1. Introduction:

Boucher was the first to use screws that crossed through the strongest point of attachment of the facet joint into the pedicle and the body of the vertebra below. He declared a pseudarthrosis rate of 14% to 17% including multilevel fusions (1).

The use of pedicle screw-assisted spinal stabilization has become increasingly popular worldwide. Pedicle screw systems engage all three columns of the spine and can resist motion in all planes. Analysis of several studies suggests that pedicle screw fixation is a safe and effective treatment for many spinal disorders (2,3). The pedicle screw-bone junction provides the strongest point of attachment of the instrument to the spine. Thus, pedicle screw fixation systems can resist motion in all planes (1).

Pedicle screws have dramatically improved the outcomes of spinal reconstruction requiring spinal fusion. Short-segment surgical treatments based on the use of pedicle screws for the treatment of neoplastic, developmental, congenital, traumatic, and degenerative conditions have been proved to be practical, safe, and effective (4). The funnel technique provides a straightforward, direct, and inexpensive way to very safely apply pedicle screws in the cervical, thoracic, or lumbar spine. Carefully applied pedicle-screw fixation does not produce severe or frequent complications. Pedicle screw fixation can be effectively and safely used wherever a vertebral pedicle can accommodate a pedicle-screw-that is, in the cervical, thoracic, or lumbar spine. Pedicle-screw fixation represents the so-called gold standard of spinal internal fixation (4).

Pedicular fixation is a relatively safe procedure and is not associated with a significantly higher complication risk than non-pedicular instrumentation. It provides short, rigid segmental stabilization that allows preservation of motion segments and stabilization of the spine in the absence of intact posterior elements, which is not possible with non-pedicular instrumentation (5). The stiffness of the pedicle fixation allows for the incorporation of fewer normal motion segments to achieve stabilization of an abnormal level. Fusion rates and clinical outcome in the treatment of thoracolumbar fractures appear to be superior to that achieved using other forms of treatment. For the correction of spinal deformity (i.e., scoliosis, kyphosis, spondylolisthesis, tumor), pedicular fixation provides the theoretical benefit of rigid segmental fixation and of facilitated deformity correction by a posterior approach, but the clinical relevance so far remains unknown (5).

2. Disadvantages and Complications:

Disadvantages and complications of percutaneous transpedicular systems are more or less the same with conventional pedicle screw applications. Some of the complications are less with the sextant system because of applying it under fluoroscopic control. So complications as misplaced screws, nerve root injury, spinal cord injury, pedicle fracture, CSF fistula, damage to retroperitoneal structures are less with this system. But considering the percutaneous systems, a more steep learning curve is required. Caudal or medial penetration of the pedicle cortex may result in durotomy or neural injury.

As in the conventional pedicle screw systems, screw pullout, breakage and toggle, hardware failure or failure at the screw-bone junction are the
most frequently encountered problems in percutaneous transpedicular screw systems.

In general, early complications of transpedicular stabilization of the spine are unusual and are infrequently associated with permanent morbidity. There is however a high proportion of postoperative radiographic failures, of about 40% rate (Mostly screw loosening, angulation or fracture). Implant removal was required in about 15% of the cases within a year. However, traditional open surgical methods for the insertion of posterior instrumentation have several disadvantages including the risk of significant blood loss, the potential for serious infections, and the need for extensive paraspinous muscular dissection. Extensive dissection may lead to muscular denervation and necrosis resulting in prolonged postoperative pain and disability. For these reasons, the development of minimally invasive techniques to achieve spinal fixation would appear desirable.

Although methods of percutaneous pedicle screw and rod fixation have been developed, these techniques become more difficult to apply between three adjacent pedicle screws and in the presence of bony impediments to rigid rod passage. In addition, the precurved metal rods used in these techniques do not allow for rod shaping. Postoperative imaging techniques (especially MRI) are in part obscured by the implant. Rigid fixation can accelerate adjacent motion segment degeneration (6).

Due to its minimally invasive insertion, the new pedicle screw and rod fixation system may potentially reduce procedural morbidity, decrease paraspinous muscle denervation and necrosis, and speed postoperative recovery (6,7). Infection rate is lower than the conventional pedicle fixation systems because of less retraction of the muscle tissue decreases muscle necrosis and lessens the risk of infection (9).

In 1977 the technique of percutaneous pedicle screw placement in the lumbar spine was introduced by Magerl (9). Although initially described for the management of spinal fractures and infections, the indications for the technique changed with the rapid improvement of more sophisticated internal fixation devices. Therefore, during the last decade the percutaneous technique of pedicle screw placement has been used almost exclusively for the temporary stabilization of spinal segments during an external fixation test. With the increasing popularity of pedicle screw fixation devices for several indications, the safety and reliability of screw insertion in the small pedicle has become a major issue. Many studies have investigated the accuracy of screw placement by a conventional open approach using simple radiograph, computed tomography (CT) scan or magnetic resonance imaging (MRI) (11,12).

With integration of robotic, endoscopic, and image-guided systems, we are embarking on exciting new frontiers with minimally invasive spine surgery. Complex spinal instrumentation can then be accomplished with more precision through small portals, thus reducing morbidity, lessening postoperative discomfort, reducing time in the intensive care unit, reducing hospitalization, decreasing medication, creating less disability, and reducing expenses (11-13).

The insertion of percutaneous lumbar pedicle screws has been previously reported (13). But a minimally invasive technique involving insertion of a longitudinal connector for these screws has proven more challenging. The Sextant system (Sextant; Medtronic Sofamor Danek, Memphis, TN) allows for the straightforward placement of lumbar pedicle screws and rods through percutaneous stab wounds. Although percutaneous lumbar pedicle screw placement has been described previously, longitudinal connector (rod or plate) insertion has been more problematic. The sextant device allows for straightforward placement of lumbar pedicle screws and rods through percutaneous stab wounds. Paraspinous muscle trauma is minimized. The quality of spinal fixation is similar to the conventional techniques. An existing multiaxial lumbar pedicle screw system was modified to allow screws to be placed percutaneously by using an extension sleeve that permits remote manipulation of the polyaxial screw heads and remote engagement of the screw-locking mechanism. A unique rod-insertion device was developed that linked to the screw extension sleeves, allowing for a precut and contoured rod to be placed through a small stab wound. The insertion device relies on the geometrical constraint of the rod pathway through the screw heads (11). So, minimal manipulation is required to place the rods in a standard submuscular position and there is essentially no muscle dissection, and the need for direct visual feedback is avoided. The screws and rods in this system are placed in an anatomical position similar to that achieved by an analogous open surgical approach. Paraspinous tissue trauma is greatly
minimized without sacrificing the quality of the spinal fixation.

One advantage of percutaneous screw placement over the conventional open procedure, however, is that it is much easier to achieve the required medial angulation because extensive soft-tissue and muscle retraction is avoided (13).

3. Surgical Procedure:

3.a. Operating Room Set up:
The surgical team setup consists of spine surgeon, anesthesiologist, scrub nurse and technician for the fluoroscopy. The fluoroscopy is wrapped with sterile cover and the C arm is located around the lumbar spine of the prone patient for real time imaging. The surgical table must be radiolucent so that both lateral and anterior-posterior imaging is possible.

3.b. Surgical Equipment and Patient Positioning:
Usually preoperative plain radiographs and a CT scan should be examined to determine bone quality, pedicle transverse diameter and screw trajectory. Surgical radiolucent spinal frames are useful, particularly for AP radiographs.

Posterior percutaneous lumbar fixation system can be performed after induction of either general or epidural anesthesia (Figure 1a, b). The patient is positioned prone on top of chest rolls so that the abdomen free. C-arm fluoroscopy device should be used for percutaneous screw guidance (Figure 2a, b). It is important to determine whether adequate AP and lateral fluoroscopic images of the lumbar spine can be obtained before preparing and draping the patient.

3.c. Surgical Technique:
After cleaning and clotting the operation area, a dynamic reference array is first used to determine the projections of pedicle under biplanar fluoroscopy. The targetting of the pedicle is done and approximately 15-mm incision is made at the skin entry point and extended into the underlying subcutaneous tissue. A K-wire is used to perforate the fascia, and a series of sequential dilators are then used to dilate the fascia and to separate bluntly the underlying paraspinal muscles down to the spine on one side of the vertebrae (Figure 3a,b). The dilators are removed, and both a tracked awl and a pedicle probe are used to create a pedicle pilot hole under virtual fluoroscopic guidance (Figure 3c).

Using real-time multiplanar virtual fluoroscopy image guidance, the chosen pedicles are tapped and screws are placed (Figure 3d,e). A thorough knowledge of pedicle-related anatomy and the sagittal and axial angulation of the individual pedicles is mandatory for safe percutaneous screw placement. These angles are best judged using preoperative computerized tomography or magnetic resonance imaging of the lumbar region. Alternatively, the pedicle can be navigated by using a conventional C-arm fluoroscope that is alternated between AP, lateral, and oblique views. If this technique is chosen, one must obtain multiple sequential images of the pedicle probe in at least two planes as it is advanced down the pedicle. It is important to keep these trajectories in mind to ensure the accuracy of the percutaneous screw placement (One advantage of percutaneous screw placement over the conventional open procedure, however, is that it is much easier to achieve the required medial angulation because extensive soft-tissue and muscle retraction is avoided) (12).

The multiaxial Sextant pedicle screws are attached to screw extenders, which have inner and outer sleeves. The inner extender sleeve is designed to be preloaded with a lock plug, which will eventually connect the screw to the rod. The outer sleeve actually extends over the multiaxial screw head. The inner sleeve starts in a first position that allows the lock plug to be partially advanced into the multiaxial screw head, by which the screw is connected to the extender–sleeve combination. The screw head remains mobile on its shank. Thus, the screw head can be manipulated remotely (rotated and angled) by moving the far end of the screw extender even after the screw has been placed within the pedicle (12).

After a pair of pedicle screws, together with their attached extenders, has been inserted, a Sextant rod is placed. The Sextant rods are precontoured into a curvilinear shape that precisely matches the contour of the Sextant rod inserter. The rods are designed to fix rigidly to the inserter, forming a smooth arc. Additionally, the Sextant inserter attaches to the screw extenders. The resulting arrangement resembles the navigational device of the same name (12).
The screw extenders are aligned at their proximal ends. This maneuver arranges the distal ends, which are connected to the multiaxial screw heads, in a way that allows the openings in the screw heads to fit the same curvilinear path of the precontoured rod. The geometrical configuration is such that this path is identical to the arc created by the rod–Sextant rod inserter union. In fact, once the joined screw extenders are attached to the rod inserter, this geometrical relationship is constrained. The arc, subtended by the inserter–rod combination, must now follow the path connecting both screw heads (Figure 3f,g).

After the screw extenders have been connected to the Sextant rod inserter, a trochar tip is attached to the inserter. The skin is marked where this tip intersects it, and a small stab wound is made using a No. 15 blade. The trochar tip serves to open the underlying fascia. Once the fascia has been penetrated, the tip is removed and a Sextant rod is attached. The rod is inserted through the same stab wound and intersects the screw heads. This is checked fluoroscopically. Appropriate forces (compression and/or distraction) can be applied to the construct prior to final tightening. The inner sleeves are now advanced to their second position, allowing a hex driver to be inserted and to permit tightening of the lock plugs (12,13).

The lock plugs are designed with a torque-limiting breakoff, which allows simultaneous locking of the rod to the screw while the extension sleeve detaches. The Sextant itself serves as a counter-torque device. The rod is remotely released from the Sextant inserter, and the latter is removed from the field, leaving a percutaneous rod–screw combination in place. The procedure can be repeated on the contralateral side of the spine (Figure 3h,i,j,k,l), after which the stab incisions are irrigated and closed. The operative time ranges from 90 to 220 minutes; the longer times occur early in the learning curve (12,13).

4. Discussion:

Percutaneous fixation of the lumbar spine was first described by Magerl (9). He used an external fixator. Mathews and Long (13) described and performed a wholly percutaneous lumbar pedicle fixation procedure in which they used plates as longitudinal connectors. They noted a high rate of nonunion (13). Lowery and Kulkarni (8) subsequently described a similar procedure in which rods were placed. They reported a high success rate. In all cases, the longitudinal connectors were placed either externally or superficially, just beneath the skin where the hardware can be irritating and requires routine removal. Also longer screws (and thus longer moment arms) are required, producing less effective biomechanical stabilization than that achieved using standard pedicle fixation systems and thus leading to a higher implant failure–related potential.

The use of the Sextant system, with or without virtual fluoroscopy, offers several distinct advantages over conventional pedicle screw fixation. The system eliminates the need for a large midline incision and significant paraspinous muscle dissection. Both the pedicle screws and the precontoured rod are placed through stab incisions. The paraspinous muscles are bluntly split rather than divided, leading to potentially shorter periods of hospitalization and recovery. Blood loss and tissue trauma are minimized. An ideal lateral-to-medial screw trajectory is much more easily accomplished, especially in larger patients, because significant paraspinous tissue retraction is avoided.

Compared with previously used percutaneous techniques, the Sextant procedure allows the screw–rod system to be placed in a standard anatomical position. This optimizes the biomechanics of the fixation and keeps the hardware in place without irri-
tating the superficial tissues of the low back, thus avoiding routine hardware removal. In addition, this technique minimizes much of the “fiddle factor” related to connecting a percutaneous rod or plate to pedicle screws. The inserter geometrically constrains the rod’s pathway, simplifying insertion of the rod. The cannulated extension sleeves allow the lock plugs to be quickly and easily seated against the rod and thereby simplifies screw–rod connection. Because the Sextant inserter remains connected to the screws and rods, appropriate forces (compression and distraction) can be applied to the construct prior to final tightening (11-13).

The technique involved in placing the Sextant system follows these same principles, allowing the surgeon to perform biomechanically sound internal spinal fixation with minimal tissue trauma. Minimally invasive approaches for performing lumbar fusion are in their infancy. The goal of these surgeries, as for all minimally invasive procedures, is to minimize approach related morbidity while achieving the same result as more traditional, invasive approaches (11).

5. Postoperative Care:

There is no special consideration regarding postoperative care after this procedure. After completion of the operation, the stab incisions are irrigated and closed. The patient is extubated at the end of the operation and transferred to his/her bed. The feeding of the patient can be started after the sounds of intestinal movements. The appropriate analgesics and anti-inflammatory drugs can be inserted if the patient needs. Patients could be mobilized within the five –six hours after this minimal invasive surgery. Fifty percent of the patients are discharged on postoperative day 1 or 2. The patient can return his job 2 weeks after operation.

6. Case Illustrations:

A 45 year-old male, admitted to our emergency department with back pain after falling down the stairs. The neurological examination of the patient was normal except severe back pain. The thorocal and lumbar direct graphies and MRI images revealed L2 vertebra compression fracture. There were no compression to the spinal cord at the lumbar CT and MRI and posterior wall of the vertebra corpus was intact (Figure 4a, b).
**Figure 3:**

(a,b) The K-wires are used to perforate the fascia and underlying paraspinal muscles and also the pedicles are targeted under fluoroscopy, (c) A series of sequential dilators are then used to dilate the fascia and paraspinal muscle, (d,e) The screw extender, after the screw has been placed within the chosen pedicle, (f,g) The arc, subtended by the inserter–rod combination and the rod is inserted through the stab wound, (h,i) A series of sequential dilators are used to the opposite side and the screws are placed with the screw extender, (j,k) The arc, subtended by the inserter–rod combination and the rod is inserted to the opposite side, (l) The lateral fluoroscopy view after the operation.
Percutaneous kyphoplasty was performed to the L2 vertebra corpus with posterior percutaneous stabilization to the L1-3 vertebrae (Figure 4c,d,e,f). The patient was mobilized the day after operation and discharged at the second day after the operation. The follow-up of the patient was uneventful.

7. References:


