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# Concept of Transforaminal Lumbar Interbody Fusion Cage Insertion Device

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***Abstract*—**Transforaminal lumbar interbody fusion (TLIF) surgeries have nowadays became popular for treatment of degenerated spinal disorders. The interbody fusion technique like TLIF maintains load bearing capacity of the spine and a suitable disc height. Currently many techniques have been introduced to cure Spondylolisthesis. This surgery provides greater rehabilitation of degenerative spines. While performing this TLIF surgery existing methods use guideway, which is a troublesome surgery technique as the use of two separate instruments is required to perform this surgery. This paper presents a concept which eliminates the use of guideway. This concept also eliminates problems that occur like reverting the cage. The concept discussed in this paper also gives high accuracy while performing surgery.

***Keywords*—**Degenerative disc diseases, pedicle screw, spine, spondylolisthesis, transforaminal lumbar interbody fusion.

## I. Introduction

APPROXIMATELY 70 years ago, a surgery which has evolved as a treatment for lumbar spinal fusion, was introduced. In the early 1990s, Harms and Jeszenszky described Transforaminal Lumbar Interbody Fusion (TLIF) surgeries to heal spinal disorders. Degenerative Disc Diseases (DDD) most commonly occurs due to aging of the spine. It is also caused due to injury to the back as the result of accidents, sudden shock. Reduction in protein content can also lead to Degenerative Disc Diseases [1]. DDD causes reduction in water-attracting molecules, and hence, water in the disc to decrease. This reduces the disc's ability to handle back movement and also induces pain. So spinal fusion surgeries are performed to stop motion at a painful vertebral segment and that should decrease the pain generated from the joint [3]. Lumbar fusion surgeries are performed for DDD, in cases where the diseases are not possibly cured by physical exercises and medicines, the surgeries are highly recommended.

The main objective of this surgery is to create solid bone between two vertebrae [3]. This reduces excessive pain which is caused by immoderate stress [1]. While performing this surgery a special spacer called a TLIF cage is inserted into two vertebrae. These surgeries are performed using medical tools. Some surgeries make use for one tool for insertion and another tool for guiding the cage. There are different approaches towards this spinal fusion surgery which involves adding a bone graft material to a segment of the spine, set up a biological response that causes the bone graft to grow between the two vertebral elements to create a bone fusion and finally the boney fusion - which results in one fixed bone replacing a mobile joint – stopping the motion at that joint segment. Bone fusion rates are enhanced because the bone graft is placed in the disc space and gutters of the spine posteriorly.

There are two methods of achieving an interbody fusion which are posterior lumbar interbody fusion (PLIF) and TLIF [2].

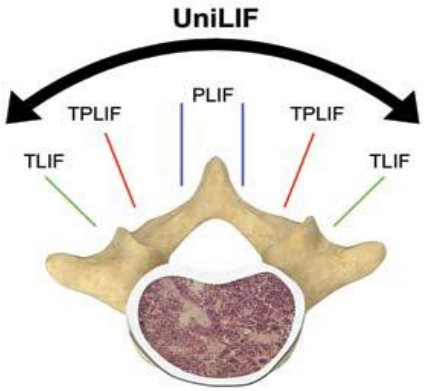


Fig. 1 Difference in TLIF and PLIF surgery

The main advantage of the TLIF procedure compared with the PLIF procedure included a decrease in potential neurological injury and preservation of posterior column integrity through minimizing lamina, facet, and parts dissection.

A cage consists of axial hollow space in which bone graft is added. Bone graft merges into a single solid bone. A cage is made up of PEEK (Poly Ether Ether Ketone) material. Its thickness ranges from 6 mm to 13 mm and is selected on the basis of requirement of the case. Its breadth is 14 mm and length 28 mm. Lordotic angle is 50.

Alternatives for PEEK are carbon fiber and Titanium mesh [2]. The main parameter in the surgery is the cage location. The location in intervertebral disc space is important. It is useful for determining lumbar lordosis. In some cases, due to the requirement according to patients, only a convex-shaped cage is used. The curved cage was designed as a bullet-type convex-shaped implant. This design is achieved so as to help the cage fit to the convexity of the vertebral endplate. The convex-shaped cage may have some advantages such as equivalent lordosis correction and tight endplate fitting [4].

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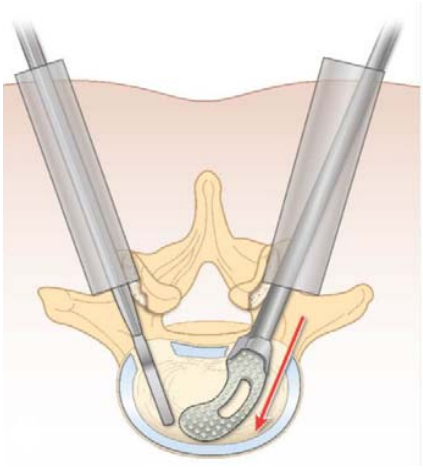

Fig. 2 TLIF cage used surgery using guideway

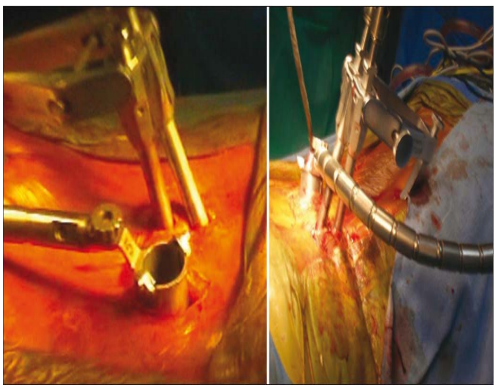

Fig. 3 Actual surgery of TLIF cage

The cage usually does not dislocate from its position while performing the surgery due to threads provided on both the sides. Breakage of the cage during surgery is nowadays highly impossible.

Fig. 4 TLIF cage used in surgery

Although TLIF is a unilateral procedure, due to this it is has to combine with posterior bilateral pedicle screw fixation. Unilateral fixation after the TLIF surgeries provides comparatively less rotational stability and stiffness than bilateral pedicle screw fixation. The TLIF procedure allows a single point of access to be used for interbody fusion and posterior surgeries. It preserves the anterior longitudinal ligament and a major portion of the posterior ligament complex with minimal compromise of spinal stability. However, the need for Para spinal muscle dissection and retraction remains a drawback that can lead to muscle degeneration, so it causes pain in low back [7]. This TLIF surgery provides fusion anterior and posterior columns of the lumbar spine. The posterior column is stabilized by the pedicle screws, rods, and bone graft material [7], whereas the anterior column is stabilized by the cage and bone graft material [5]. Pedicle screws are temporary fixations whereas cage is permanently inserted in the body. But there are few problems associated with the insertion of these pedicle screws while performing TLIF surgery, provided that the surgeon should be experienced and adheres to the principles and details of the operative technique.

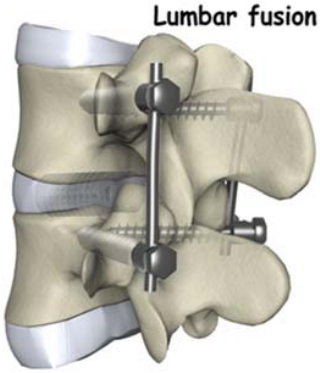


Fig. 5 Pedicle screw fixation in lumbar fusion surgery

Fig. 6 Pedicle screw fixation using a guideway

Some risk factors need to be considered while performing TLIF surgeries. Failure of the surgery is uncommon. But dislodgement is a possibility, but especially for the titanium cylindrical threaded cages, the risk is low. Another risk factor

is that there is a possibility of the cage impinging on a nerve root, but this is uncommon.

Material used for pedicle screws is Titanium alloys. Pedicle screws are removed when bones are fused together. Rate of success of the spinal fusion surgery is increased by the usage of pedicle screws. Due to this the surgery becomes costly. Also implementation of pedicle screws causes excessive tissue damages [6].

## II. Design

### A. Holding Mechanism

The design and fabrication of the device should help to eliminate problems such as using a guideway. The cage, after holding in the designed device, should not rotate on its own as there are grooves inside the cage for holding the cage firmly. The surgeries can be performed more conveniently with the suggested design. The device is designed in such a manner that it should perform the combined function of holding and positioning of the cage, and can be used by surgeons around the world for performing Lumbar Fusion Surgeries easily. This designed instrument makes use of positive locking mechanism, so while using it there will be no slip between the mating parts.

The instrument consists of a central rod, with a T-shaped projection at the end; this projection holds the cage and also restricts its linear motion while allowing only angular motion - this provides firm locking of the cage. Also, the cage is provided with a hole having a diameter equal to the length of T-projection. In this design, two supplementary rods are provided which support the cage and control its angular movement. The supplementary rods are curved at the end which helps in supporting the cage.

This entire mechanism is constrained in 20 mm diameter outer tube. The front portion of the outer tube is flattened to a width of 6mm, as it cannot be more than the thickness of the cage. As this mechanism provides firm holding of the cage, which is necessary, because while performing surgery tool is hammered and this force is enough to twist the cage while in the locked position. However in this design, as the cage is positively locked, it does not rotate even after application of hammering force.

### B. Handle

The handle is split into three parts. The outer tube is operated with the help of the first part of the handle; this part has internal threads which engage with the outer thread on the outer tube. When this part is rotated, the outer tube is pulled against the spring; and as a result, the cage can be held the T-projection of the central rod. Treads provide positive locking; due to this, the outer tube can be pulled up to any intermediated position. Another advantage is that it can hold that position against hammering force.

The second part of the handle operates the inner rod, and restricts the rotation of the rod to $90^0$. A ball and grub screw arrangement is provided to lock the rotation of the handle, and in turn, the rotation of the central rod. This also allows the operator to understand that the rod is rotated.

Supplementary rods are operated with a thimble. These rods are attached with a plate which is also attached to the outer tube. This allows supplementary rods to move relative to each other in the opposite direction. This causes rotation of the TLIF cage. The thimble controls the angular movement of the cage. This entire mechanism is fixed in the third part of the handle which is stationary.

## III. Design Considerations

As the outer tube is pressed against the spring force, stiffness of the spring can be obtained from (1),

$$K = -F/x \quad (1)$$

where, $F$: Force applied, $x$: Displacement of outer tube, $K$: Stiffness of spring.

TABLE I
DIMENSIONS OF THE TOOL

| | |
|---|---|
| Diameter of the supporting rod | 3 mm |
| Diameter of the central locking rod | 6 mm |
| Distance between supporting rod and central rod | 1.5 mm |
| Inner diameter of the outer pipe | 20 mm |
| Outer diameter of outer pipe | 22 mm |

TABLE II
DIMENSION OF A TLIF CAGE

| | |
|---|---|
| Width of the cage | 10 mm |
| Length of the cage | 28 mm |
| Thickness of the cage | 6 mm (minimum)* |

* Thickness of the cage varies from 6 mm to 13 mm

TABLE III
MATERIAL USED FOR TOOL AND ITS PROPERTIES

| | |
|---|---|
| Stainless Steel 304 | Corrosion resistance, nonmagnetic, low electrical and thermal conductance, non-toxic, excellent forming and welding |
| Anodized Aluminum | For better corrosion resistance, easy to maintain, ease of fabrication, durable and will not peel over time, increased hardness |
| Custom Stainless Steel 630 | Resistance to oxidation, good ductility, high strength, higher toughness, cold working ability |

## IV. Discussions

Lumbar fusion surgeries are performed to decompress the spinal nerves. It should stabilize the vertebral column in disc displacement, unstable spines, spinal pains, spondylolisthesis, and deformed spines, and therefore, to overcome these problems interbody fusion techniques were developed. To provide solid fixation of spinal segments and also to maintain proper disc height lumbar fusion surgeries are performed [4]. TLIF has been used to treat unilateral or bilateral symptoms. The major advantages of TLIF include the avoidance of unnecessary exposure of the contralateral structures, less retraction of the cauda equina, less muscle stripping, and consequently, less postoperative pain. Back pain in the lower back region may impact on a person's life style. Severe pain causes restlessness and the person cannot perform physical activities like lifting heavy objects, playing, etc. Thus, to overcome these difficulties, TLIF surgeries are now

recommended by surgeons and are gaining more and more popularity these days. The results are also good, and so there is a huge scope in the modification, fabrication and manufacturing of these devices. TLIF cage surgeries are commonly used for curing spondylolisthesis and degenerative disc disorder [4]. Evolution in spine hardware and surgical technique has offered an ample variety of instrumentation and surgical approaches. Common surgical options include anterior approach decompression and reconstruction, posterior pedicle screw fixation, and combined anterior and posterior approach; though there are many biomedical and clinical approaches.

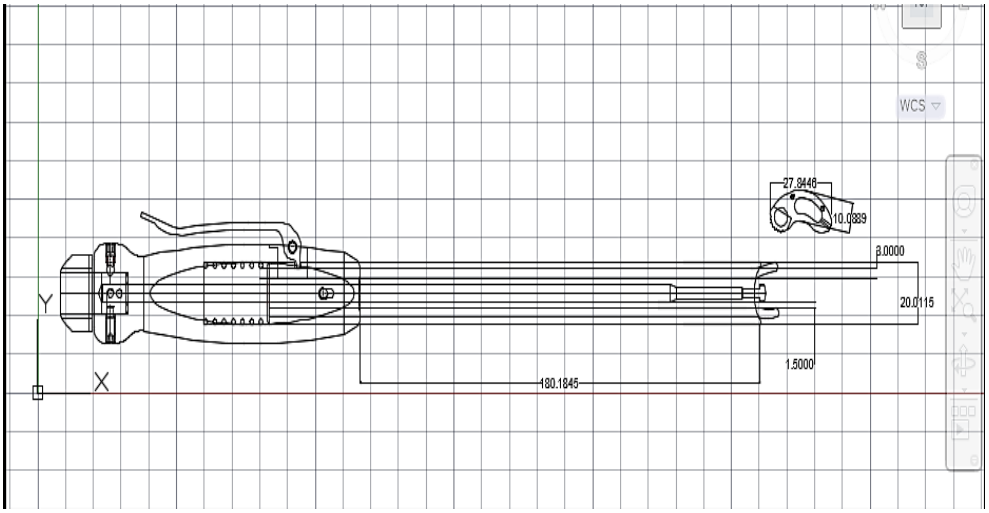


Fig. 7 CAD design of mechanism

While performing surgery, proper positioning of the cage is very important factor, because, if cage is not positioned properly it may lead to destruction of lordosis and surgeons will have to perform the surgery again. Existing techniques use a guideway for proper positioning of the cage. So to minimize the complexity of the surgery, use of the guideway can be eliminated. The focus is on designing a device which has both the mechanism i.e. holding and positioning of the cage using a single device, which will help in reducing and limiting the difficulties faced while performing the surgeries. Sometimes, the interbody cages offer additional excellent fixation so most of the patients do not need more instrumentations like pedicle screws. Biomechanical studies have concluded that unilateral fixation after performing TLIF surgeries have less rotational stability and stiffness [7].

## V. Conclusions

The proposed design is to overcome problems such as the use of guideway and proper positioning of the cage. This concept enables cage to rotate up to $80^0$ without disengaging the tool. With advancements in the design, a single tool performing both the functions is manufactured. This tool holds and positions the cage and is comparatively superior to earlier examples. This device can significantly shorten operative times, as only one instrument is needed for performing TLIF surgery. Also, it results in less blood loss and less damage to the patient's other organs. Thus, the chances of failure will also be reduced. Some neurological complications will also be reduced, as the number of instruments that are used for the TLIF surgery is reduced. The use of only one instrument will lead to less risk of nerve damage. By using this instrument there will be less injury to the support structure of the spine.

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