior strength-to-weight ratio and corrosion resistance(6).

The AO (Arbeitsgemeinschaft für Osteosynthesefragen) Foundation, established in the 1950s, played a critical role in standardizing orthopedic screw designs and surgical techniques, leading to widespread adoption of cortical and cancellous screw systems(7).

Over the years, advances in biomaterials research have introduced bioabsorbable screws, which eliminate the need for hardware removal, and locking plate technology, which improves fixation stability in osteoporotic bone(8). The development of patient-specific implants using additive manufacturing has recently emerged as a promising approach to enhance surgical outcomes(9).

Despite technological advancements, orthopedic screws still pose clinical challenges. One of the primary concerns is implant failure due to screw loosening, which is particularly problematic in osteoporotic patients with poor bone quality(10). This issue has led to the development of locking screws and augmentation techniques, such as cement reinforcement, to enhance fixation strength(11).

Another challenge is infection risk, especially in open fractures where hardware-associated infections can lead to severe complications, necessitating implant removal and prolonged antibiotic therapy(12). Additionally, improper screw placement can result in iatrogenic injuries, such as nerve damage or joint penetration, underscoring the need for intraoperative imaging guidance(13).

Moreover, the selection of screw type, diameter, and length must be carefully considered based on the biomechanical properties of the bone and the mechanical load it bears. Improper selection can result in inadequate stability, leading to delayed healing or implant failure(14). Research into bioactive coatings, which enhance osseointegration and antimicrobial resistance, aims to address these limitations and improve clinical outcomes(15).

This paper aims to provide a comprehensive review of the classification, biomechanical properties, and technological advancements in orthopedic screws. The primary objectives are:

1. To analyze the fundamental principles of orthopedic screw design, including material composition and biomechanical interactions.
2. To classify different types of screws based on their design features and clinical applications.

By exploring these topics, this paper will provide orthopedic surgeons and researchers with a detailed understanding of current trends and future directions in orthopedic screw technology.

Biomechanical Principles

Orthopedic screws play a critical role in fracture fixation and bone stabilization. Their structural design, material composition, biomechanical performance, and interaction with bone significantly influence their clinical effectiveness and longevity. Understanding these fundamental principles is essential for optimizing surgical outcomes.

Orthopedic screws are composed of various components, including the head, body, threads, and tip (Figure 1), each serving a specific function in providing stability and fixation. The screw head is responsible for engaging with the screwdriver, facilitating insertion and removal, and providing support for bone fragments or fixation plates. The design of the screw head directly affects its interaction with surgical instruments, with hexagonal heads ensuring a firm grip and reducing slippage, while Phillips and Torx heads distribute torque more efficiently and prevent screw damage during insertion(16).

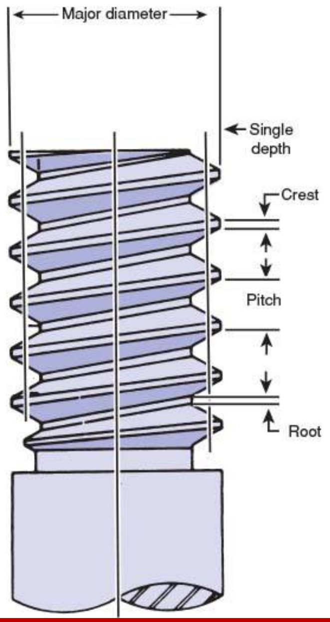


Figure 1: Components of the Screw. Reference: AO Surgery, https://surgeryreference.aofoundation.org

The screw body, consisting of the inner and outer diameter (Figure 2), influences its bending resistance and load-bearing capacity. The inner diameter determines the screw's flexural strength, while the difference between the inner and outer diameters (known as thread depth) is a key determinant of pullout strength and maximum torque resistance before thread stripping. Solid-core screws offer greater structural stability, whereas cannulated screws allow guided insertion through a guide pin, making them advantageous in minimally invasive techniques(17).

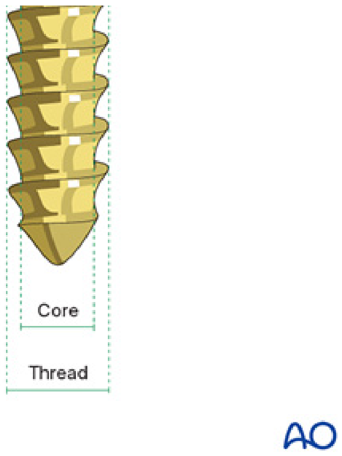


Figure 2: Screw Shaft, Reference: AO Surgery, https://surgeryreference.aofoundation.org

The screw thread pattern plays a crucial role in its mechanical engagement with bone. Cortical screws have finer threads designed to penetrate denser bone, whereas cancellous screws, with deeper threads, achieve better purchase in spongy bone(18). The pitch of the screw, defined as the distance between threads, determines the screw's advancement per 360-degree rotation. Screws with a smaller pitch have more threads per unit length and advance less per full turn than screws with a larger pitch.

The screw tip varies depending on surgical requirements. Self-drilling tips eliminate the need for pre-drilling, self-tapping tips create their own threads, and blunt tips reduce the risk of injury to soft tissues and neurovascular structures(19).

Understanding the biomechanics of screws is crucial for their effective use in orthopedic surgery. The primary goal is to achieve adequate fixation and compression without compromising screw-bone contact integrity. Over-tightening a screw can lead to plastic deformation of the bone, jeopardizing structural stability. In this regard, computational simulations have been employed to study stress distribution and bone remodeling around different screw designs, highlighting the importance of biomechanical compatibility.

The torque applied to screws in bone plate applications directly affects contact area and fixation strength. Research has shown that using a lower torque than currently applied in clinical practice does not negatively impact the final mechanical strength of the construct. These findings further support the idea that the level of applied torque may play a role in pathological bone responses following plate fixation, particularly in conditions such as osteoporosis (osteopenia).

The material properties of orthopedic screws determine their mechanical performance, biocompatibility, and degradation characteristics. Titanium and its alloys are widely used due to their corrosion resistance, lightweight nature, and high biocompatibility, which reduces the risk of allergic reactions and implant rejection(20). Additionally, their lower stiffness compared to stainless steel minimizes stress shielding effects and allows for better load sharing with bone(21). Stainless steel screws, commonly used in trauma surgery, provide superior mechanical strength and cost-effectiveness but are more susceptible to corrosion in high-stress environments(22). Cobalt-chrome alloys exhibit excellent wear resistance and are ideal for high-load-bearing applications such as joint replacements and spinal instrumentation, although their high density and stiffness may lead to localized stress concentrations(23). Bioabsorbable materials, including polylactic acid (PLA) and polyglycolic acid (PGA)-based screws, degrade over time and eliminate the need for implant removal, making them suitable for pediatric applications and sports medicine. However, their lower initial mechanical strength and variable degradation rates pose challenges in maintaining stability during the healing process(24).

The biomechanical principles governing orthopedic screws involve inner and outer diameter dynamics, thread pitch effects, force distribution, and stress patterns. The inner and outer diameters define the screw's resistance to bending forces and its pullout strength. A larger outer diameter enhances bone engagement, while a smaller inner diameter increases the risk of implant failure under high loads. The difference between these diameters, known as thread depth, plays a critical role in optimizing bone purchase and minimizing stress concentrations at the bone-implant interface(25). Thread pitch, or the distance between consecutive threads, affects insertion torque, pullout strength, and bone-screw engagement. Screws with a smaller pitch create a higher number of thread-bone contacts, improving fixation strength, especially in osteoporotic bone(26). Force distribution across the screw is influenced by axial loading, shear forces, and torque application. Proper torque management prevents over-tightening, which can lead to bone microfractures and implant loosening(27). Stress patterns vary depending on the bone type and loading conditions. Cortical bone screws experience higher localized stresses due to the dense bone structure, whereas cancellous screws distribute loads over a larger surface area, reducing stress concentrations(28).

The screw-bone interface is a critical determinant of implant stability, healing potential, and long-term success. Cortical bone interaction involves a higher degree of mechanical engagement due to the density of cortical bone, requiring precise pre-drilling and appropriate insertion angles to minimize stress fractures(29). Cancellous bone interaction, on the other hand, relies on deeper and more aggressive threads to maximize purchase in porous bone structures. However, excessive tightening can lead to bone resorption and reduced stability over time(30). Interface stability is initially achieved through primary fixation, where mechanical interlocking secures the screw in place, and secondary stability, which develops as the bone remodels around the implant. Enhanced interface stability can be achieved through bioactive coatings that promote osseointegration(31). The biological response to screw implantation involves bone remodeling, osteointegration, and potential foreign body reactions. While titanium and bioabsorbable materials generally promote favorable osteointegration, stainless steel and cobalt-chrome implants may trigger localized inflammatory responses, leading to implant loosening in some cases(32).

Classification of Orthopedic Screws

Orthopedic screws are categorized based on their design characteristics and functional applications. The classification of screws plays a crucial role in determining their mechanical performance, clinical utility, and surgical outcomes. The major classification includes cortical screws, cancellous screws, and locking screws, each designed to accommodate specific bone densities, loading conditions, and fixation needs(33).

Design-Based Classification

Orthopedic screws can be classified based on their design parameters, including thread pattern, shaft characteristics, and head configuration. The primary design-based classification consists of cortical screws, which are designed for compact bone, cancellous screws, which are used in spongy bone structures, and locking screws, which provide angular stability when used with locking plates. These variations ensure optimal fixation strength and mechanical stability for different anatomical regions and fracture types(34).

Cortical Screws

Cortical screws are specifically designed for dense cortical bone, which is found in the diaphyseal regions of long bones. Their design features include a smaller thread depth and closer thread spacing, which enhances their purchase in hard bone (Figure 3).

Figure 3: Cortical Screw. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Unlike cancellous screws, cortical screws require pre-drilling to prevent excessive stress that could lead to microfractures(35). The mechanical properties of cortical screws are characterized by high insertion torque and pullout resistance, ensuring strong fixation in dense bone. The fine threads enable better load distribution, reducing the risk of implant failure. However, due to the high stress concentrations in cortical bone, over-tightening can lead to bone resorption and screw loosening(36). The clinical applications of cortical screws are extensive, including diaphyseal fracture fixation, bone plate fixation, and interfragmentary compression. They are often used in long bone fracture management, spinal fixation, and joint fusion procedures. Their primary function is to provide rigid stabilization in cortical bone environments, ensuring minimal micromotion that could interfere with bone healing(37). Despite their advantages, cortical screws have certain limitations. They are less effective in osteoporotic bone due to the reduced bone density, which diminishes screw purchase. Additionally, they may require higher insertion torque, increasing the risk of bone microfractures and screw stripping during application(38).

Cancellous Screws

Cancellous screws are designed to engage with spongy bone, which is typically found in the epiphyseal regions of long bones and the vertebrae. Their thread depth is greater, allowing them to anchor more effectively in porous bone, and their wider thread spacing facilitates greater bone purchase in cancellous structures(39).

Partial Thread Cancellous Screws

Partial-thread cancellous screws have a smooth, unthreaded proximal shaft, allowing interfragmentary compression when inserted across fracture sites (Figure 4).

This design characteristic enables dynamic stabilization, making them ideal for fracture healing in trabecular-rich areas such as the femoral neck, humeral head, and tibial plateau(40). The usage scenarios for partial-thread screws include fracture compression in metaphyseal and epiphyseal regions, particularly in hip and knee fractures. They are commonly used in sliding hip screws, cannulated fixation systems, and arthrodesis procedures(41). The compression mechanics of partial-thread screws rely on their differential thread engagement. The unthreaded portion allows movement between the fragments, while the threaded distal segment engages the far cortex, generating axial compression across the fracture plane. This mechanism enhances bone healing by promoting direct bone-to-bone contact(42).

Full Thread Cancellous Screws

Full-thread cancellous screws have a uniformly threaded shaft, making them ideal for applications where interfragmentary compression is not required (Figure 5). Their design features include deep, widely spaced threads, which maximize bone purchase in spongy structures, ensuring secure fixation in osteoporotic or low-density bone(43).

Figure 4: Partially Threaded Cancellous Screws, Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Figure 5: Partially Threaded Cancellous Screws, Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

The application areas for full-thread cancellous screws include fracture fixation in weight-bearing regions such as the proximal femur, tibial plateau, and vertebral bodies. These screws are particularly useful in bone grafting procedures and revision surgeries, where stable fixation is necessary for long-term integration(44).

The biomechanical properties of full-thread cancellous screws emphasize load distribution across a larger surface area, reducing localized stress concentrations.

Their deep threads provide enhanced resistance to pullout forces, making them particularly effective in cases where screw loosening is a concern, such as in osteoporotic patients(45).

Locking Thread Screws

Locking thread screws are specialized fixation devices that provide angular stability when used with locking plates. Unlike conventional screws, which rely on friction between the plate and bone, locking screws thread directly into the plate, forming a rigid construct that prevents micromotion(46).

The thread pattern specifics of locking screws feature self-tapping, self-drilling, and unicortical or bicortical configurations, allowing for customized fixation based on anatomical requirements. Their primary advantage is the ability to minimize screw toggle, reducing the risk of implant failure in unstable fractures(47).

The fixation mechanics of locking screws depend on their ability to secure both the screw-plate and screw-bone interfaces simultaneously.

This dual fixation enhances construct rigidity, making them suitable for complex fractures, periprosthetic fractures, and osteoporotic bone stabilization(48). The clinical indications for locking screws include fractures requiring absolute stability, osteoporotic bone fixation, and polytrauma cases where early weight-bearing is needed.

Locking screws are widely used in proximal humeral fractures, distal femoral fractures, and periarticular injuries, where they help reduce implant-related complications(49) (Figure 6).

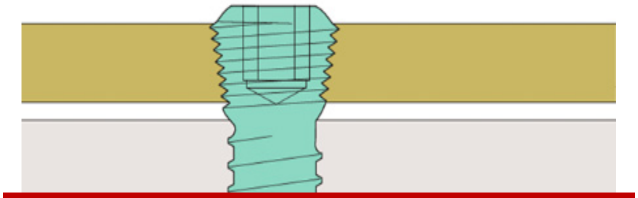


Figure 6: Locking Screws. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Standard Locking Screws

In standard locking screws, the design mechanism includes a threaded screw head that locks into the plate hole, preventing micromotion between the plate and the screw (Figure 7).

This feature provides angular stability and reduces the need for absolute compression between the screw and bone(47).

The integration of the screw with the plate allows them to function as a single structural unit, effectively distributing load and minimizing the risk of implant failure, particularly in fractures involving weakened bone(50).

The fixation stability in osteoporotic patients is enhanced, as the locking mechanism maintains a rigid structure and reduces the likelihood of screw loosening and implant failure(51).

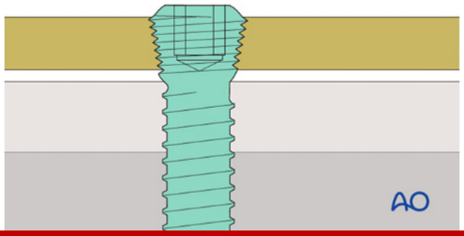


Figure 7: Standard Locking Screws. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Variable-Angle Locking Screws

Variable-angle locking screws offer a range of entry angles, enabling surgeons to optimize fixation points based on fracture geometry.

Unlike standard locking screws, which are positioned at a predetermined angle, variable-angle screws can be inserted at angles of up to 15 degrees, providing greater flexibility in complex fractures(52).

Technical considerations include the use of precise drilling guides and angle control to ensure proper screw locking, as incorrect angles can compromise fixation stability(53).

The clinical applications of variable-angle screws are particularly beneficial in periarticular fractures, distal radius fractures, and tibial plateau reconstructions, where multidirectional fixation is necessary(54) (Figure 8-10).

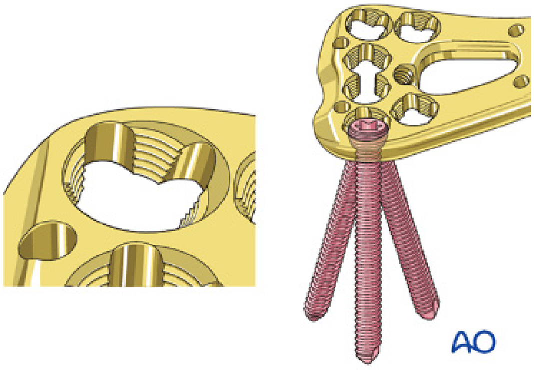


Figure 8: Variable Angle Locking Screws. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

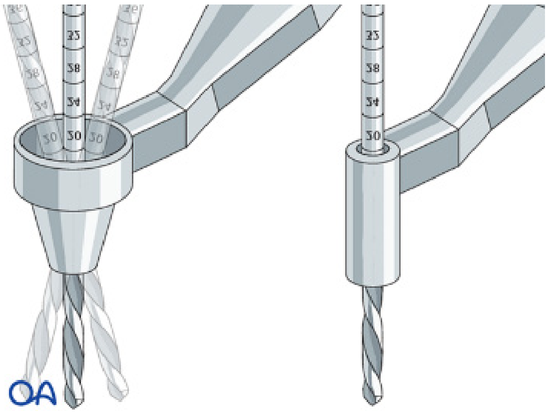


Figure 9: Variable Angle Locking Screws. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

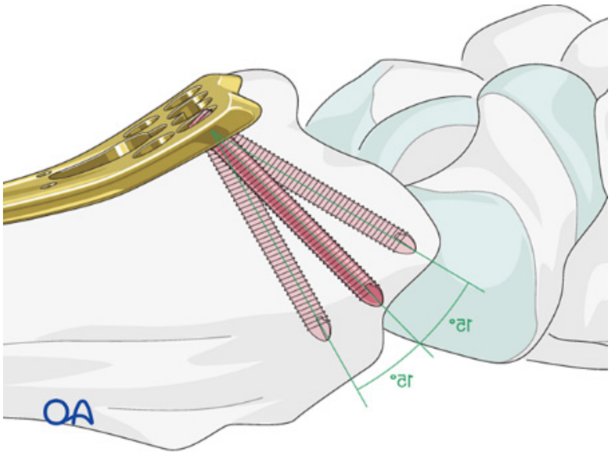


Figure 10: Variable Angle Locking Screws. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Cannulated Screws

Cannulated screws are designed with a hollow central shaft, allowing them to be guided over a thin metallic wire (guide wire) for precise placement. This design enhances surgical accuracy and minimizes trauma, particularly in minimally invasive and percutaneous procedures(55,56) (Figure 11).

The design features of cannulated screws include a threaded outer surface and a central hollow core, enabling insertion over a guidewire while maintaining a strong bone hold. They are available in fully threaded and partially threaded configurations, with partially threaded screws providing compression across fracture sites(57). The guide wire technology ensures optimal screw trajectory, reducing the risk of malalignment during insertion, particularly in complex anatomical regions such as the femoral neck, ankle, and scaphoid bones(58).

The percutaneous applications of cannulated screws are valuable in treating fractures with minimal soft tissue disruption, reducing post-operative pain and recovery time. Their use is widespread in hip fractures, foot and ankle injuries, and scaphoid fractures, where precision and minimal exposure are essential for bone healing(59). Surgical considerations involve careful guidewire placement before definitive screw insertion to prevent misalignment or screw migration. Furthermore, biomechanical studies suggest that cannulated screws with larger core diameters provide greater strength, reducing the risk of failure in weight-bearing applications(60).

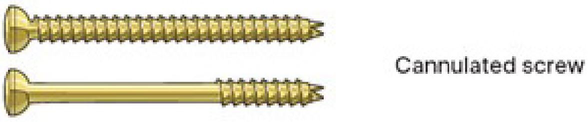


Figure 11: Cannulated Screws. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Self-Drilling Screws

Self-drilling screws eliminate the need for pre-drilling, streamlining the implantation process and reducing surgical steps. Their cutting features include sharp, fluted tips, which allow the screws to penetrate bone without the need for a separate drill bit, making them ideal for rapid fixation in trauma settings(61).

The installation technique for self-drilling screws involves direct insertion using rotational torque, allowing them to tap their own pathway into bone. This feature is particularly useful in percutaneous fixation, spinal surgery, and small fragment fracture management, as it eliminates additional bone drilling and preserves bone stock(62). Usage guidelines emphasize careful torque control, as excessive force during insertion can cause bone splitting or thermal necrosis(63).

Self-drilling screws are widely used in hand and foot surgeries, as well as vertebral stabilization, where precision and minimal drilling trauma are critical. They are especially beneficial in osteoporotic bone, where excessive drilling can lead to structural weakening and potential fixation failure(49).

Bioabsorbable Screws

Bioabsorbable screws have emerged as a promising alternative to traditional metallic implants, particularly in orthopedic surgeries requiring temporary fixation. These screws eliminate the need for secondary removal surgery, reducing patient morbidity and healthcare costs.

The primary materials used for bioabsorbable screws include poly-L-lactic acid (PLLA), polyglycolic acid (PGA), poly-DL-lactic-co-glycolic acid (PLGA), and magnesium-based alloys. These polymers are chosen based on their mechanical properties, degradation rates, and biocompatibility. PLLA offers high mechanical strength but a slow degradation rate, while PGA has faster degradation but lower strength. Recent studies also explore magnesium-based bioabsorbable screws, which promote osseointegration and bone regeneration(64, 65).

The degradation of bioabsorbable screws depends on hydrolysis and enzymatic activity, leading to a gradual loss of mechanical integrity and eventual resorption into the body. The degradation rate varies with polymer composition, molecular weight, crystallinity, and implant environment. Magnesium-based screws degrade via oxidation and dissolution, with hydrogen gas evolution being a potential side effect. Researchers have been exploring surface coatings and alloying elements such as calcium and zinc to control degradation rates and enhance biocompatibility(66, 67).

Bioabsorbable screws are extensively used in fracture fixation, ligament reconstruction, and osteotomy stabilization. They have been widely applied in anterior cruciate ligament (ACL) reconstruction, maxillofacial surgeries, and pediatric orthopedics. One of the main advantages is their ability to eliminate implant-related complications such as migration, stress shielding, and implant failure, which are common with permanent metallic implants(68,69).

Clinical studies indicate that bioabsorbable screws provide comparable fixation strength to metal screws, with satisfactory fracture healing rates. However, complications such as inflammatory reactions, foreign body responses, and cystic formations have been reported in some cases. Innovations in polymer chemistry and composite materials, such as PLGA reinforced with hydroxyapatite, aim to improve mechanical strength and biological safety(70, 71).

Drug-Releasing Screws

Drug-releasing screws represent an advanced orthopedic technology designed to deliver therapeutic agents locally at the site of implantation. These screws aim to reduce infection rates, enhance bone healing, and mitigate inflammation.

The integration of drug-eluting technology into orthopedic screws involves polymer coatings, porous structures, and nano-encapsulation techniques. Drugs such as antibiotics (gentamicin, vancomycin), growth factors (BMP-2), and anti-inflammatory agents are incorporated into the screw matrix or surface coatings for controlled and sustained release(72, 73).

Drug-releasing screws are primarily used in trauma, revision surgeries, and joint arthroplasty to prevent post-operative infections and improve osseointegration. In infected fracture fixations, antibiotic-loaded screws have demonstrated a significant reduction in bacterial colonization and improved patient outcomes. Growth factor-releasing screws are gaining attention for their role in accelerating bone healing and reducing non-union rates(74, 75).

Recent clinical trials have reported positive outcomes with antibiotic-releasing screws, demonstrating a 50% reduction in deep infection rates in high-risk patients. However, the efficacy of growth factor-releasing screws remains under investigation, with ongoing studies exploring their long-term impact on bone remodeling. Challenges such as drug stability, burst release, and regulatory approvals remain barriers to widespread clinical adoption(76, 77).

Function-Based Classification

Orthopedic screws can also be classified based on their functional role in fracture fixation and joint stabilization.

Lag Screws

Lag screws are mechanically designed to create interfragmentary compression, which enhances bone healing by reducing motion at the fracture site.

The lag screw principle is based on differential thread engagement, where the near cortex is overdrilled, allowing the screw to pull the fracture fragments together. This technique increases primary stability and facilitates early mobilization(78, 79) (Figure 12).

Proper lag screw placement requires precise drilling, countersinking, and torque application. The drill hole size, insertion angle, and tightening force influence the compressive force generated across the fracture. Inadequate countersinking or excessive tightening may lead to cortical damage or screw failure(80, 81).

Lag screws are widely used in long bone fractures (humerus, femur, tibia), periarticular fractures, and pelvic ring injuries. They are commonly employed in ankle fractures, radial head fractures, and scaphoid non-unions. Headless lag screws, such as Herbert screws, are preferred in articular surfaces to minimize implant prominence(82, 83).

Clinical studies have demonstrated that lag screw fixation significantly improves fracture stability and reduces healing time compared to non-compression techniques. However, complications such as screw pullout, cortical cracking, and implant breakage are reported in cases of poor surgical technique or osteoporosis. Advancements in titanium and bioabsorbable lag screws aim to improve mechanical longevity and biological integration(84, 53).

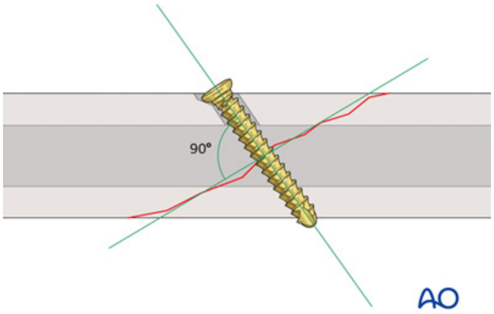


Figure 12: Lag screw. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Compression Screws

Compression screws function based on dynamic compression principles, where the design and biomechanical properties allow controlled interfragmentary compression during fracture healing(85).

These screws are commonly used in fracture fixation, particularly in cancellous bone, due to their ability to promote primary bone healing without excessive stress shielding(86) (Figure 13). The technical considerations of compression screws include the need for proper placement and torque application to avoid over-compression, which can lead to bone necrosis or implant failure(87).

Studies have demonstrated that locking compression screws offer enhanced biomechanical stability compared to non-locking designs, particularly in osteoporotic bone(88).

In clinical usage, these screws are widely applied in the fixation of ankle fractures, proximal femoral fractures, and scaphoid fractures, with research supporting improved functional outcomes and reduced nonunion rates(89)

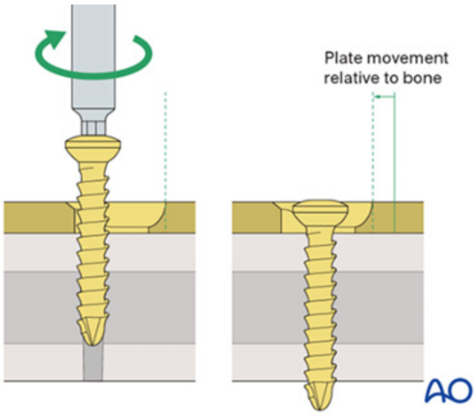


Figure 13: Compression screw. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Cortex Screws

Cortex screws are designed to provide rigid fixation in cortical bone, with a narrow pitch and a smaller thread profile that enhances engagement with the dense outer cortical structure(90). The design features of cortex screws include a fully threaded shaft, ensuring strong hold and resistance to loosening under load-bearing conditions(91). These screws are frequently used for small fragment fixation, particularly in fractures involving the distal radius, metacarpals, and foot bones(92). Clinical indications for cortex screws include their use in fracture compression, plating constructs, and syndesmotic stabilization in the ankle joint(93). Recent biomechanical studies suggest that dual cortical screw fixation offers superior rotational stability compared to single screw constructs in treating distal fibular fractures(94) (Figure 14).

Figure 14: Cortex screw. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Push-Pull Screws

Push-pull screws are utilized as reduction tools in complex fractures, particularly for achieving anatomical alignment before definitive fixation(95). The reduction technique involves inserting the push-pull screw into a fractured bone segment, applying controlled traction, and subsequently securing the fracture with plate or nail fixation(96).

These screws play a critical role in length restoration following long bone fractures, including femoral shaft fractures and tibial malunions(97). Application methods vary depending on the fracture type; however, recent advancements in guided reduction tools and push-pull devices have improved precision and reduced complications related to malalignment(98). Clinical trials have demonstrated that push-pull screw-assisted reduction leads to enhanced post-operative alignment and reduced revision surgery rates in high-impact fractures(99) (Figure 15).

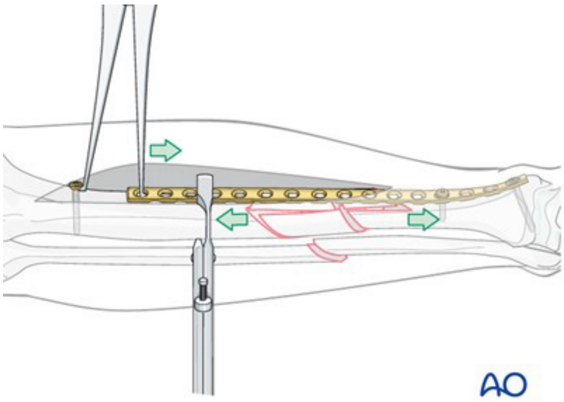


Figure 15: Push-pull screw. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Midfoot Fusion Bolt

The Midfoot Fusion Bolt (MFB) is an advanced intramedullary fixation device developed to provide rigid stabilization for midfoot arthrodesis, especially in patients suffering from severe deformities, neuropathic conditions, or midfoot collapse(100). Traditional fixation methods, including plates and screws, have been associated with complications such as hardware failure, inadequate load distribution, and stress shielding. The Midfoot Fusion Bolt aims to overcome these limitations by offering strong intramedullary support while reducing soft tissue disruption and ensuring optimal weight-bearing properties.

The MFB is typically composed of titanium or stainless steel and features a solid or cannulated design that allows for optimal bone purchase and stability.

It is available in different diameters and lengths, depending on the anatomical requirements of the patient. The bolt is designed with threaded and non-threaded sections, which enhance osseointegration and load distribution across the fusion site. Some models incorporate variable-angle locking features, which allow customized positioning and provide enhanced stability in complex midfoot fusion cases(101) (Figure 16).

Figure 16: Midfoot Fusion Bolt (MFB) screw. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

The primary application of the Midfoot Fusion Bolt is in Charcot neuroarthropathy, Lisfranc injuries, and midfoot arthritis, where conventional fixation techniques may fail to provide adequate mechanical stability. The MFB can be implanted using either an open or percutaneous approach, with the percutaneous method reducing surgical trauma and minimizing infection risks.

Studies have demonstrated that intramedullary fusion techniques using the Midfoot Fusion Bolt lead to higher rates of fusion success compared to traditional plating techniques(102).

Several biomechanical and clinical studies have evaluated the efficacy of the Midfoot Fusion Bolt in providing superior stability, improved load distribution, and reduced implant failure rates.

Compared to standard plates and screws, the MFB has shown higher resistance to shear and axial loading, which contributes to improved patient outcomes and shorter recovery periods. Clinical trials have also reported a significantly lower rate of implant-related complications, making the Midfoot Fusion Bolt an effective solution for midfoot reconstruction surgeries(103).

Positional Screws

Positional screws are widely utilized in orthopedic surgery for applications where bone-to-bone compression is not required. Unlike lag screws, which actively create interfragmentary compression, positional screws maintain structural integrity by ensuring firm bone alignment without exerting excessive compressive forces(104).

The primary function of positional screws is to maintain the spatial relationship between two bone fragments while preventing undesired displacement. This is particularly useful in cases where bone segments need to be held in place without compression, such as in syndesmotic fixation, osteotomy stabilization, and joint fusions.

The ability to securely hold bone fragments together while avoiding excessive compression is particularly beneficial in complex fractures and osteotomies, where improper load distribution could lead to implant failure(105) (Figure 17).

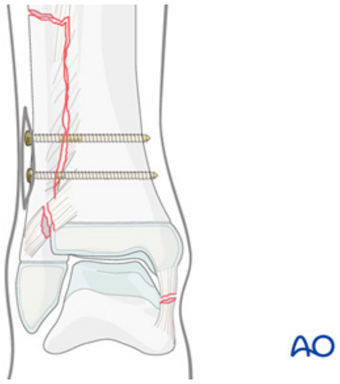


Figure 17: Positional screw. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

When using positional screws, precise drilling and screw selection are essential to prevent complications such as screw pullout or cortical damage.

Surgeons must carefully assess the bone density and mechanical stability before deciding the appropriate screw length and diameter. Positional screws require pre-drilled pilot holes to ensure accurate positioning, and it is crucial to ensure bi-cortical engagement for maximum stability. Intraoperative fluoroscopy is often used to verify correct screw placement, reducing the risk of malpositioning and implant failure(106).

The most common applications of positional screws include syndesmotic fixation, osteotomy stabilization, and securing bone grafts.

These screws are particularly useful in ankle, wrist, and elbow surgeries, where maintaining anatomical bone relationships is critical for functional recovery. Recent studies have emphasized the importance of using positional screws in non-compressive joint fusions, as they provide stability without interfering with natural healing processes(107).

Polar Screws

Polar screws are primarily used as blocking screws in intramedullary nailing, where they function to prevent malalignment and enhance the stability of the intramedullary implant. These screws are particularly effective in cases where short-segment fractures require additional stabilization to counteract rotational or axial displacement(108).

Polar screws are typically inserted adjacent to an intramedullary nail, where they act as a mechanical block that prevents excessive motion of the nail within the medullary canal. This technique is especially beneficial in proximal or distal fractures of long bones, where the nail alone may not provide sufficient rotational control. By reducing the risk of malalignment, polar screws significantly enhance post-operative stability and fracture healing(109).

The placement of polar screws ensures precise control of alignment, particularly in cases of metaphyseal fractures, where the potential for rotational deformity is high. By restricting micromotion, these screws contribute to early bone healing and reduce complications associated with implant loosening. Polar screws are often placed under fluoroscopic guidance, allowing the surgeon to achieve optimal positioning while minimizing surgical trauma(110).

For optimal biomechanical function, polar screws must be positioned strategically around the intramedullary nail to counteract forces in all directions. Proper cortical engagement and screw angulation are critical to maximizing fixation strength and avoiding implant failure. Recent research has demonstrated that placing polar screws at specific anatomical locations can significantly improve load distribution, thereby reducing implant-related complications(111).

Interlocking Screws

Interlocking screws are an integral component of intramedullary nailing systems, providing longitudinal and rotational stability to fracture sites. These screws are commonly used in long bone fractures to prevent axial displacement and enhance overall implant strength(112) (Figure 18).

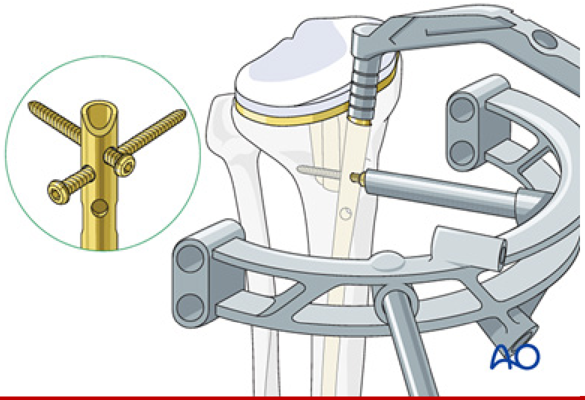


Figure 18: Interlocking screw. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

The primary function of interlocking screws is to secure an intramedullary nail within the bone, preventing excessive motion and implant migration. This locking mechanism ensures rigid fixation, which is crucial for successful bone healing in high-load-bearing fractures such as those of the femur, tibia, and humerus(113).

Studies have shown that interlocking screws enhance resistance to axial loads, reducing the risk of implant failure and malunion. Their ability to distribute mechanical stress across the bone minimizes stress shielding, a common issue in orthopedic surgery where bone resorption occurs due to uneven load transfer. Innovations in titanium alloy screws have further improved biomechanical performance, making them a preferred choice in modern orthopedic trauma management(114).

Interlocking screws are widely used in femoral, tibial, and humeral fractures, particularly in cases where intramedullary nailing alone is insufficient to maintain alignment.

By providing additional stability, these screws contribute to faster rehabilitation, reduced pain, and lower complication rates. Clinical studies indicate that patients treated with interlocking screws experience better functional recovery, emphasizing their critical role in orthopedic fixation techniques(115).

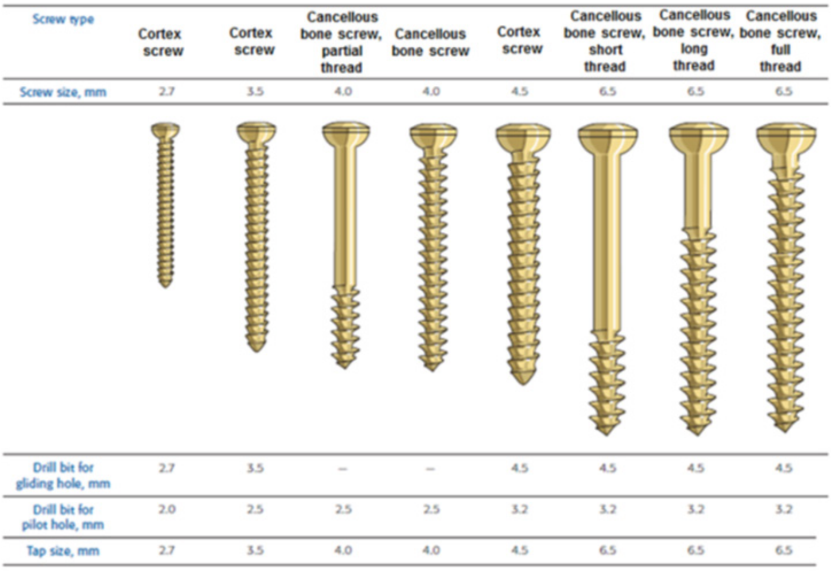
Technical Considerations

Drill Bit Selection and Usage

Drill bit selection is a critical factor in orthopedic surgery, influencing both the precision of screw placement and the mechanical stability of the fixation construct. The diameter, length, and material composition of the drill bit must be carefully chosen based on the type of bone (cortical or cancellous) and the specific surgical application(116). Studies indicate that high-speed drilling generates excessive heat, which can lead to thermal necrosis, compromising bone integrity and healing outcomes(117). In contrast, low-speed drilling with adequate irrigation minimizes heat generation, reducing the risk of osteonecrosis and improving screw purchase(118). The geometry of the drill bit, including flute design and tip angle, also affects the efficiency of bone removal and insertion torque during screw placement(119). Another essential factor is the use of pilot holes, which help in precise screw placement and minimize stress fractures around the drilled area(120). Pre-drilled holes reduce insertion torque and prevent excessive bone compression, which is particularly relevant for self-tapping screws(121). Furthermore, using sharp, well-maintained drill bits enhances the accuracy of insertion and decreases mechanical resistance, thereby improving the long-term success of orthopedic implants(122). A comparative study of various drill bit types found that carbide-tipped drill bits produce less heat and are more durable than standard stainless steel drill bits, making them the preferred choice for repeated surgical use(123) (Figure 19).

Torque Management Principles

Proper torque application is essential for achieving stable fixation while avoiding complications such as screw loosening or stripping of bone threads. Torque refers to the rotational force applied during screw insertion, which determines the stability of the bone-implant interface(124). Studies show that optimal insertion torque should be within 70-80% of the maximum pullout strength to achieve adequate fixation without compromising bone integrity(125). Excessive torque can cause microfractures or stripping of the bone threads, whereas insufficient torque may result in implant instability and failure(126).



Screw type	Cortex screw	Cortex screw	Cancellous bone screw, partial thread	Cancellous bone screw	Cortex screw	Cancellous bone screw, short thread	Cancellous bone screw, long thread	Cancellous bone screw, full thread
Screw size, mm	2.7	3.5	4.0	4.0	4.5	6.5	6.5	6.5
Drill bit for gliding hole, mm	2.7	3.5	–	–	4.5	4.5	4.5	4.5
Drill bit for pilot hole, mm	2.0	2.5	2.5	2.5	3.2	3.2	3.2	3.2
Tap size, mm	2.7	3.5	4.0	4.0	4.5	6.5	6.5	6.5

Figure 19: Drill Size Based on Screw Size. Image Source: AO Surgery Reference, https://surgeryreference.aofoundation.org

Torque control is particularly important in osteoporotic patients, where lower bone density reduces the screw's ability to grip the bone effectively(127). To address this, torque-limiting devices have been developed to prevent over-tightening, ensuring consistent screw engagement while minimizing the risk of implant failure(128). Additionally, cement augmentation techniques can be used in cases of poor bone quality to enhance fixation strength by increasing screw-bone contact area(129). Some modern orthopedic screws are designed with built-in torque indicators, allowing surgeons to precisely control insertion force and reduce the incidence of biomechanical failure(130).

Insertion Techniques

Screw insertion techniques vary depending on the type of screw used and the anatomical location of the implant. The traditional hand-driven insertion method provides tactile feedback to the surgeon, allowing for precise control over torque application and depth(131). However, power-assisted screwdrivers are increasingly used for faster and more consistent insertion, particularly in procedures requiring multiple screws(132). A study comparing manual versus power-driven insertion found that power tools reduce intraoperative time but may increase the risk of over-tightening if not properly controlled(133).

Another key consideration is the trajectory of screw insertion. Orthopedic screws should be placed perpendicular to the fracture plane to maximize compression and stability(134). In cases where angulated insertion is required, preoperative planning with computer navigation systems can enhance accuracy and prevent malpositioning(135). Cannulated screws, commonly used for minimally invasive procedures, require precise guidewire placement before final insertion to ensure optimal alignment(134). In spinal surgery, robotic-assisted insertion techniques have been introduced to improve screw accuracy and reduce the risk of neural or vascular injury(136).

Fixation Methods

Intramedullary Approach

Intramedullary fixation involves placing screws or nails within the medullary cavity of long bones to provide internal support while minimizing disruption to the periosteal blood supply. This method is commonly used in femoral and tibial fractures, where it offers superior biomechanical stability compared to plate fixation(137).

Studies have shown that intramedullary screws distribute load more evenly along the bone axis, reducing stress concentrations and lowering the risk of implant failure(138). However, precise insertion technique is critical, as malalignment can lead to rotational instability and delayed healing(139). Recent advancements in intramedullary fixation include the development of expandable nails that conform to the medullary canal, providing enhanced stability without the need for multiple locking screws(140). Additionally, biomechanical evaluations suggest that hybrid constructs, combining intramedullary screws with external fixation, can improve outcomes in complex fractures where conventional methods are insufficient(141).

Extramedullary Techniques

Extramedullary fixation methods, such as plating and external fixation, are used when direct mechanical support is required without disturbing the medullary canal. These techniques are particularly effective in periarticular fractures, where intramedullary nails may not provide adequate fixation due to anatomical constraints(142). Locking plates, which allow for fixed-angle screw insertion, have become the gold standard for complex fractures, providing superior resistance to shear and torsional forces(143).

Biomechanical studies indicate that dual plating techniques, where two plates are applied at different angles, provide greater stability than single-plate constructs, especially in distal femoral fractures(144). Another innovation in extramedullary fixation is the use of variable-angle locking plates, which allow surgeons to customize screw trajectories based on patient-specific anatomy(145). Although extramedullary fixation provides strong mechanical support, potential drawbacks include increased surgical exposure, soft tissue irritation, and higher infection risk compared to intramedullary techniques(146).

Future Directions

The future of orthopedic screw technology is set to witness significant advancements driven by material innovations, biomechanical optimizations, and the integration of smart monitoring systems. One of the key directions in orthopedic screw development is the enhancement of bioabsorbable materials. Current bioabsorbable screws degrade at fixed rates, which may not always align with the healing process of the bone. Future research aims to develop bioadaptive materials that can modulate their degradation rate based on the physiological state of the surrounding bone tissue.

These innovations will help reduce complications related to premature degradation or prolonged presence of implants in the body, which can interfere with natural bone remodeling processes. Another major direction in orthopedic screw evolution involves the refinement of biomechanical properties. Current screws often suffer from issues such as inadequate pullout strength or suboptimal load distribution, leading to implant failure or prolonged healing times. Future screw designs will likely incorporate surface modifications, nanotechnology coatings, and advanced thread geometries to enhance osseointegration and minimize stress shielding. The development of variable-angle screws with increased customization capabilities will also provide better adaptability to diverse anatomical structures, particularly in complex fracture fixations.

In addition to material and mechanical innovations, the incorporation of smart implants equipped with real-time monitoring capabilities is set to transform orthopedic surgery. Smart screws embedded with micro-sensors can provide valuable data on bone healing progression, implant stability, and mechanical loads experienced by the implant. Such technologies can enable early detection of complications such as screw loosening, infection, or delayed union, allowing for timely intervention and improved patient outcomes.

Furthermore, the application of artificial intelligence and machine learning in orthopedic surgery is expected to enhance the precision of screw placement through automated preoperative planning and intraoperative guidance.

As research continues to evolve, interdisciplinary collaboration among materials scientists, biomedical engineers, and orthopedic surgeons will play a critical role in translating laboratory innovations into clinical applications. Future orthopedic screws will not only offer superior mechanical performance but also provide a more dynamic and interactive role in patient recovery, minimizing the need for revision surgeries and enhancing overall surgical success rates. While the challenges in achieving these innovations remain considerable, the rapid advancements in biomaterials, computational modeling, and implant design suggest that the future of orthopedic fixation is poised for transformative breakthroughs.

Conclusion

Orthopedic screws have been a fundamental component of fracture fixation and reconstructive surgeries for decades, and their evolution has been shaped by advancements in biomaterials, biomechanical understanding, and surgical techniques.

The extensive classification of screws based on their design and function highlights the level of customization available to orthopedic surgeons, allowing for precise and efficient fracture stabilization across various anatomical regions. The ongoing developments in screw technology, particularly in the fields of bioabsorbable materials, smart implants, and drug-releasing mechanisms, reflect a growing emphasis on patient-specific solutions and enhanced clinical outcomes.

Despite the significant strides made in improving orthopedic screw performance, several challenges remain. Issues such as screw loosening, infection, improper fixation, and implant-related complications continue to impact patient recovery and long-term success rates.

The integration of advanced materials, such as magnesium and hybrid polymer composites, alongside innovative fixation techniques, is expected to mitigate these challenges. Furthermore, the adoption of digital technologies, including intraoperative navigation and robotic-assisted surgery, is revolutionizing the precision of screw placement and optimizing biomechanical stability.

The future of orthopedic screw technology is centered around achieving greater biocompatibility, enhanced mechanical properties, and the ability to provide real-time feedback on bone healing. As the field moves toward patient-specific implant solutions and personalized medicine, the role of 3D printing and computational modeling will become increasingly prominent in the design and manufacturing of orthopedic screws. Additionally, continued research into minimally invasive surgical techniques will help reduce complications associated with open surgeries and expedite recovery times for patients.

In conclusion, the evolution of orthopedic screws is a testament to the continuous efforts in medical engineering and surgical innovation.

By addressing current challenges and leveraging emerging technologies, the next generation of orthopedic screws will not only improve fixation stability but also contribute to better patient outcomes through enhanced integration, reduced risk factors, and increased longevity.

The field remains dynamic, and with ongoing research and collaboration among multidisciplinary teams, orthopedic fixation is expected to reach new heights in safety, efficacy, and functionality.

Acknowledgement

The authors would like to thank the Clinical Research Development Unit of Imam Khomeini Hospital, Mazandaran University of Medical Science Sari, Iran for their support cooperation and assistance throughout the period of study.

References

1. Zan R, Shen S, Huang Y, Yu H, Liu Y, Shi Yang, et al. Research hotspots and trends of biodegradable magnesium and its alloys. Smart Mater Med. 2023;4(1): 468-479. https://doi.org/10.1016/j.smaim.2023.01.002.
2. Li Y, Felländer-Tsai L. The bone-anchored prostheses for amputees–Historical development, current status, and future aspects. Biomaterials. 2021 273:120836. DOI: 10.1016/j.biomaterials.2021.120836.
3. Meng M, Wang J, Huang H, Liu X, Zhang J, Li Z. 3D printing metal implants in orthopedic surgery: Methods, applications, and future prospects. J Orthop Translat. 2023;42:94-112. DOI: 10.1016/j.jot.2023.08.004
4. Tao L, Zhou S, Tao Z, Wen K, Da W, Meng Y. The publication trends and hot spots of scoliosis research from 2009 to 2018: a 10-year bibliometric analysis. Ann Transl Med. 2020;8(6):365. DOI: 10.21037/atm.2020.02.67.
5. Kubicek J, Tomanec F, Cerny M, Vilimek D, Kalova M, Oczka D. Recent trends, technical concepts, and components of computer-assisted orthopedic surgery systems. Sensors. 2019;19(23):5199. DOI: 10.3390/s19235199
6. Wang J.L, Xu J.K, Hopkins C, Chow D.H.K, Qin L. Biodegradable magnesium-based implants in orthopedics—a general review and perspectives. Adv Sci (Weinh). 2020;7(8):1902443. DOI: 10.1002/advs.201902443.
7. Vaishya R, Patralekh M.K, Vaish A, Agarwal A.K, Vijay V. Publication trends and knowledge mapping in 3D printing in orthopaedics. J Clin Orthop Trauma. 2018;9(3):194-201. DOI: 10.1016/j.jcot.2018.07.006.
8. Singh V, Mahajan R, Das K, Chhabra H.S, Rustagi T. Surgical Trend Analysis for Use of Cement Augmented Pedicle Screws in Osteoporosis of Spine: A Systematic Review (2000-2017). Global Spine J. 2019;9(7):783-795. DOI: 10.1177/2192568218801570.
9. Agarwal R, Gupta V, Singh J. Additive manufacturing-based design approaches and challenges for orthopedic bone screws: A state-of-the-art review. J Braz Soc Mech Sci Eng. 2022;44(12):3102.
10. Szczęsny G, Kopec M, Politis D.J, Kowalewski Z.L, Łazarski A, Szolc T. A review on biomaterials for orthopedic surgery and traumatology: From past to present. Materials (Basel). 2022;15(10):3622. DOI: 10.3390/ma15103622
11. Joskowicz L, Hazan EJ. Computer-aided orthopedic surgery: Incremental shift or paradigm change?. Adv Exp Med Biol. 2018;1093:21-30. doi: 10.1007/978-981-13-1396-7_2.
12. Ścibior A, Pietrzyk Ł, Plewa Z, Skiba A. Vanadium: Risks and possible benefits in the light of a comprehensive overview of its pharmacotoxicological mechanisms and multi-applications with a summary of further research trends. J Trace Elem Med Biol. 2020;61:126508. DOI: 10.1016/j.jtemb.2020.126508.

13. Hallab NJ, Jacobs JJ. Orthopedic Applications. In book: Biomaterials Science 2020. p.1079-1118.e1. DOI:10.1016/B978-0-12-816137-1.00070-2.
14. Helm P.A, Teichman R, Hartmann S.L, Simon D. Spinal Navigation and Imaging: History, Trends, and Future. IEEE Trans Med Imaging. 2015;34(8):1738-46. DOI: 10.1109/TMI.2015.2391200.
15. Giannoudis P.V, Chloros G.D, Ho Y.S. A historical review and bibliometric analysis of research on fracture nonunion in the last three decades. Int Orthop. 2021;45(7):1663-1676. DOI: 10.1007/s00264-021-05020-6.
16. Elsayed M.D. Biomechanical factors that influence the bone-implant-interface. Res Rep Oral Maxillofac Surg. 2019;3(1):1-4. DOI: 10.23937/iaoms-2017/1710023.
17. Jin W, Chu P.K. Orthopedic implants. Encycloped Biomed Eng. 2019;2:425-39. DOI: 10.1016/B978-0-12-801238-3.10999-7.
18. Nekhlopochyn O.S, Verbov V.V, Karpinsky M.Y, Yaresko O.V. Biomechanical evaluation of the pedicle screw insertion depth and role of cross-link in thoracolumbar junction fracture surgery: a finite element study under compressive loads. Ukrain Neurosurg J. 2021;27(3):25-32. DOI: 10.25305/unj.230621
19. Grzeskowiak R.M, Schumacher J, Dhar M.S, Harper D.P, Dhar M.S, Mulon P.Y, et al. Bone and cartilage interfaces with orthopedic implants: a literature review. Front Surg. 2020;7:601244. DOI: 10.3389/fsurg.2020.601244.
20. Xu M, Yang J, Lieberman I.H, Haddas R. Finite element method-based study of pedicle screw–bone connection in pullout test and physiological spinal loads. Med Eng Phys. 2019;67:11-21. DOI: 10.1016/j.medengphy.2019.03.004.
21. Bianco R.J, Arnoux P.J, Wagnac E, Mac-Thiong J.M, Aubin C.É. Minimizing pedicle screw pullout risks: a detailed biomechanical analysis of screw design and placement. Clin Spine Surg. 2017;30(3):E226-32. DOI: 10.1097/BSD.0000000000000151.
22. Wray S, Mimran R, Vadapalli S, Shetye S.S, McGilvray K.C, Puttlitz C.M. Pedicle screw placement in the lumbar spine: effect of trajectory and screw design on acute biomechanical purchase. J Neurosurg Spine. 2015;22(5):503-10. DOI: 10.3171/2014.10.SPINE14205.
23. Gao X, Fraulob M, Haïat G. Biomechanical behaviours of the bone–implant interface: a review. J R Soc Interface. 2019;16(156):20190259. DOI: 10.1098/rsif.2019.0259.
24. Suryavanshi A, Khanna K, Sindhu K.R, Bellare J, Srivastava R. Development of bone screw using novel biodegradable composite orthopedic biomaterial: From material design to in vitro biomechanical and in vivo biocompatibility evaluation. Biomed Mater. 2019;14(4):045020. DOI: 10.1088/1748-605X/ab16be.
25. Liu Y, Xu J, Sun D, Luo F, Zhang Z, Dai F. Biomechanical and finite element analyses of bone cement-Injectable cannulated pedicle screw fixation in osteoporotic bone. J Biomed Mater Res B Appl Biomater. 2016;104(5):960-7. DOI: 10.1002/jbm.b.33424.
26. Schliemann B, Seifert R, Rosslenbroich S.B, Theisen C, Wähnert D, Raschke M.J, et al. Screw augmentation reduces motion at the bone-implant interface: a biomechanical study of locking plate fixation of proximal humeral fractures. J Shoulder Elbow Surg. 2015;24(12):1968-73. DOI: 10.1016/j.jse.2015.06.028.
27. Jain P, Rana M, Biswas J.K, Khan M.R. Biomechanics of spinal implants—a review. Biomed Phys Eng Express. 2020;6(4):042002. DOI: 10.1088/2057-1976/ab9dd2.
28. Innocenti B, Bori E, Armaroli F, Schlager B, Jonas R, Wilke H.J, Galbusera F. The use of computational models in orthopedic biomechanical research. In Human orthopaedic biomechanics 2022. pp. 681-712. Academic Press.
29. Molinari L, Falcinelli C, Gizzi A, Martino A.D. Biomechanical modeling of metal screw loadings on the human vertebra. Acta Mechan Sin. 2021;37:307-20.
30. Makary C, Menhall A, Zammarie C, Lombardi T, Lee S.Y, Stacchi C, et al. Primary stability optimization by using fixtures with different thread depth according to bone density: a clinical prospective study on early loaded implants. Materials (Basel). 2019;12(15):2398. DOI: 10.3390/ma12152398.
31. Schaller B, Burkhard J.P.M, Chagnon M, Beck S. Imwinkelried T, Assad M.Fracture healing and bone remodeling with human standard-sized magnesium versus polylactide–co-glycolide plate and screw systems using a mini-swine model. J Oral Maxillofac Surg. 2018; 76(10):2138-2150. DOI: 10.1016/j.joms.2018.03.039.
32. Merolli A. Bone repair biomaterials in orthopedic surgery. InBone Repair Biomaterials 2019 Jan 1 (pp. 301-327). Woodhead Publishing.
33. Elkolaly M.A, Hasan H.S. MH cortical screws, a revolutionary orthodontic TADs design. J Orthod Sci. 2022;11(1):53. DOI: 10.4103/jos.jos_49_22.
34. Banerjee A, Biberthaler P, Shanmugasundaram S, editors. Handbook of Orthopaedic Trauma Implantology. Springer Nature; 2023 Oct 31.
35. Singh RP, Gupta V, Pandey PM, Mridha AR. Effect of drilling techniques on microcracks and pull-out strength of cortical screw fixed in human tibia: an in-vitro study. Annals of Biomedical Engineering. 2021 Jan;49(1):382-93. DOI: 10.1007/s10439-020-02565-2
36. Feng X, Lin G, Fang CX, Lu WW, Chen B, Leung FK. Bone resorption triggered by high radial stress: the mechanism of screw loosening in plate fixation of long bone fractures. Journal of Orthopaedic Research®. 2019 Jul;37(7):1498-507. DOI: 10.1002/jor.24286
37. Cho H.M, Choi S.M, Park J.Y, Lee Y, Bae J.H. A finite element analysis and cyclic load experiment on an additional transcortical-type hole formed around the proximal femoral nail system's distal locking screw. BMC Musculoskelet Disord. 2022;23(1):92. DOI: 10.1186/s12891-022-05006-4.
38. Wang R, Zhang H, Cui H, Fan Z, Xu K, Liu P, et al. Clinical effects and risk factors of far cortical locking system in the treatment of lower limb fractures. Injury. 2019;50(2):432-437. DOI: 10.1016/j.injury.2018.09.013.
39. Lanzetti R.M, Caraffa A, Lupariello D, Ceccarini P, Gambaracci G, Meccariello L, et al. Comparison between locked and unlocked intramedullary nails in intertrochanteric fractures. Eur J Orthop Surg Traumatol. 2018;28(4):649-58. DOI: 10.1007/s00590-018-2143-9.
40. Wu C, Deng J, Pan J, Li T, Tan L, Yuan D. Anatomical conditions and patient-specific locked navigation templates for transverse sacroiliac screw placement: a retrospective study. J Orthop Surg Res. 2020;15(1):260. DOI: 10.1186/s13018-020-01752-0.

41. Yammine K, Karam K, Assi C. Cortical versus cancellous screws in treating medial malleolar fractures: A systematic review of comparative clinical and biomechanical studies. Foot (Edinb). 2019;40:81-6. DOI: 10.1016/j.foot.2019.05.002.
42. Fan Z, Huang Y, Su H, Jiang T. How to choose the suitable FNS specification in young patients with femoral neck fracture: a finite element analysis. Injury. 2021;52(8):2116-25. DOI: 10.1016/j.injury.2021.05.043.
43. Wang Z, Yin Y, Li Q, Sun G, Peng X, Yin H, et al. Comparison of early complications between the use of a cannulated screw locking plate and multiple cancellous screws in the treatment of displaced intracapsular hip fractures in young adults: a randomized controlled clinical trial. J Orthop Surg Res. 2018;13:1-0. DOI: 10.1186/s13018-018-0901-3.
44. Guimarães J.A.M, Rocha L.R, Rocha T.H, Bonfim D.C, da Costa R.S, dos Santos Cavalcanti A, Roesler C.R, Machado J.A, Aguiar D.P, Duarte M.Eet al. Vertical femoral neck fractures in young adults: a closed fixation strategy using a transverse cancellous lag screw. Injury. 2017;48 Suppl 4:S10-S16. DOI: 10.1016/S0020-1383(17)30769-6.
45. Omid R, Trasolini N.A, Stone M.A, Namdari S. Principles of locking plate fixation of proximal humerus fractures J Am Acad Orthop Surg. 2021;29(11):e523-35. DOI: 10.5435/JAAOS-D-20-00558.
46. Musapour M, Nayebi A, Ghavanloo E. Fatigue life study of Cortical and Cancellous screws: Experimental method and critical plane models. Eng Fail Anal. 2024;159:108109.
47. Pal A.K, Baksi D. Biomechanics of Orthopaedic Implants Demystified. In Handbook of Orthopaedic Trauma Implantology 2023 Nov 1 (pp. 629-668). Singapore: Springer Nature Singapore. DOI:10.1007/978-981-15-6278-5_36-1.
48. Cronier P, Pietu G, Dujardin C, Bigorre N, Ducellier F, Gerard R. The concept of locking plates. Orthop Traumatol Surg Res. 2010;96(4):S17-36. DOI: 10.1016/j.otsr.2010.03.008.
49. Ni M, Wong D.W, Mei J, Niu W, Zhang M. Biomechanical comparison of locking plate and crossing metallic and absorbable screws fixations for intra-articular calcaneal fractures. Sci China Life Sci. 2016;59(9):958-64. DOI: 10.1007/s11427-016-0010-9.
50. Auer J.A. Surgical equipment and implants for fracture repair. Equine Fracture Repair. 2019:107-26. DOI: 10.1002/9781119431749.ch8.
51. Nienhaus M, Zderic I, Wahl D, Gueorguiev B, Rommens P.M. A locked intraosseous nail for transverse patellar fractures: a biomechanical comparison with tension band wiring through cannulated screws. J Bone Joint Surg Am. 2018;100(12):e83. DOI: 10.2106/JBJS.17.00272.
52. Wu P.H, Dixit A, Kiat Tan D.M, Shen L, Chee Y.H. Prospective study of surgical fixation of radial head fractures using cannulated headless compression screws for simple and complex radial head fractures. J Orthop Surg (Hong Kong). 2017;25(2):2309499017716278. DOI: 10.1177/2309499017716278.
53. Tang W, Jian Q, Dong C, Chen T, Liu B. Development and validation of a specialized system for self-tapping medical bone screw testing. Med Eng Phys. 2023;118:104005. DOI: 10.1016/j.medengphy.2023.104005.
54. Jamil M, Rafique S, Khan A.M, Hegab H, Mia M, Gupta M.K, et al. Comprehensive analysis on orthopedic drilling: A state-of-the-art review. Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine. 2020 Jun;234(6):537-61. DOI: 10.1177/0954411920911283.
55. Blom A, Warwick D, Whitehouse M, editors. Apley & solomon's system of orthopaedics and trauma. CRC press; 2017 Aug 29. DOI: 10.4324/9781315118192.
56. Han F, Zhong Z, Zhou M, Chen Q, Liu Y, Rui Y, et al. A novel technique for treating simple transverse patellar fractures using cannulated screws: a cadaveric and clinical study. J Orthop Surg Res. 2023;18(1):835. DOI: 10.1186/s13018-023-04309-z.
57. Lopez-Ovenza J.M, Tapia A, Duca J.I. Clinical and radiographic outcomes using standard length of cannulated screws for traditional Latarjet procedure. JSES Int. 2025;9(1):25-30. DOI: 10.1016/j.jseint.2024.08.202.
58. Zhang Y, Wang H, Wang T, Chen W, Zhu Y. Biomechanics of the Fracture Fixation. In book: Frontiers in Orthopaedic Biomechanics. 2020:301-37. DOI:10.1007/978-981-15-3159-0_12.
59. Wagner F.C, Neumann M.V, Wolf S, Jonaszik A, Izadpanah K, Piatek S, et al. Biomechanical comparison of a 3.5 mm anterior locking plate to cannulated screws with anterior tension band wiring in comminuted patellar fractures. Injury. 2020;51(6):1281-7. DOI: 10.1016/j.injury.2020.03.030.
60. Elkin D.M, Galloway J.D, Koury K, Ni J.J, Reilly M.C, Adams M.R, et al. Patella fracture fixation with a non-locked anterior plating technique: A biomechanical study. Injury. 2021;52(4):686-91. DOI: 10.1016/j.injury.2020.11.040.
61. Douthit C, Blue M, Wooldridge A.N, Lierly-Chick M, Gilbert K, Grimes J. Comparison of Joint Compression and Pull-Out Strength of 6.5-mm Self-Drilling Screws with Headed and Headless in Subtalar Arthrodesis: A Pilot Study. UNM Orthop Res J. 2019;8(1):27.
62. Gardner A.W, Toh M.Z, Yew K.S, Lie D.T, Chou S.M. Cannulated versus non-cannulated cancellous screw fixation for femoral neck fractures: a synthetic bone biomechanical study. J Orthop Surg (Hong Kong). 2015;23(1):41-6. DOI: 10.1177/230949901502300110.
63. Galhoum A, Alrashidi Y, Herrera-Pérez M, Wiewiorski M, Miller M.B, Barg A, et al. Hindfoot Double Arthrodesis in Adults Using Cannulated Screws: How We Do It?. Tech Foot Ank Sur. 2022;21(2):63-9. DOI: 10.1097/BTF.0000000000000299.
64. Odekerken JC, Dirks AJ, Loontjens JA, Brans BT, Rijk LN, Arts JJ, Welting TJ, Walenkamp GH. A novel polymer-based osteoconductive drug-eluting coating for orthopaedic implants. Orthopaedic Infections: Pre-clinical Models. 2015:161. DOI:10.26481/dis.20150424jo
65. Ponsar H. Customizable Drug-Loaded Implants Produced via Fused Deposition Modeling (Doctoral dissertation, Dissertation, Düsseldorf, Heinrich-Heine-Universität, 2022).
66. Auer J.A, Grainger D.W. Fracture management in horses: Where have we been and where are we going?. Vet J. 2015 Oct 1;206(1):5-14. DOI: 10.1016/j.tvjl.2015.06.002.
67. Losic D, Aw M.S, Santos A, Gulati K, Bariana M. Titania nanotube arrays for local drug delivery: recent advances and perspectives. Expert Opin Drug Deliv. 2015;12(1):103-27. DOI: 10.1517/17425247.2014.945418.
68. Davachi S.M, Kaffashi B. Polylactic acid in medicine. Pol Plast Tech Eng. 2015;54(9): 150106043200007. DOI:10.1080/03602559.2014.979507.

69. Asikainen S, Paakinaho K, Kyhkynen A.K, Hannula M, Malin M, Ahola N, et al. Hydrolysis and drug release from poly (ethylene glycol)-modified lactone polymers with open porosity. Eur Pol J. 2019;113:165-75. DOI: 10.1016/j.eurpolymj.2019.01.056.
70. Ambardekar R. (2015). Controlled drug release from oriented biodegradable polymers (Doctoral dissertation, University of Bradford).
71. Yang Y, Yang Y, Hou Z, Wang T, Wu P, Shen L, et al. Comprehensive review of materials, applications, and future innovations in biodegradable esophageal stents. Front Bioeng Biotechnol. 2023;11:1327517. DOI: 10.3389/fbioe.2023.1327517.
72. Ghosh A, Orasugh J.T, Ray S.S, Chattopadhyay D. Integration of 3D printing–coelectrospinning: Concept shifting in biomedical applications. ACS Omega. 2023;8(31):28002-25. DOI: 10.1021/acsomega.3c03920.
73. Jamróz W, Szafraniec J, Kurek M, Jachowicz R. 3D printing in pharmaceutical and medical applications–recent achievements and challenges. Pharm Res. 2018;35(9):176. 1. DOI: 10.1007/s11095-018-2454-x.
74. Dhandapani V, Saseedharan P, Groleau D, Vermette P. Overview of approval procedures for bioadhesives in the United States of America and Canada. J Biomed Mater Res B Appl Biomater. 2022;110(4):950-66. DOI: 10.1002/jbm.b.34956.
75. King D, McGinty S. Assessing the potential of mathematical modelling in designing drug-releasing orthopaedic implants. J Cont Rel. 2016;239:49-61.
76. Hamza H.M, Malik M.M, Asad M, Ali S, Awan A.A. Advances in orthopedic implants: the role of nanotechnology in enhancing performance and longevity. Regenerative Med Rep. 2025:10-4103. DOI:10.4103/REGENMED.REGENMED-D-24-00024.
77. Quarterman J.C, Geary S.M, Salem A.K. Evolution of drug-eluting biomedical implants for sustained drug delivery. Eur J Pharm Biopharm. 2021;159:21-35. DOI: 10.1016/j.ejpb.2020.12.005.
78. Awadalla M, Al-Dirini M, O'Rourke D, Solomon B, Heldreth M, Rullkoetter P, et al. Influence of stems and metaphyseal sleeve on primary stability of cementless revision tibial trays used to reconstruct AORI IIB defects. J Orthop Res. 2019;37(5):1033-41. DOI: 10.1002/jor.24232.
79. Garlapaty A, Cook J.L, Bezold W, Schweser K. Activated nitinol compression staples are associated with favorable biomechanical properties for talonavicular arthrodesis. J Orthop. 2024;52:90-3. DOI: 10.1016/j.jor.2024.02.032.
80. Li S, Wang Z.H, Chang S.M. Whether or not practicing early weight-bearing makes the differences in the risk of reoperation after cephalomedullary nailing. Injury. 2025:56(8):112006. DOI: 10.1016/j.injury.2024.112006.
81. Wood R, Zeigler T. Provisional Reduction to Avoid the Wedge Effect and Control Rotational Deforming Force During Cephalomedullary Nail Insertion for Unstable Intertrochanteric and Basicervical Femoral Neck Fractures: A Novel Surgical Technique. Tech Orthop. 2024;39(3):86-89. DOI: 10.1097/BTO.0000000000000661.
82. Mahaisavariya C, Jitprapaikulsarn S, Mahaisavariya B, Chantarapanich N. Torsional stability of fixation methods in basicervical femoral neck fractures: a biomechanical study. J Orthop Surg Res. 2024;19(1):371. DOI: 10.1186/s13018-024-04842-5.
83. Jiang D, Rao X, Lu H, Liu D, Li M, Liu Y, et al. The finite element analysis study of the impact of single and double lag screw fixation on ankle fractures of different sizes. Com Met Biom Biomed Eng. 2024;28(4):1-10. DOI:10.1080/10255842.2024.2347483.
84. Dal Porto-Kujanpaa S.E, Sakkab R, Bagsic S.R, Puglisi L, Collins M.L, Rice BM. Short term temporal outcomes after intramedullary fixation of lateral malleolus fractures. J Foot Ankle Surg. 2025;64(2):162-165. DOI: 10.1053/j.jfas.2024.09.011.
85. Nixon A.J, Auer J.A, Watkins J.P. Principles of fracture fixation. Equine Fracture Repair. 2019 Oct 28:127-55. DOI: 10.1002/9781119108757.ch9.
86. Hicks R.B, Glass K.G, Watkins J.P. Proximal interphalangeal locking compression plate for pastern arthrodesis in horses. Equine Vet J. 2022;54(4):740-9. DOI: 10.1111/evj.13476.
87. Nunamaker D.M. Orthopedic implant failure. Equine fracture repair. 2019 Oct 28:831-4.
88. Hazra S. Quest for better fracture reduction in Orthopaedic traumatology. InHandbook of Orthopaedic Trauma Implantology 2023 Jul 23 (pp. 1-21). Singapore: Springer Nature Singapore.
89. Bohl D.D, Mehraban N, Foran I, Hamid K.S. Routine Fixation of Weber B Fibula Fractures with a Lateral Locking Plate and No Lag Screw. Foot Ankle Orthop. 2020;5(4):2473011420S00140. DOI: 10.1177/2473011420S00140.
90. Watrous G. Biomechanical comparison of the 1.5 mm locking compression plate with the 1.5 and 2.0 mm mini-cuttable plates & Effect of bone-plate distance on the biomechanical properties of the 1.5 mm locking plate (Doctoral dissertation, University of Guelph).
91. Wang W.L, Tosti R. A novel technique for correcting radial length and translation in distal radius fractures. Tech Hand Up Extrem Surg. 2018;22(3):116-9. DOI: 10.1097/BTH.0000000000000201.
92. Ju D.G, Debbi E.M, Neustein A.Z, Moon C.N. Fibular lengthening osteotomy with revision syndesmotic repair for ankle fracture malunion. J Orthop Trauma. 2019; 33 Suppl 1:S38-S39. DOI: 10.1097/BOT.0000000000001534.
93. Taylor K.F, Sharma J, Davisson N.A, Roush E.P, Jones C.M, Lewis G.S. Effect of metacarpal fixation configuration on strength and fracture gap displacements in a cadaveric model of externally fixed distal radius fractures. Hand (N Y). 2021;16(2):241-7. DOI: 10.1177/1558944719851231.
94. Barr C, Behn A.W, Yao J. Plating of metacarpal fractures with locked or nonlocked screws, a biomechanical study: how many cortices are really necessary?. Hand (N Y). 2013;8(4):454-9. DOI: 10.1007/s11552-013-9544-3.
95. Shibuya N, Smith R.S, Escobedo L.A, Agarwal M.R. A push-pull distraction method for arthroscopic subtalar joint arthrodesis. J Foot Ankle Surg. 2014;53(6):825-8. DOI: 10.1053/j.jfas.2014.03.010.
96. Alter T.H, Varghese B.B, DelPrete C.R, Katt B.M, Monica J.T. Reduction techniques in volar locking plate fixation of distal radius fractures. Tech Hand Up Extrem Surg. 2022;26(3):168-177. DOI: 10.1097/BTH.0000000000000380.
97. Woodward C, Donegan D. Operative technique: A modification of the “push-pull screw” distraction technique for obtaining fibular length. UPOJ. 2015;25:18-20.

98. McCown S.A, Weatherby P.J, Morris R.P, Panchbhavi V.K, Hagedorn J.C, Weiss W.M, et al. Preventing Iatrogenic Fibula Fractures Using the Push-Pull Technique: A Biomechanical Comparison of Unicortical Versus Bicortical Post Screws. Orthopedics. 2024;47(5):308-12. DOI: 10.3928/01477447-20240702-02.
99. Putzeys G. The Humeral Head Push–Pull Plate Technique: An Alternative Way to Stabilize the Humeral Head in Varus Angulated Proximal Humeral Fractures in the Elderly. J Orthop Trauma. 2023;37(12):e478-83. DOI: 10.1097/BOT.0000000000002604.
100. Wurm M, Schuh R, Wanivenhaus A, Windhager R, Trnka H.J. The Midfoot Fusion Bolt: A new perspective? Orthopäde. 2015;44(1):65-70. DOI: 10.1007/s00132-014-3057-9.
101. Wiewiorski M, Yasui T, Miska M, Frigg A, Valderrabano V. Solid bolt fixation of the medial column in Charcot midfoot arthropathy. J Foot Ankle Surg. 2013;52(1):88-94. DOI: 10.1053/j.jfas.2012.05.017.
102. Safavi P.S, Jupiter D.C, Panchbhavi V. A systematic review of current surgical interventions for Charcot neuroarthropathy of the midfoot. J Foot Ankle Surg. 2017;56(6):1249-1252. DOI: 10.1053/j.jfas.2017.06.011.
103. Mehlhorn A.T, Walther M, Iblher N, Südkamp N.P, Volz M. Complication assessment and prevention strategies using midfoot fusion bolt for medial column stabilization in Charcot’s osteoarthropathy. Foot (Edinb). 2016;29:36-41. DOI: 10.1016/j.foot.2016.10.005.
104. Butt D.A, Hester T, Bilal A, Edmonds M, Kavarthapu V. The medial column Synthes Midfoot Fusion Bolt is associated with unacceptable rates of failure in corrective fusion for Charcot deformity: Results from a consecutive case series. Bone Joint J. 2015;97-B(6):809-13. DOI: 10.1302/0301-620X.97B6.34844.
105. Mehlhorn A.T, Ugland K.I, Hörterer H, Gottschalk O, Walther M. A high-profile thread with grit-blasted and acid-etched surface reduces loosening of medial column fusion bolt in unstable Charcot foot. Foot Ankle Surg. 2020;26(6):637-643. DOI: 10.1016/j.fas.2019.08.004.
106. Anciano V, Barcel A, Kaiser P, Habet N, Wang S, Duemmler M, et al. Compressive Strength of Midfoot Fusion Nail vs Midfoot Fusion Bolt and Role of Subtalar Fusion in Midfoot Charcot Fixation Model. Foot Ankle Int. 2024;45(8):888-895. DOI: 10.1177/10711007241251816.
107. Siebachmeyer M, Boddu K, Bilal A, Hester T.W, Hardwick T, Fox T.P, et al. Outcome of one-stage correction of deformities of the ankle and hindfoot and fusion in Charcot neuroarthropathy using a retrograde intramedullary hindfoot arthrodesis nail. Bone Joint J. 2015;97-B(1):76-82. DOI: 10.1302/0301-620X.97B1.34542.
108. Ågren P.H. Midfoot Fusion Bolt, a New Implant, and Description of the Technique for Stabilization of Severe Midfoot Instability Including Charcot Foot Reconstruction. Tech Orthop. 2012;27(2):130-4. DOI: DOI: 10.1097/BTO.0b013e31825d6e16.
109. Ahluwalia R, O’dak S, Reichert I.L.H, Vas P, Edmonds M, Kavarthapu V. The Medial Column Fusion Bolt: Meta-Analysis of Its Medium Term Results. Foot Ankle Orthop. 2016 Aug 19;1(1):2473011416S00302. DOI:10.1177/2473011416S00302.
110. Gougoulias N, Lampridis V. Midfoot arthrodesis. Foot Ankle Sur. 2016;22(1):17-25. DOI: 10.1016/j.fas.2015.04.004.
111. Pope E.J, Takemoto R.C, Kummer F.J, Mroczek K.J. Midfoot fusion: a biomechanical comparison of plantar planting vs intramedullary screws. Foot Ankle Int. 2013 Mar;34(3):409-13. DOI: 10.1177/1071100712464210.
112. Jarrell S.E, Owen J.R, Wayne J.S, Adelaar R.S. Biomechanical comparison of screw versus plate/screw construct for talonavicular fusion. Foot ankle int. 2009;30(2):150-6. DOI: 10.3113/FAI-2009-0150.
113. Anciano V, Barcel D, Kaiser P, Habet N, Irwin TA, Jones III CP. Strength and Compressive Ability of Midfoot Fusion Nail vs Midfoot Fusion Bolt and Role of Subtalar Fusion. Foot Ankle Orthop. 2022;7(1):2473011421S00004. DOI: 10.1177/2473011421S00004.
114. Karaismailoglu B, Peiffer M, Raduan F, Hollander J.J, Knebel A, Kwon J.Y, et al. Radiological Safety Atlas of Minimally Invasive Midfoot Fusion: A Cadaver Study. Foot Ankle Surg. 2025;31(5):448-453. DOI: 10.1016/j.fas.2025.01.009.
115. Marks R.M, Parks B.G, Schon L.C. Midfoot fusion technique for neuroarthropathic feet: Biomechanical analysis and rationale. Foot Ankle Int. 1998;19(8):507-10. DOI: 10.1177/107110079801900801.
116. Lang S.D, Gilmer B.B. A Dual-Motor Drill Reduces Plunge, Simultaneously Gauges Depth, and Saves Time When Placing Orthopedic Screws. Orthopedics. 2020;43(5):e465-70. DOI: 10.3928/01477447-20200521-09.
117. Sadowitz P.M, Jones S.C, Beale B.S, Cross A.R, Hudson C.C. Effect of screw insertion angle and speed on the incidence of transcortical fracture development in a canine tibial diaphyseal model. Vet Surg. 2023 Nov;52(8):1112-20. DOI: 10.1111/vsu.14009.
118. Zdero R, MacAvelia T, Janabi-Sharifi F. Force and torque measurements of surgical drilling into whole bone. In book: Experimental Methods in Orthopaedic Biomechanics 2017 Jan 1 (pp. 85-100). Academic Press. DOI:10.1016/B978-0-12-803802-4.00006-8.
119. Faldini C, Viroli G, Fiore M, Barile F, Manzetti M, Di Martino A, et al. Power-assisted pedicle screws placement: Is it as safe and as effective as manual technique? Narrative review of the literature and our technique. Musculoskelet Surg. 2021;105:117-23. DOI: 10.1007/s12306-021-00714-x.
120. Inceoglu S, Ferrara L, McLain R.F. Pedicle screw fixation strength: pullout versus insertional torque. spine j. 2004;4(5):513-8. DOI: 10.1016/j.spinee.2004.02.006.
121. Moldovan F, Bățagă T. Torque control during bone insertion of cortical screws. Proced Manufact. 2020;46:484-90. DOI:10.1016/j.promfg.2020.03.070.
122. Öktenoğlu B.T, Ferrara L.A, Andalkar N, Özer A.F, Sarioğlu A.Ç, Benzel E.C. Effects of hole preparation on screw pullout resistance and insertional torque: a biomechanical study. J Neurosurg. 2001;94(1 Suppl):91-6. DOI: 10.3171/spi.2001.94.1.0091.
123. Islam M.A, Kamarrudin N.S, Daud R, Mohd Noor S.N, Azmi A.I, Razlan Z.M. A review of surgical bone drilling and drill bit heat generation for implantation. Metals. 2022;12(11):1900. DOI: 10.3390/met12111900.
124. MacAvelia T, Salahi M, Olsen M, Crookshank M, Schemitsch E.H, Ghasempoor A, et al. Biomechanical measurements of surgical drilling force and torque in human versus artificial femurs. J Biomech Eng. 2012;134(12):124503. DOI: 10.1115/1.4007953.

125. Jamil M, Rafique S, Khan A.M, Hegab H, Mia M, Gupta M.K, et al. Comprehensive analysis on orthopedic drilling: A state-of-the-art review. Proc Inst Mech Eng H. 2020 Jun;234(6):537-61. DOI: 10.1177/0954411920911283.
126. Alambeigi F, Bakhtiarinejad M, Sefati S, Hegeman R, Iordachita I, Khanuja H, et al. On the use of a continuum manipulator and a bendable medical screw for minimally invasive interventions in orthopedic surgery. IEEE Trans Med Robot Bionics. 2019;1(1):14-21. DOI: 10.1109/tmrb.2019.2895780.
127. Ricci WM, Tornetta III P, Petteys T, Gerlach D, Cartner J, Walker Z, Russell TA. A comparison of screw insertion torque and pullout strength. Journal of orthopaedic trauma. 2010 Jun 1;24(6):374-8. DOI: 10.1097/BOT.0b013e3181c4a655
128. Ryken T.C, Clausen J.D, Traynelis V.C, Goel V.K. Biomechanical analysis of bone mineral density, insertion technique, screw torque, and holding strength of anterior cervical plate screws. J neurosurgery. 1995;83(2):324-9. DOI: 10.3171/jns.1995.83.2.0324.
129. Müller M.E, Allgöwer M, Schneider R, Willenegger H. Screws and plates and their application. Manual of INTERNAL FIXATION: Techniques Recommended by the AO-ASIF Group. 1992:179-290.
130. Helgeson M.D, Kang D.G, Lehman Jr R.A, Dmitriev A.E, Luhmann S.J. Tapping insertional torque allows prediction for better pedicle screw fixation and optimal screw size selection. Spine J. 2013;13(8):957-65. DOI: 10.1016/j.spinee.2013.03.012.
131. Bertollo N, Walsh W.R. Drilling of bone: practicality, limitations and complications associated with surgical drill-bits. In book: Biomechanics in applications. 2011 Sep 9;4:53-83. DOI:10.5772/20931.
132. Sigua-Rodriguez E.A, de Medeiros R.C, Goulart D.R, Bomfim-Azevedo V.L, Olate S, de Albergaria-Barbosa J.R. Comparative evaluation of different fixation techniques of the sagittal split ramus osteotomy in 10 mm advancements: mechanical testing and screw insertion torque. J Cra Max Surg. 2018;46(12):2082-7.
133. Perna F, Borghi R, Pilla F, Stefanini N, Mazzotti A, Chehrassan M. Pedicle screw insertion techniques: an update and review of the literature. Musculoskelet Surg. 2016;100(3):165-9. DOI: 10.1007/s12306-016-0438-8.
134. Baluch D.A, Patel A.A, Lullo B, Havey R.M, Voronov L.I, Nguyen N.L, et al. Effect of physiological loads on cortical and traditional pedicle screw fixation. Spine (Phila Pa 1976). 2014;39(22):E1297-302. DOI: 10.1097/BRS.0000000000000553.
135. Kim Y.J, Lenke L.G. Thoracic pedicle screw placement: free-hand technique. Neurol India. 2005;53(4):512-9. DOI: 10.4103/0028-3886.22622.
136. Mobbs R.J, Phan K, Assem Y, Pelletier M, Walsh W.R. Combination Ti/PEEK ALIF cage for anterior lumbar interbody fusion: early clinical and radiological results. J Clin Neurosci. 2016;34:94-9. DOI: 10.1016/j.jocn.2016.05.028.
137. Khan I.A, Singh A, Akhtar U. Role of Dynamization in Fracture Healing of Femur and Tibia After Intramedullary Interlocking Nail: A One Year Hospital Based Prospective Study. Res J Med Sci. 2024;18(12):317-22. DOI:10.36478/makrjms.2024.12.317.322.
138. Jindal S. A prospective study to evaluate the outcome of antibiotic cement impregnated intramedullary nailing in infected fractures of femur and tibia. Int J Life Sci Biotech Pharma Res. 2024. Available from: http://www.ijlbpr.com/uploadfiles/75vol13issue12pp397-401.20241213083816.pdf.
139. Kumar DR, Nitheesh S, Rakesh MM, Krishnan GA, Subash Y. A comparative study of plating vs nailing-retrograde nailing for femur and antegrade nailing for tibia for floating knee. International Journal of Orthopaedics. 2023;9(3):182-7. DOI: 10.22271/ortho.2023.v9.i3c.3425
140. Sanchez-Fernandez H, Julbe J.I.A, Gonzalez J.A.R, Frontera S.E, Ramírez N, Martinez P.R. Atypical Tibial Fracture Following Chronic Bisphosphonate Use: A Case Report and Review of the Literature. Cureus. 2024;16(11):e73165. DOI: 10.7759/cureus.73165.
141. Kim J.Y, Lee S.W. Tibial Insufficiency Fracture with Characteristics of an Atypical Fracture: A Rare Case and Literature Review. Medicina (Kaunas). 2024;60(11):1814. DOI: 10.3390/medicina60111814.
142. Abdioğlu A.A, VAriş O, Aslan O, Paksoy K, Öner K, Uygun H. Evaluation of Treatment Outcomes in Orthopaedic Firearm Injuries: A Review of 52 Cases. J General Med/Genel Tıp Derg. 2024;34(6). 10.54005/geneltip.1427229.
143. Wallace SJ, Rozbruch SR. Lengthening and correction of femur malunion followed by high tibial osteotomy. In: Limb Lengthening and Reconstruction Surgery Case Atlas: Adult Deformity, Tumor, Upper Extremity. Cham: Springer Nature Switzerland; 2025. p. 295-9. DOI: 10.1007/978-3-319-02767-8_491-1
144. Desrochers-Perrault F, Aubin CE, Wang X, Schwend R.M. Biomechanical analysis of iliac screw fixation in spinal deformity instrumentation. Clin Biomech (Bristol). 2014;29(6):614-21. DOI: 10.1016/j.clinbiomech.2014.04.016.
145. Cho W, Cho S.K, Wu C. The biomechanics of pedicle screw-based instrumentation. J Bone Joint Surg Br. 2010;92(8):1061-5. DOI: 10.1302/0301-620X.92B8.24237.
146. Lehman Jr R.A, Polly Jr D.W, Kuklo T.R, Cunningham B, Kirk K.L, Belmont Jr P.J. Straight-forward versus anatomic trajectory technique of thoracic pedicle screw fixation: a biomechanical analysis. Spine. 2003;28(18):2058-65. DOI: 10.1097/01.BRS.0000087743.57439.4F.