Cervical pedicle screw guiding jig, an innovative solution

Abhishek Kashyap^a, Shreesh Kadur^{b,*}, Abhishek Mishra^b, Gaurang Agarwal^b,
Abhay Meena^b, Lalit Maini^a

^a Department of Orthopaedics, Maulana Azad Medical College and Lok Nayak Hospital, New Delhi, India

^b Maulana Azad Medical College and Lok Nayak Hospital, New Delhi, India

ARTICLE INFO

Article history:

Received 9 June 2018

Accepted 14 July 2018

Available online 17 July 2018

Keywords:

Pedicle screw

Cervical spine

3d printing

Jig

ABSTRACT

Pedicle screws are one the commonest used modality in spinal instrumentation. However, the method of pedicle screw fixation in cervical spine as compared to thoracic and lumbar spine is still technically demanding because it carries the risk of catastrophic damage to the surrounding neurovascular structures. We have utilized virtual planning and 3D (3-dimension) printing to develop a patient specific jig to guide the accurate placement of pedicle screws. A patient with bifacetal dislocation C7 over D1 classified as flexion-distraction injury type 3 who was planned for decompression and fusion by posterior instrumentation at C6, C7, D1 and D2 was selected. A CT scan with 1 mm cuts was used to produce DICOM images of the same. Using these DICOM images virtual planning was done on MIMICS and 3 MATICS software to create patient specific jigs. These jigs were then 3D printed using a 3D printer and used for accurate placement of pedicle screws intra-operatively after adequate sterilization. Our procedure is low cost but high technology based. It is simple, accurate, and very cost effective. The technology transfer is very easy and can be adopted easily.

© 2018

1. Introduction

Pedicle screws are one the commonest used modality in spinal instrumentation. However, the application of pedicle screws in cervical spine is limited as compared to thoracic and lumbar spine because of and small pedicle size and close proximity to the surrounding structures. Most surgeons use lateral mass screws and anterior instrumentation frequently due to better safety and shorter learning curve. The pedicle screw fixation technique in cervical spine offers biomechanical advantages over lateral mass screw technique because of its firm hold along the three columns of the spine.^{1,2}

We have utilized virtual planning and 3D (3-dimension) printing to develop a patient specific jig to guide the accurate placement of pedicle screws.

2. Case history

A 45 year old male with fall of heavy object presented 2 days after the injury. Patient had complete quadriplegia with bowel bladder involvement graded as ASIA-A (American Spine Injury Association).³ The radiological work up of the patient included X-rays, CT (computed tomography) scan (Fig. 1) with 1 mm cuts and MRI (Magnetic Resonance Imaging). Diagnosis of bifacetal dislocation C7 over D1 classified as flexion-distraction injury type 3 was made. Patient was planned for decompression and fusion by posterior instrumentation at C6, C7, D1 and D2 was made.

3. Surgical jig development and its application

3.1. Jig development

The virtual planning was done using CT scan with 1 mm cuts to produce Digital Imaging and Communications in Medicine (DICOM) images. DICOM images were imported to MIMICS software ver17 and 3D reconstruction of the desired surgical area was created.

The 3d model of the cervical spine was exported as .stl (stereolithography) file and transferred into 3 MATICS ver13. software. The guiding cylinders trajectory of pedicle screw at the desired level was placed virtually with the 3D model (Fig. 2). Cylinders

* Corresponding author. #52, flat no: 202, Saathwik Residency, Ramanjaneya Nagar, Chikkalsandra, Banagalore, 560061, India.

E-mail addresses: kashyap.dr@gmail.com (A. Kashyap), shreesh90@gmail.com (S. Kadur), mishra.abhishek85@gmail.com (A. Mishra), gaurang140389@gmail.com (G. Agarwal), abhijnvk@gmail.com (A. Meena), lalit_maini@rediffmail.com (L. Maini).

Fig. 1. 3D RECON and sagittal view of CT scan with arrows showing bifacetal dislocation of C7 over D1.

were made hollow to pass k-wires. The model and the screws were evaluated by Slicing and Transparency tool for assessing the pedicle breach. The posterior surface of lamina and lateral mass were marked to create a surface over which a structure was built. The right and left jigs were then connected by a bridge (Fig. 2). Similar

jig was created for C7 level also. Jigs and the spine model of the patient were 3D printed as FDM. Jigs were tested again with the guiding wires (Fig. 3). All of the guide wires were found appropriate. The printed jigs were sterilized using ETO (ethylene trioxide).

Fig. 2. Showing guiding cylinders for pedicle screw trajectory, anticipated jig model placed over posterior elements of the spine and the 3d model of the jig.

Fig. 3. Showing jigs being tested with guide wires.

3.2. Surgical technique

Posterior midline incision was used and exposure was done up to the lateral masses bilaterally.⁴ Surgical jig was placed over the corresponding vertebra (Fig. 4). One mm k-wire was drilled into pedicle and body. The jig was then removed and cannulated drills were drilled over the kirschner-wires. The pedicle screws of appropriate sizes which were determined using CT scan were inserted. The pedicle screws of D1 and D2 were inserted using freehand technique. Decompression was done at C7-D1 level and reduction was achieved. This was followed by placement of connecting rods and inter transverse fusion using auto graft. Surgical wound was closed in layers over a suction drain. Post operatively CT scan was done to assess the accuracy of the pedicle screw insertion (Figs. 5–7).⁵

4. Discussion

Pedicle screw fixation of the cervical spine offers biomechanical advantages over lateral mass fixation techniques. Studies have shown that pedicle screws have superior initial strength when compared with lateral mass screws after a plain axial pullout.⁶ Construct stability using cervical pedicle screws was assessed in a bovine three-column injury model and found to be superior.⁷ It was

Fig. 4. Intra-operative placement of jigs over the corresponding vertebra.

Fig. 5. Post-operative axial CT image showing type 0 breach in C6 vertebra.

Fig. 6. Post-operative axial CT image showing type 0 breach in C7 vertebra.

Fig. 7. Post-operative sagittal CT image showing pedicle screw in C6 and C7.

also found that the incidence of screw loosening and loss of reduction was higher with lateral mass screws over pedicle screws.^{8,9} However, the method of cervical pedicle screw fixation is still technically demanding because it carries the risk of catastrophic damage to the surrounding neurovascular structures.^{1,2} Various methods have been explored for precise pedicle screw placement. These methods can be broadly grouped as follows: (1) techniques relying on morphometric measurements (anatomical landmarks and averaged angular dimensions), (2) fluoroscopic-guided techniques (3) computerized image guided screws and (4) techniques that use patient specific templates.^{10–14} Due to anatomic variabilities free hand technique is highly inaccurate. Fluoroscopy-guided insertion for pedicle screw fixation has been the gold standard for safe and accurate placement. However, it has the disadvantages of radiation exposure and limited maneuverability for the surgeon because of the space occupied by the image intensifier.

The latest trends in patient specific templates have facilitated accurate pedicle screw fixation particularly for the cervical spine because of recent advances in stereolithography or 3D printing.¹⁴ The development of free-ware DICOM software readers allows creation of 3D-rendered images from CT and magnetic resonance imaging (MRI) and convert them to “.stl” files. By exporting these “.stl” files to commercially available office desktop 3D printers, we can now create a 3D model of a patient's spine using rapid prototyping techniques. These 3D models offer higher precision because they are tailored to the specific characteristics of the anatomy of an individual. Design of the surgical guides can also be modified according to the surgeon's needs and have eliminated the need for expensive equipment and time-consuming intra-operative registration and calibration.

Our procedure is low cost but high technology based. It is simple, accurate, and very cost effective. The technology transfer is very easy and can be adopted easily. We have not incurred any difficulties in the initial two cases with the 3D jig.

5. Conclusion

3-D printing is a cost effective and accurate modality for cervical pedicle screw insertion.

Acknowledgements

Advice and technical support: Prof. Sunil Jha, Associate

Professor, Department of Mechanical Engineering, IIT Delhi.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jcot.2018.07.010>.

References

1. Panjabi MM, Shin EK, Chen NC, Wang JL. Internal morphology of human cervical pedicles. *Spine*. 2000 May 15;25(10):1197–1205.
2. Ebraheim NA, Xu R, Knight T, Yeasting RA. Morphometric evaluation of lower cervical pedicle and its projection. *Spine*. 1997 Jan 1;22(1):1–5.
3. Anon. *International Standards for Neurological Classification of Spinal Injury*. Atlanta, GA: American Spine Injury Association; 2008.
4. Hoppenfield S, Boer PD, Buckley R. *Surgical Exposures in Orthopaedics: the Anatomic Approach*. fifth ed. New York, NY: Lippincott Williams and Wilkins; 2017:715–738 (chapter 6).
5. Raley DA, Mobbs RJ. Retrospective computed tomography scan analysis of percutaneously inserted pedicle screws for posterior transpedicular stabilization of the thoracic and lumbar spine: accuracy and complication rates. *Spine*. 2012 May 20;37(12):1092–1100.
6. Kowalski JM, Ludwig SC, Hutton WC, Heller JG. Cervical pedicle screws: a biomechanical comparison of two insertion techniques. *Spine*. 2000;25:2865–2867.
7. Kotani Y, Cunningham BW, Abumi K, McAfee PC. Biomechanical analysis of cervical stabilization systems: an assessment of transpedicular screw fixation in the cervical spine. *Spine*. 1994;19:2529–2539.
8. Heller JG, Estes BT, Zaouali M, Diop A. Biomechanical study of screws in the lateral masses: variables affecting pull-out resistance. *J Bone Joint Surg Am*. 1996;78:1315–1321.
9. Yoshimoto H, Sato S, Hyakumachi T, Yanagibashi Y, Masuda T. Spinal reconstruction using a cervical pedicle screw system. *Clin Orthop*. 2005;431:111–119.
10. Abumi K, Itoh H, Taneichi H, Kaneda K. Transpedicular screw fixation for traumatic lesions of the middle and lower cervical spine: description of the techniques and preliminary report. *J Spinal Disord*. 1994 Feb 1;7(1):19–28.
11. Ludwig SC, Kramer DL, Balderston RA, Vaccaro AR, Foley KF, Albert TJ. Placement of pedicle screws in the human cadaveric cervical spine: comparative accuracy of three techniques. *Spine*. 2000 Jul 1;25(13):1655–1667.
12. Richter M, Cakir B, Schmidt R. Cervical pedicle screws: conventional versus computer-assisted placement of cannulated screws. *Spine*. 2005 Oct 15;30(20):2280–2287.
13. Fu M, Lin L, Kong X, et al. Construction and accuracy assessment of patient-specific biocompatible drill template for cervical anterior transpedicular screw (ATPS) insertion: an in vitro study. *PLoS One*. 2013 Jan 10;8(1):e53580.
14. Paiva WS, Amorim R, Bezerra DA, Masini M. Application of the stereolithography technique in complex spine surgery. *Arquivos de neuro-psiquiatria*. 2007 Jun;65(2B):4.