CORTICAL BONE TRAJECTORY IN POSTERIOR LUMBAR FIXATION

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ABSTRACT

Background: *CBT was proposed as a new trajectory that can improve the fixation of pedicle screws in response to screw loosening in osteoporotic patients. CBT involves a medial-to-lateral direction and a caudocephalad path aiming at maximizing thread contact with higher-density bone with a final aim of this track to improve the adhesion of the screws in osteoporotic vertebrae and to prevent instrumentation failure. However, some studies revealed contradictory findings concerning its effectiveness.*

Aim of the Work: *A systematic review discussing cortical bone trajectory in posterior lumber fixation.*

Methods: *This systematic review consisted of 4 steps, including a systematic search of the literature (Step 1), selection of studies (Step 2), recording of study characteristics (Step 3) and extraction of data on clinical outcomes (Step 4).*

Results: *Literature search and filtration yielded 22 studies (six retrospective reviews, seven prospective, two comparative with historical control group, five systematic reviews, two systematic reviews with meta-analysis).*

Conclusion: *Review of the enrolled studies confirmed that CBT is a safe, plausible alternative modality to the traditional pedicle screw in posterior lumbar fixation. The use of CBT was associated with some complications; yet their incidence was found to be lower, when compared with the traditional pedicle screw, in the majority of the included studies. However, these studies use different techniques, different screw length and diameter and outcome measures. That is why CBT is recommended as a safe alternative of traditional screw in posterior lumbar fixation and further studies using standardized protocols are needed to confirm findings of the current study.*

Keywords: *Posterior lumbar fixation, cortical bone trajectory, traditional pedicle screw fixation*

INTRODUCTION:

Pedicle screw fixation has been the mainstay technique for lumbar spine stabilization for several decades, its superior biomechanical strength and properties surpassing alternative forms of fixation[(1)].

Pedicle screw fixation offers multiple advantages, allowing superior correction of spinal deformities, and reduced rates of loss of fixation and non-union Therefore, this technique has been used in the treatment of a number of lumbar disorders such as deformities, fractures, tumors and degenerative disease and so on[(2)].

The traditional insertion pathway for pedicle screws involves atranspedicular lateral

to medial trajectory with the initial insertion point at the junction of the transverse process and lateral wall of the facet joint [3].

Several complications are associated with traditional pedicle screw fixation. Screw misplacement rates for pedicle fixation reportedly range from 21%–40% despite the use of navigation techniques [4]. Screw loosening and loss of surgical construct stability may occur Particularly in patients with osteopenia or osteoporosis [5].

Additional draw backs include the significant muscle dissection required for pedicle screw insertion because of its lateral to medial trajectory [6], and increased risk of neuro-vascular injury documented by multiple reports of incorrect placement of pedicle screw[7].

Over recent years, there have been a number of developments in screw design and implantation techniques, including a proposal for an alternative trajectory for screw fixation aimed at increasing purchase of the pedicle screw in higher density bone. The first one to report the cortical bone trajectory (CBT), in which screws follow a lateral path in the axial plane and caudocephalad path in the sagittal plane. In contrast to conventional pedicle screw fixation, CBT screws do not penetrate the vertebral body trabecular space [8].

AIM OF THE WORK:

A systematic review discussing cortical bone trajectory in posterior lumber fixation.

METHODS

This systematic review consisted of 4 steps, including a systematic search of the literature (Step 1), selection of studies (Step 2), recording of study characteristics (Step 3) and extraction of data on clinical outcomes (Step 4).

Step 1: Data sources and search strategy: The literature search was performed according to PRIMSA guidelines using the following electronic databases: The Cochrane database of systematic reviews, the Cochrane central register of controlled trials, PubMed and MEDLINE as database for search. The search strategy included several different terms and synonyms for: posterior lumbar fixation, cortical bone trajectory, traditional pedicle screw fixation.

Step 2: Selection of studies and screening of titles and abstracts: First, all titles and abstracts were screened for the following criteria:

Article concerned: prospective rando-mizes trials as well as both prospective and retrospective cohort studies.

Inclusion criteria: Clinical studies reporting cortical bone trajectory in posterior lumber fixation. Studies published at any time and up to date. English literature.

Exclusion criteria: Case reports, comments, letters, guidelines, protocols, abstracts and review papers. Studies with unclear reporting of methods or results. Animal and cadaveric studies.

Step 3: Study characteristics: The follow-ing study characteristics were systematically extracted from the selected full-text papers: authors, year of publication, study design, mean age and duration of the follow-up, pathological indications, outcomes and reported complications.

Step 4: Outcomes of the included studies: Outcomes of CBT as well as reported complications were systematically extracted from the selected full-text papers. The initial literature search identified 74 articles which were assessed for possible inclusion. 1st screening of titles and abstracts excluding duplicates and articles not in English language is done. 32 articles were identified for 2nd screening. 2nd screening of the full articles for study characteristics meeting the inclusion criteria is done and 22 articles were included. A schematic representation of literature extraction process is shown in (Diagram. 1).

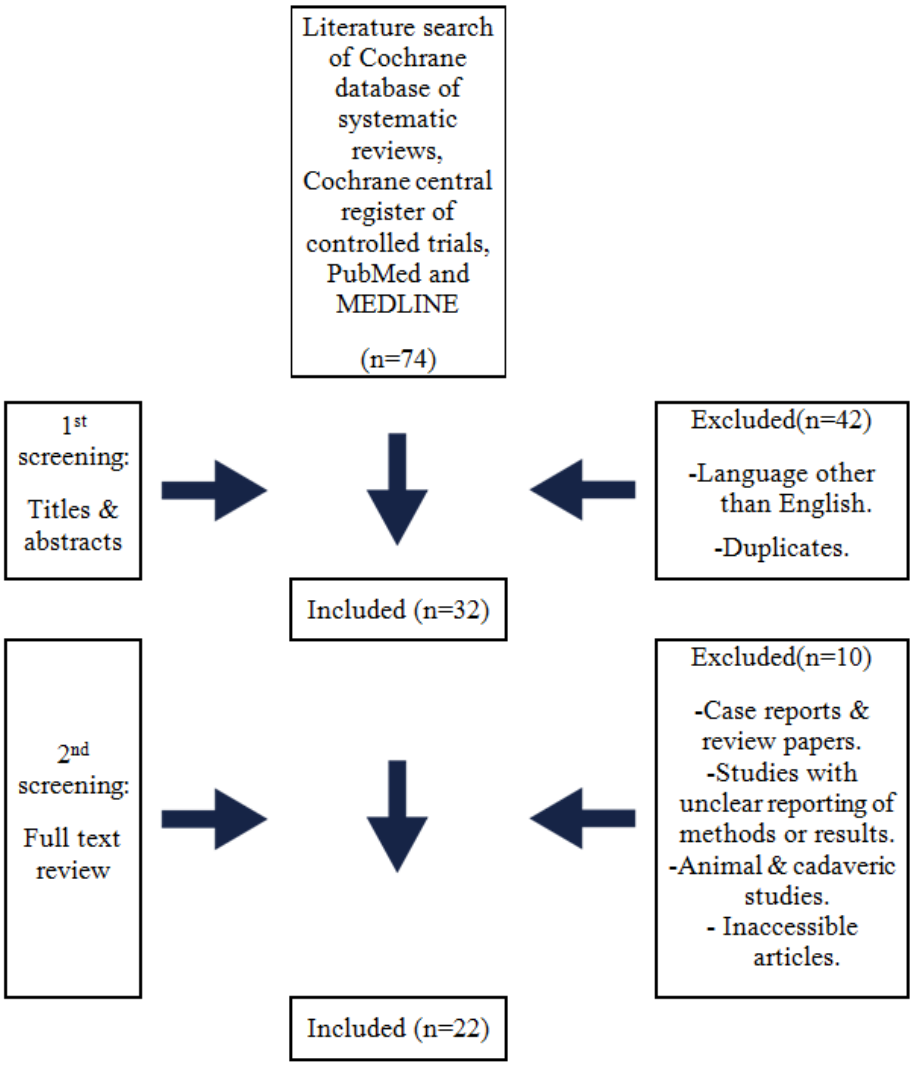

Diagram (1): Flowchart of study design

RESULTS:

Twenty two studies were included in our final analysis. Table (1) shows the summary of the design of the included studies, while the baseline characteristics of these studies are illustrated in Table (2). Table (3) shows the pathological conditions in which CBT was assessed in the included studies. The outcomes of the included studies are illustrated in table (4) and the reported complications are shown in table (5).

Table (1): Summary of study design of included studies

Authors	Year	Journal	Study design
Mizuno et al.[9]	2014	Neurologia Medico Chirurgica (Tokyo)	Retrospective review
Rodriguez et al.[10]	2014	Neurosurgical Focus	Retrospective review
Glennie et al.[11]	2015	Journal of Clinical Neuroscience	Retrospective review
Kojima et al.[12]	2015	Acta Neurochirurgica	Prospective comparative
Matsukawa et al.[13]	2015	Spine	Prospective
Phan et al.[14]	2015	Orthopedic Surgery	Systematic review
Ninomiya et al.[15]	2016	Asian Spine Journal	Prospective comparative
Sakaura et al.[16]	2016	Journal of Neurosurgery: Spine	Comparative with historical control group
Snyder et al.[17]	2016	World Neurosurgery	Retrospective review
Delgado-Fernandez et al.[18]	2017	Asian Spine Journal	Systematic review
Keorochana et al.[19]	2017	World Neurosurgery	Systematic review and meta-analysis
Phan et al.[20]	2017	Journal of Spine Surgery	Systematic review
Asamoto et al.[21]	2018	Journal of Neurological Surgery Part A: Central European Neurosurgery	Prospective
Gonchar et al.[22]	2018	Clinics in Surgery	Prospective comparative
Marengo et al.[23]	2018	BioMed Research International	Prospective comparative
Sakaura et al.[24]	2018	Journal of Neurosurgery: Spine	Comparative with historical control group
Wochna et al.[25]	2018	Cureus	Retrospective review
Cofano et al.[26]	2019	World Neurosurgery	Systematic review
Hoffman et al.[27]	2019	International Journal of Spine Surgery	Retrospective review
Karki et al.[28]	2019	Open Journal of Orthopedics	Systematic review
Zhang et al.[29]	2019	Journal of Orthopedic Surgery and Research	Systematic review and meta-analysis
Zhang et al.[30]	2019	Journal of Orthopedic Surgery and Research	Prospective comparative

Table (2): Baseline characteristics of included studies

Authors	Mean age of patients (years)	Period of follow up (months)
Mizuno et al.[9]	68.3 (R:47-80)	15 (R:3-26)
Rodriguez et al.[10]	69.4 (R:58-82)	12.2 (R:10-15)
Glennie et al.[11]	66.9 (R:40-87)	16.4
Kojima et al.[12]	66 (R:16-89)	NR
Matsukawa et al.[13]	63.9±14.8 (R:24-88)	NR
Ninomiya et al.[15]	62.2±2.5 in CBT group, 61.4±2.6 in traditional pedicle screw group	12
Sakaura et al.[16]	68.7±9.5 in CBT group, 67.0±8.7 in traditional pedicle screw group	35.4±6.8 in CBT group, 40.2±10.4 in traditional pedicle screw group
Snyder et al.[17]	NR	13.2±7.9 (R:3-41)
Asamoto et al.[21]	66.3 (R:21-89)	30.5 (R:12-60)
Gonchar et al.[22]	69±11 in CBT group, 66±17 in traditional pedicle screw group	24
Marengo et al.[23]	45.75±9.63 in CBT group, 54±12.01 in traditional pedicle screw group	12
Sakaura et al.[24]	70.7±7.3 in CBT group, 68.3±9.6 in traditional pedicle screw group	39.4±7.8 in CBT group, 35.4±11.4 in traditional pedicle screw group
Wochna et al.[25]	46.5±15.13 in CBT group, 49.24±17.54 in traditional pedicle screw group	NR
Hoffman et al.[27]	48.5±13.4 in CBT group, 53.4±10.85 in traditional pedicle screw group	52.5 (R:8-74)

Table (3): Pathological indications for CBT in patients in the included studies

Authors	Indications
Mizuno et al.[9]	Single level lumbar spondylolisthesis
Rodriguez et al. [10]	ASD with: adjacent level stenosis, disc space collapse, spondylolisthesis
Glennie et al.[11]	Degenerative lumbar spine diseases
Kojima et al.[12]	Degenerative lumbar spine diseases
Matsukawa et al.[13]	Degenerative spondylolisthesis, Degenerative discopathy, lumbar segmental instability with spinal stenosis, Degenerative scoliosis
Ninomiya et al.[15]	Degenerative lumbar spondylolisthesis
Sakaura et al.[16]	Degenerative lumbar spondylolisthesis
Snyder et al.[17]	Degenerative lumbar disease
Asamoto et al.[21]	Lumbar spondylolisthesis
Gonchar et al.[22]	Degenerative spondylolisthesis, adult deformity, foraminal stenosis, lumbar canal stenosis, isthmic spondylolisthesis, osteoporotic vertebral body collapse, trauma, discitis
Marengo et al.[23]	Foraminal stenosis, isthmic spondylolisthesis, degenerative spondylolisthesis, recurrent disc herniation
Sakaura et al.[24]	Degenerative lumbar spondylolisthesis
Wochna et al.[25]	Unstable traumatic thoracolumbar fractures

Table (4): Reported outcomes of CBT in patients in the included studies

Authors	**Outcomes**
Mizuno et al.**[9]**	Postoperative JOA score 23.1 points (R:18-29 points), Recovery rate 66.1% (R:39-100%)
Rodriguez et al. **[10]**	Improved symptoms (100%), Complete resolution of pre-operative symptoms (40%),
Glennie et al.**[11]**	Revision at 12 months post-operative (25%), Overall satisfaction with procedure (62.5%)
Kojima et al.**[12]**	Significantly "four-times" higher CT number (Hounsfield scale) compared with traditional trajectory
Ninomiya et al.**[15]**	Percent slippage decreased from 11.1% "pre-operative" to 3.2% at 1 year post-operative.
Sakaura et al.**[16]**	Compared with traditional screw: significantly higher improvement in JOA score, significantly lower ASD, non-statistically significant lower successful fusion rate
Keorochana et al.**[19]**	Compared with traditional screw: significantly lower incidence of complications, non-statistically significant different outcomes for pain VAS score (back and leg), disabilities score, JOA, intra-operative complications and fusion rates.
Phan et al**[20]**	Compared with traditional screw: greater bone density, but no difference in slippage at one year
Asamoto et al.**[21]**	Significant improvement in JOA and VAS scores (100%), Bone fusion (89.1%)
Gonchar et al.**[22]**	Fusion rate (99%), Compared with traditional screw: non-statistically significant higher improvement in JOA and VAS scores
Marengo et al.**[23]**	Compared with traditional screw: Significantly shorter length of stay and less blood loss, significantly lower post-operative VAS and ODI scores, non-statistically significant higher fusion rate
Sakaura et al.**[24]**	Compared with traditional screw: Significantly shorter operative duration and non-statistically significant less intra-operative blood loss, higher recovery rate, less solid bony union, lower incidence of symptomatic ASD
Wochna et al.**[25]**	Compared with pedicle screw: Significantly more intra-operative blood loss and non-statistically significant shorter operative time and length of stay
Hoffman et al.**[27]**	Compared with traditional screw: Significantly less intra-operative blood loss, shorter length of stay and non-statistically significant shorter operative time
Karki et al.**[28]**	Compared with traditional screw, CBT has similar clinical outcome based on pain intensity, ODI status and JOA score as well as similar fusion rate and radiological evaluated complications
Zhang et al.**[29]**	Compared with traditional screw: Significantly shorter operative duration and length of stay, less intra-operative blood loss, less incidence of complications, less incidence of ASD and ODI index
Zhang et al.**[30]**	Compared with traditional screw: Significantly higher bone mineral density

Table (5): Reported overall rate of complications with CBT

Authors	Reported complications (Incidence rate)
Mizuno et al.[9]	Intra-operative cortical bone fracture at screw compression (8.3%)
Rodriguez et al. [10]	No complications
Glennie et al.[11]	Loss of reduction (50%), Screw loosening (37.5%)
Ninomiya et al.[15]	Spacer backout (9.1%)
Sakaura et al.[16]	Symptomatic ASD with need for additional reoperation (3.2%), Dural laceration (2.1%), Misplacement of pedicle screw (2.1%), Superficial wound infection (2.1%), Symptomatic hematoma (1.1%)
Snyder et al.[17]	Thrombosis (3.8%), Hardware failure (2.5%), Pseudoarthrosis (2.5%), Deep wound infection requiring surgical debridement (1.3%), epidural hematoma (1.3%),
Gonchar et al.[22]	Screw breakage (1.3%), Screw loosening (0.6%), Pseudoarthrosis (0.6%)
Sakaura et al.[24]	ASD (9.1%), Dural laceration (4.5%), Delayed wound healing (4.5%)
Wochna et al.[25]	No complications
Hoffman et al.[27]	Hardware failure (8.7%), Screw loosening (8.7%), CSF leak

DISCUSSION:

Alternative cortical trajectories for pedicle fixation in lumbar fusion have been proposed in clinical practice for over a decade, CBT was proposed by *Santoni in 2009* as a new trajectory that can improve the fixation of pedicle screws in response to screw loosening in osteoporotic patients. The traditional insertional pathway runs through the pedicle axis with a lateral-to-medial trajectory starting at the junction between the transverse process and the lateral wall of the facet and ending at the vertebral body. On the other hand, CBT involves a medial-to-lateral direction and a caudo-cephalad path aiming at maximizing thread contact with higher-density bone. The aims of this track are to improve the adhesion of the screws in osteoporotic vertebrae and to prevent instrumentation failure [8].

This systematic review was conducted aiming to discuss cortical bone trajectory in posterior lumber fixation.

Literature search and filtration yielded 22 studies (six retrospective reviews, seven prospective, two comparative with historical control group, five systematic reviews, two systematic reviews with meta-analysis).

The included studies evaluated the use of CBT in a variety of indications (degenerative lumber spondylolisthesis, spinal deformity, degenerative discopathy, foraminal stenosis, lumber canal stenosis, unstable traumatic thoracolumber fracture) and patients were followed up for periods ranging from 12 up to 74 months.

The current review revealed that CBT was associated with improved symptoms [15, 10, 9, 21], an acceptable recovery rate [9] and bone fusion [21, 22].

CBT was proven to be superior to the traditional screw as regards less intra-operative blood loss [23,27,29], shorter operative duration [24,29], shorter length of stay [23,27,29], higher bone density [20, 12, 30], higher improvement in JOA score[16], lower incidence of ASD [16, 29] and overall lower incidence of complications[19, 29].

On the other hand, non-statistically significant differences, yet showing better results with CBT, were reported in a number of studies [16, 19, 23, 24, 27, 28]. Meanwhile, CBT was associated with significantly more intra-operative blood loss, compared with the traditional screw, in only one study [25].

And the overall reported incidence of complications following CBT in the studies included in the current review revealed some manageable complications, supporting the safety of its use.

These findings indicate that CBT is a safe, plausible alternative modality to the traditional pedicle screw in posterior lumbar fixation.

There were several limitations in this study. First, some of the included studies were retrospectively designed or with historically control groups, which may have selection bias. Second, study disparities and limitations in size, different designs with different follow-up periods, different techniques, different screw length and diameter and outcome measures, contribute significant bias. And finally, the different follow-up periods, particularly for patients with short-term follow up, may underestimate the incidence of complications.

Conclusion:

Review of the enrolled studies confirmed that CBT is a safe, plausible alternative modality to the traditional pedicle screw in posterior lumbar fixation. The use of CBT was associated with some complications; yet their incidence was found to be lower, when compared with the traditional pedicle screw, in the majority of the included studies. However, these studies use different techniques, different screw length and diameter and outcome measures. That is why CBT is recommended as a safe alternative of traditional screw in posterior lumbar fixation and further studies using standardized protocols are needed to confirm findings of the current study.

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المسار العنقي الفقاري القشري في عمليات التثبيت الخلفي بين الفقرات القطنية

الخلفية: لقد تم إستحداث المسارالعنقي الفقاري القشرى كمسار جديد يمكن أن يؤدى إلى تحسين اتجاه المسامير التقليدية لعنق الفقرة لمواجهة تخلخل المسامير فى مرضى هشاشة العظام. و يتضمن تركيب المسمار القشرى الإتجاه العنقى الفقارى إتخاذ إتجاه أنسى-إلى-جانبى و مسار فى إتجاه الرأس بهدف تعظيم ملامسة الخيط مع العظام الأعلى كثافةً بغرض تحسين إلتصاق المسامير فى الفقرات التى تعانى من هشاشة العظام و منع فشل الإجراء. و على الرغم من ذلك ؛ فقد أظهرت بعض الدراسات نتائج متعارضة فيما يتعلق بمدى كفاءته.

الهدف من البحث: مناقشة المسار العنقي الفقاري القشري في عمليات التثبيت الخلفي بين الفقرات القطنية.

الطرق: و لقد نتج عن البحث فى الدراسات السابقة إدراج ٢٢ دراسة بحثية بخصوص تأثيره.

و لقد أظهرت هذه الدراسة أن إستخدامه يعد بديلًا آمنًا و معقولًا للمسمار التقليدى فى الحالات التى تستدعىالتثبيت الخلفي للفقرات القطنية. كما أظهرت الدراسة بعض المضاعفات التى صاحبت إستخدامه ؛ إلا أن معدلات حدوث هذه المضاعفات كانت أقل عند مقارنتها بإستخدام المسار التقليدى و ذلك فى أغلبية الدراسات البحثية التى شملتها الدراسة.

النتائج: غير أن الدراسات البحثية التى شملتها هذه الدراسة إعتمدت على إستخدام تقنيات مختلفة و مسامير ذات أطوال و أقطار مختلفة و كانت لها مخرجات مختلفة.

الخلاصة: و بناءً على ذلك ، فقد خلصت هذه الدراسة بعد مراجعة الدراسات البحثية المدرجة عن التوصية بإستخدام المسارالعنقي الفقاري القشرى كبديل آمن للمسار التقليدى فى تثبيت الفقرات القطنية. كما أوصت هذه الدراسة بإجراء المزيد من الدراسات البحثية بإستخدام بروتوكولات موحدة بهدف التحقق من نتائج هذه الدراسة.