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Research Article

Study of Pedicle Screw Fixation System

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Abstract

Spinal implants or instrumentation have been used for many years for the re-alignment and stabilization of unstable or deformed spine. A pedicle screw is a particular type of bone screw designed for implementation into vertebral pedicle. These screws are used to correct deformity or treat trauma and also are used to immobilize part of spine to assist fusion by holding vertebrae together. Over the years, pedicle fixation systems have proved to be biomechanically superior for segmental fixation. Thus, numerous systems and variations are being developed.

Keywords: *DDD, Pedicle screw, Spine, Spondylilsthesis, TILF*

1. Introduction

Bone screws have been used in spinal instrumentation since 1940s. Tourney in 1943 and King in 1944 used the bone screw to obtain internal spinal fixation at the time of fusion. Pedicle screws were first used in 1959 by Boucher. Roy Camille was the first to use pedicle screws connected to a dorsal plate. Cotrel and Dubousset were first to use system with both screw and hooks connecting them with rods and plate.

Spinal implants or instrumentations are used for the realignment and stabilization of unstable or deformed spine, in case of Spondylolisthesis (i.e. spine slippage), traumatic fracture, chronic degenerative disc disease and other form of spinal injuries. In Most the spinal implants metals such as titanium, titanium-alloy or stainless steel are used. Some are made of non-metallic compounds. Hooks and rods are used, along with pedicle screws.

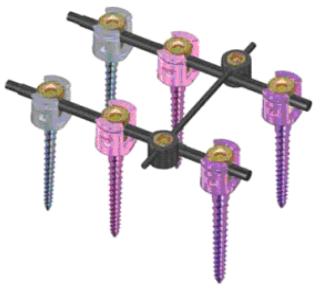

Fig. 1 Pedicle screw system

Rods: - One of the indigenous implants used in spine to restrict the movement of spine, and to stabilize the spine into correct alignment.

Pedicle screws-Pedicle screws are designed specially so that they can be implanted into the pedicles of the spinal vertebrae. Pedical screws were used in lumbar region of spine, but now a day surgeons are using it in thoracic region also. Rods are attached to screws as they provide strong fixation point. These rods can correct deformities and facilitate fusion

Hooks-Hooks are used as intermediate member between rods and vertebrae Types of pedicle screws

1. Mono-axial screw- In this type head of the screw is fixed. There are zero degrees of freedom.

Fig. 2 Mono-axial screw

2. Poly-axial screw-The head of this screw is moving. It swivels helping to defray vertebral stress. Nowadays poly-axial screws are preferred by surgeons due to flexibility and comparative ease of fixation.

Fig. 3 Poly-axial screw

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Pedicle anatomy- Dorsal spine element and vertebral body is connected by Pedicle. It is a strong, cylindrical Bone; consisting of tough shell of vertical bone and core of cancellous bone. Size and angle of Pedical varies throughout the spinal column. The transverse pedicle width is narrower than sagittal pedicle width except in lower lumbar spine.

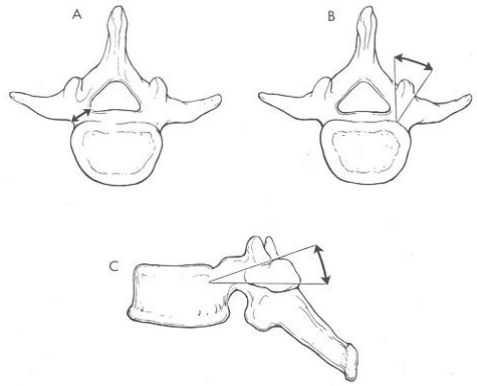

Fig. 4 Pedicle anatomy

2. Need of pedicle screw system

Human ligamentous spine consists of vertebrae, interposing discs, and ligaments forming a complex structure. For example, the lumbar region of the spine contains five vertebrae and their supporting soft tissue structures. Each lumbar vertebra consists of a body and a posterior vertebral arch. The posterior elements consist of the facets, pedicles, transverse processes, laminae, and spinous process. The vertebra is held together by ligament. In between the two vertebral bodies, vertebral disc is interposed made up of the nucleus pulposus, the annulus, and the two cartilaginous end plates. In a normal person, these spinal structures along with the muscles spanning the spine function in unison to provide trunk flexibility, support of the upper body weight, and protection of the spinal cord and nerve roots that pass through the spinal canal and foramen.

Spinal injuries can cause severe effect. Sometimes it can cause death. In such cases spinal surgeries are compulsory. In this surgery injuries are cured either by dissecting or by removing the impinging or mal-functioning structures. However, depending upon the amount of bony and soft tissue decompression achieved, these procedures may lead to clinical instability.

The loss of ability of the spine under physiological loads to maintain its pattern of displacement so that there is no initial or additional neurological deficit, no major deformity, and no incapacitating pain is known as Clinical instability. The goal of spinal fusion is to restore stability to a clinically unstable spine, with a minimum decrease in spinal motion and minimal damage of normal structure and function of the spinal fusion surgery is to maintain correction, provides structural integrity, and by diminishing the spine's movement may reduce pain.

In the thoracolumbar spine, is one of the most commonly used method of instrumentation is Spinal fixation with pedicle screws. This technique provides instant rigid fixation with a least number of fused vertebrae.

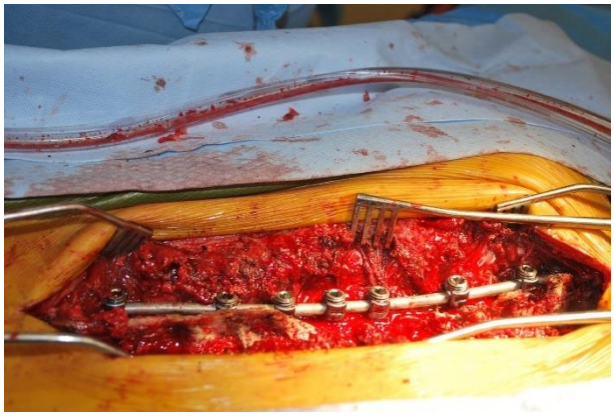

Fig. 5 Pedicle screw actual surgery

Wolff's law qualitatively describes the ability of bone to form ideal structures to support loads and to adapt structurally to varying forces. Wolff's law of trabecular architecture states that bone adapts its structure to mechanical loading conditions; axial load sharing is necessary for a fusion to occur. In normal bone, a continuous remodeling process, known as the strain-adaptive remodeling theory, is occurring resulting from normal physiologic osteoclastic and osteoblastic activities.

For the majority of spinal construct testing, ultrahigh molecular weight polyethylene (UHMWPE) blocks are used rather than vertebrae to eliminate the imbalance that bone properties and geometry may introduce. The standard is used to quantify the static and dynamic mechanical characteristics of different designs of spinal implant assemblies.

3. Material for pedicle screw

Stainless-steel and titanium implants are surgically approved and normally integrate into bone without complications, but sometimes slight tissue reaction is observed in some patiants. The bone repair time around metallic implants is in the range of months, and the integration process is often described in terms of bone in-growth into threads, pores, holes, asperities, etc. Increased bone formation around titanium implants is associated with improved mechanical stability whereas stainless steel appears less readily incorporated and has shown a comparatively lower mechanical binding strength than titanium in pig spine experiments. Thus, stainless steel implants do not adopt with bone structure probably because of the material structure.

Whereas Titanium is used for manufacturing of implants because of its properties like, immunity to

corrosion, bio-compatibility, high strength to weight ratio, low modulus and density and the capacity for joining with bone and other tissue – Osseo integration. Due to combination of these chemical and mechanical properties Titanium implants are damage tolerant. It is virtually nonmagnetic and hence it does not interfere during MRI scanning.

4. Advantages of pedicle screw fixation

Pedicle screw can rigidly stabilize both the ventral and dorsal aspects of the spine as they transverse all three columns of the vertebrae. Pedical is the strongest part of bone hence pedicle screws can be rigidly fixed in pedicle without damaging bone-metal. Furthermore, the rigidity of the pedicle fixation allows for the incorporation of fewer normal motion segments in order to achieve stabilization of an abnormal level.

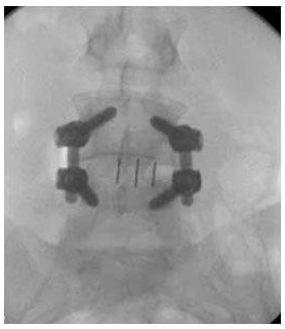

Fig. 6 Pedicle screw fixation

Pedicle screw fixation does not require intact dorsal elements. Thus, it can be used after a laminectomy or traumatic disruption of laminae, spinous processes and/or facets. Additionally advantages include fewer requirements for postoperative bracing and improvements in fusion rates.

5. Limitations

Pedicle screw fixation is difficult as it needs lengthy operative time so there is significant blood loss. Also it is extremely difficult, requiring different cerebral, surgical and technical skills. Experienced surgeons can only perform such type of surgeries as the risk to patient's life is too high. Even though various new, easy, user friendly techniques, as well as technically advanced implants are used, still the failure rate of this type of surgery is high. The most common problems are screw bending, breakage and loosening. Infection is also another implant-related complication. Failure of pedicle screw by fracture of hardware is reported in 6-7% of cases. Failure is likely to occur due to loosening or due to a loading situation that exceeds the load-bearing capacity of the implant. In osteoporosis, where bone density is decreased, affects between 5 and 20% of women older than 50 years old. The main problem with these fractures is that due to bone fragility, the plates and screws used to treat them surgically do not sufficiently engage with the bone or they became loosened as a result of the mechanical demands of daily life.

Postoperative imaging studies (such as CT scan, etc.) are blurred by implants. To insert pedicle screw properly amount of dissection is very large, i.e. for optimum screw trajectory substantial dissection has to be provided. Pedicle screw can cause degeneration of adjacent vertebra. These surgical techniques are very costly.

Failure are also reported in the presence of pseudo arthrosis that subjects the implants to continued fatigue loading until instrument failure occurs, unstable or deficient anterior column due to the presence of tumors or unhealed fractures leading to excessive loading of posterior instruments, spinal deformities loading excessively the implants (kyphosis or spondylolisthesis). The failures and complications could be confronted by optimizing the design of the pedicle screws in order to achieve higher stability and mechanical strength reducing at the same time the implant-bone failure area.

Conclusion

Pedicle screw fixation provides restoration of spinal lordosis. Mono screws in pedicle screw system yields higher axial and torque gripping capacity, stiffness and load carrying capacity in all relevant directions of loading compared to poly screws. It also provides structural integrity to the spines. The immediate rigid fixation with a minimum number of fused segments is achieved.

References

V. K. Goel, N. A. Ebraheim(2005), "*Role of mechanical factors in the evaluation of pedicle screw type spinal fixation devices*, "Neurology India, December 2005 ,Vol. 53 ,Issue 4, 399-407

Thomas R. Haher, Amy W. Yeung, Danielle M. Ottaviano, Andrew A. Merola, Steven A. Caruso(2001), "*The inverse effects of load transfer and load sharing on axial compressive stiffness*", The Spine Journal 1, 324–330.

John T. Lysack, David Yen, Genevieve A. Dumas (2000), *"In vitro flexibility of an experimental pedicle screw and plate instrumentation system on the porcine lumbar spine*" Medical Engineering & Physics, 22 461–468.

Keavenly TM, Bartel DL(2004), "*Fundamental load transfer patterns for press-fit, surface-treated intramedullary fixation stems*", J Biomechanics, 1994; 27:1147–57.

Ryken TC, Clausen JD, Traynelis VC, Goel VK. (1995), "*Biomechanical analysis of bone mineral density, insertion technique, screw torque, and holding strength of anterior cervical plate screws*", J Neurosurgery, 83:324-9.

Oleg Prymak, Denise Bogdanski, Manfred Köller, Stefan A. Esenwein, Gert Muhr, Felix Beckmann, Tilmann Donath, Michel Assad, Matthias Epple. (2005), "*Morphological characterization and in vitro biocompatibility of a porous nickel–titanium alloy*", Biomaterials, 26 5801–5807.

A. Yánez, J.A. Carta, G. Garcés (2010), "*Biomechanical evaluation of a new system to improve screw fixation in osteoporotic bones*", Med Eng Phys 10.1016

A. Rohlmann, G. Bergmann, F. Graichen, H.-M. Mayer (1998), "*Placing a bone graft more posteriorly may reduce the risk of pedicle screw breakage: analysis of an unexpected case of pedicle screw breakage*" Journal of Biomechanics, 31 763-767.

P. Tengvall, B. Skoglund, A. Askendal, P. Aspenberg, (2004),"*Surface immobilized bisphosphonate improves stainless-steel screw fixation in rats*", Biomaterials, 25 2133–2138.

Robert W. Gaines Jr. (2000) "*The Use of Pedicle-Screw Internal Fixation for the Operative Treatment of Spinal Disorders*", J Bone Joint Surg Am.; 82:1458.