A Survey on Cortical Bone Trajectory for Spinal Fusions

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ABSTRACT

There have been a number of developments in screw design and implantation techniques over recent years, including proposal of an alternative trajectory entitled as cortical bone trajectory (CBT). Cortical bone trajectory has been investigated in recent medical treatments as an alternative for screw fixation aimed at increasing purchase of pedicle screws in higher density bone. CBT screw insertion follows a lateral path in the transverse plane and caudocephalad path in the sagittal plane. This technique has been advocated because it is reportedly less invasive, improves screw−bone purchase and reduces neurovascular injury. Furthermore CBT pedicle screw fixation provides stabilization to multilevel lumbar segment with low-grade spondylolisthesis comparable to the standard trajectory pedicle screw construct. However, these claims have not been supported by robust clinical evidence. Recent investigations focus on evaluations of CBT as a pioneer method.

Keywords: cortical, trajectory, osteoporosis, fixation, spinal, fusion

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INTRODUCTION

Since the introduction of pedicle screw by Boucher in 1959[1], pedicle screw fixation has been accepted as the mainstay of instrumentation in arthrodesis of the lumbar spine. At the next steps multiple trajectories and insertion techniques were investigated. The commonly practiced convergent trajectory today was popularized by Friedrich Magerl in the 1980 [2,3]. There are main limitation in technique: 1) significant muscle dissection and lateral exposure are required while placing screw in this axis. Although the triangulated screw constructs formed by placing screws along the anatomic axis of the pedicle have increased construct stability and pullout strength,[4,5] patients with large body habitus will be problematic in this method. 2) The increased risk of failure in osteoporotic bone is another disadvantage of traditional pedicle screw fixation. It is quality of the trabecular bone in the vertebra that determines fixation quality of the pedicle screw. In biomechanical studies it is shown that pullout and toggle performance of pedicle screws obviously debases when bone quality decreased [6].

In 1976 and 1992, Roy-Camille et al described a vertical screw insertion trajectory that crossed the axis of the pedicle, which contacts a greater proportion of cortical bone at its endpoint than traditional insertion techniques [7]. Multiple authors have proposed alternative trajectory. In 2007, Sterba et al suggested, in a pedicle screw fatigue study, that a straight trajectory was more stable than the traditional convergent trajectory. This was later supported by İnceoğlu et al using screws placed by a similar trajectory in a fatigue study.[8]

Pedicle screws have become common and reliable instruments in treating a variety of spinal disorders. Pedicle screws offer multiple advantages, allowing superior correction of spinal deformities, and reduced rates of loss of fixation and non-union [9]. Consequently, it has been used in the treatment of fractures, tumors and degenerative disease.

The pedicle screws insertion pathway involves a transpedicular lateral to medial trajectory with the initial insertion point at the junction of the transverse process and lateral wall of the facet [10]. But still several related complications remain unresolved. Although navigation techniques are used, screw misplacement rates for pedicle fixation reportedly range from 21%–40% [11]. Loss of surgical construct stability and screw loosening may occur, particularly in patients with osteopenia or osteoporosis. Muscle dissection is another disadvantage.

CORTICAL BONE TRAJECTORY

A cortical bone trajectory (CBT) is a novel lumbar pedicle screw trajectory that was advocated by Santoni et al in 2009 [12]. In contrast with pedicle screws, CBT follows a mediolateral and caudocranial directed path through the pedicle and maximizes thread contact with the cortical bone surface, providing enhanced screw purchase. Traditional pedicle screw trajectory involves following the anatomical orientation and direction of the pedicle to engage trabecular bone. In an attempt to engage the cortical bone, the trajectory of the cortical screw is from caudal to cephalad within the sagittal plane and medial to lateral within the axial plane. This pathway not only seeks to minimize the engagement of trabecular bone within the pedicle and allow for greater holding strength, but also minimizes the risk of medial pedicle breach by following a lateralized trajectory [13].

In a recent review by Phan et al Biomechanical and Morphometric Evidence and Clinical Evidence at the end Advantages and Disadvantages and Limitations of Clinical Evidence Indications and Contraindications are explained [14]. Finally concludes that the recently introduced CBT/MLST for pedicle screws offers several advantages over traditional pedicle screws. Biomechanical studies have confirmed the advantages of the former, including

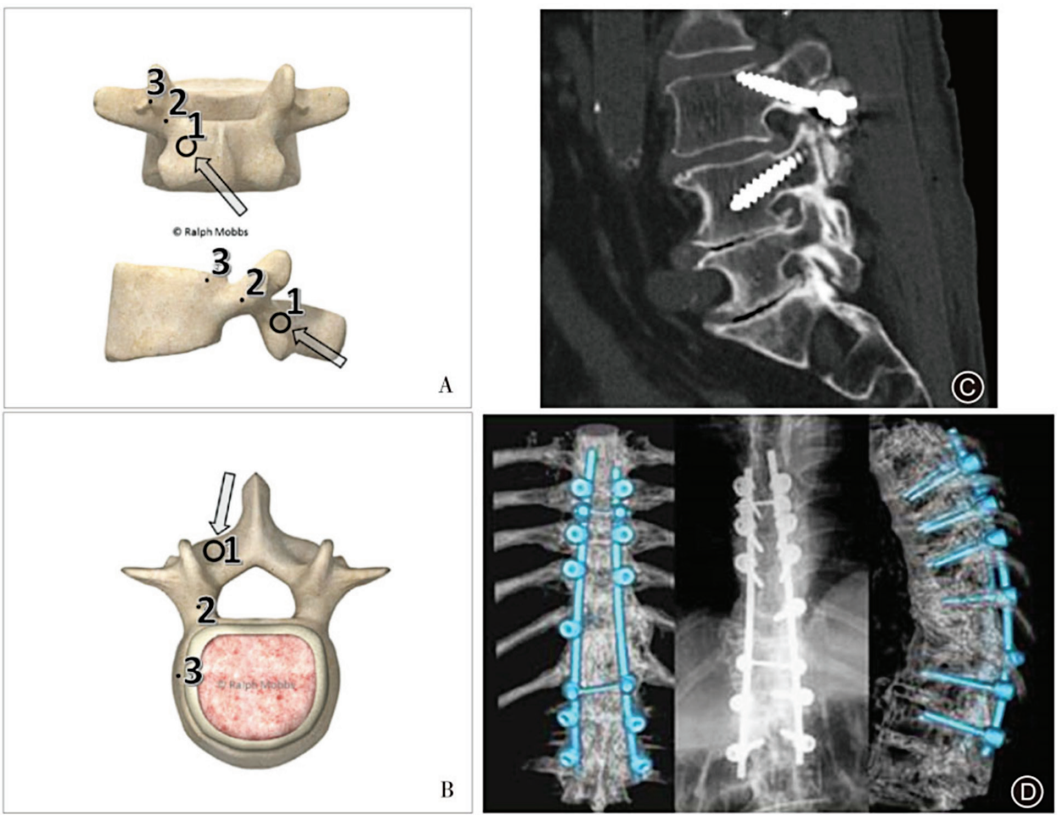

Figure 1. Medio-lateral superior trajectory (MLST) for cortical bone trajectory screws. (A) Model showing the starting point for the MLST technique (Point 1). Points 2 and 3 demonstrate the trajectories that the surgeon can use during lateral or anteroposterior radiography, respectively. (B) Model showing the axial trajectory for an MLST screw (arrow). The screw follows a medial to lateral path, thus avoiding lateral dissection of the paraspinal musculature. (C) Lateral radiograph showing the trajectory of an MLST screw in L3, starting at the pars with the screw angled towards the lateral aspect of the endplate. Note the L4 pedicle screw is angled in a superior-inferior direction, the opposite of the MLST screw [17]. (D) Three-dimensional CT demonstrating CBT/MLST screw insertion.

improved bone-screw purchase and stability that are at least comparable to those of traditional trajectories. However, there is still a lack of robust clinical data for CBT in lumbar surgery. Further clinical studies with long-term follow-up are required to investigate the long-term outcomes of CBT pedicle screws for stabilization in various lumbar spine pathologies. Biomechanical study of CBT revealed a 30% increase in uniaxial yield pullout load and equivalent characteristics of the screw-rod construct compared with the traditional trajectory [15]. Furthermore, screw insertion through a medial starting point avoids wide dissection of the superior facet joint and minimizing muscle dissection. Despite the increased use of CBT screws in the lumbar spine, little has been reported on the insertion technique for sacral CBT.

The CS fixation has been shown to provide stability to the spine comparable to the PS fixation in a single motion segment, but it is still not clear whether this finding would hold true in the case of a long segment fixation. More importantly, the question of how the CS would perform in the presence of significant instability still remains unanswered. In a study by Cheng and colleagues [15] these questions are studied. (Fig 1) They show that The CS construct provided stabilization to multilevel lumbar segment with multilevel low-grade spondylolisthesis comparable to the PS construct. The bone density did not seem to influence the quality of the stabilization. Fixation quality provided by both systems was influenced by the level of segmental instability to a similar degree. (Fig 2)

In some cases sacral CBT is investigated [16]. In this study, a novel sacral screw trajectory is introduced,

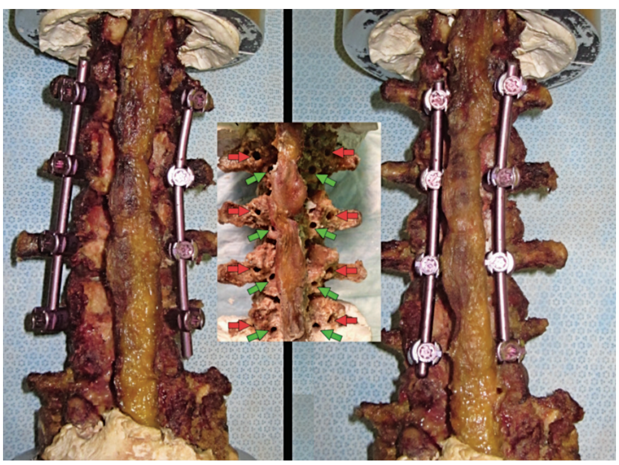

Figure 2. Each specimen was instrumented (L1-4) and tested with both standard and cortical trajectory pedicle screws. Due to the difference in screw start points and insertion trajectories, there was minimal interaction between the constructs.

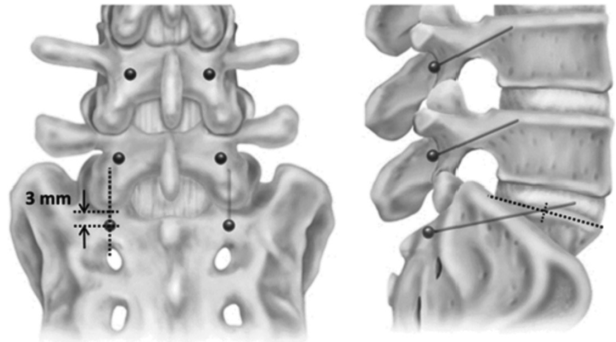

Figure 3. Schematic illustrations of the penetrating endplate screw. Left: The entrance point of the penetrating endplate screw that is in line with the lumbar CBT. Right: The direction of the PES toward the middle of the sacral endplate [18].

which maximizes engagement with denser bone by the screws penetrating the S-1 superior endplate through a more medial entry point than in the traditional trajectory. The penetrating S-1 endplate screw is directed straight forward at this anatomical region to obtain better bone quality contact and safety advantages with the protrusion of the screw tip into the inter-vertebral disc space.(Fig 3)

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