

Technique and Application of Atlas Internal Fixation

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Abstract

The developmental history of the internal fixation screw and the different methods of atlantoaxial fixation were briefly introduced in this chapter. Furthermore, the anatomy of the atlas and the corresponding measurement parameters were introduced. The different screw entry points and surgical techniques of C1 lateral mass screws were introduced in detail, and the VERTEX internal fixations were introduced in two cases. Finally, the precautions in the process of C1 lateral mass screw placement are summarized.

Keywords

Atlas · Atlas internal fixation · C1 lateral mass screw · Screw entry points · Atlantoaxial fusion

1.1 Atlas Internal Fixation: A Historical Perspective

Atlas fixation technique was developed to meet the needs of reconstruction of atlantoaxial stability. It has undergone the development of the wire technique, the laminoplasty technique, and the lateral mass technique. Milestones in the development of atlas fixation techniques include Gallie technique [1] (Fig. 1.1); Brooks-Jenkins technique [2] (Fig. 1.2); Dickman method [3], also called Sonntag technique (Fig. 1.3); Halifax technique [4] (Fig. 1.4); Jeanneret and Magerl technique [5] (Fig. 1.5); Goel technique by Goel and Laher [6] (Fig. 1.6); Harms and Melcher technique [7] (Fig. 1.7); and Tan's technique [8] (Fig. 1.8).

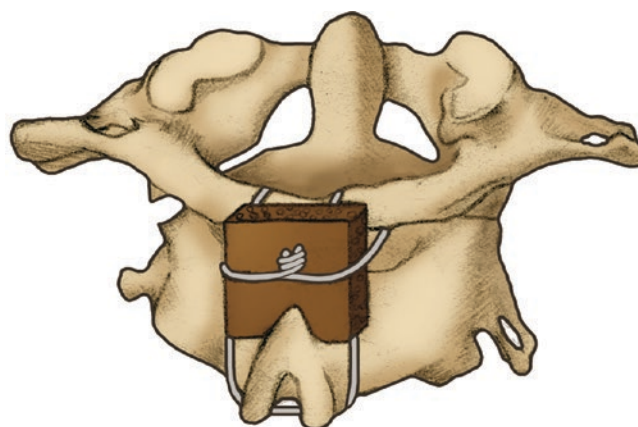


Fig. 1.1 Gallie technique for atlantoaxial fusion

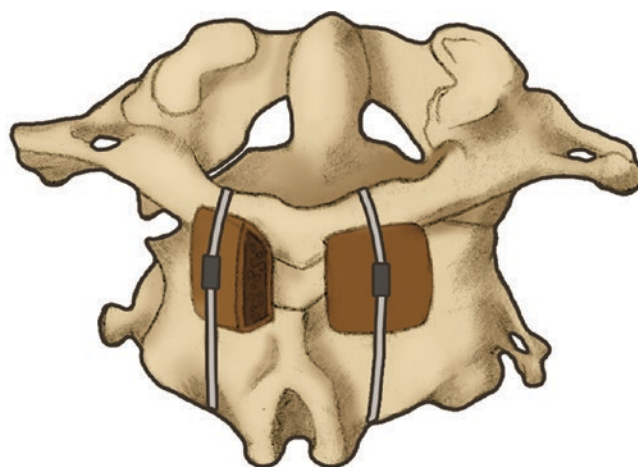


Fig. 1.2 Brooks-Jenkins technique for atlantoaxial fusion

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Fig. 1.3 Sonntag technique for atlantoaxial fusion

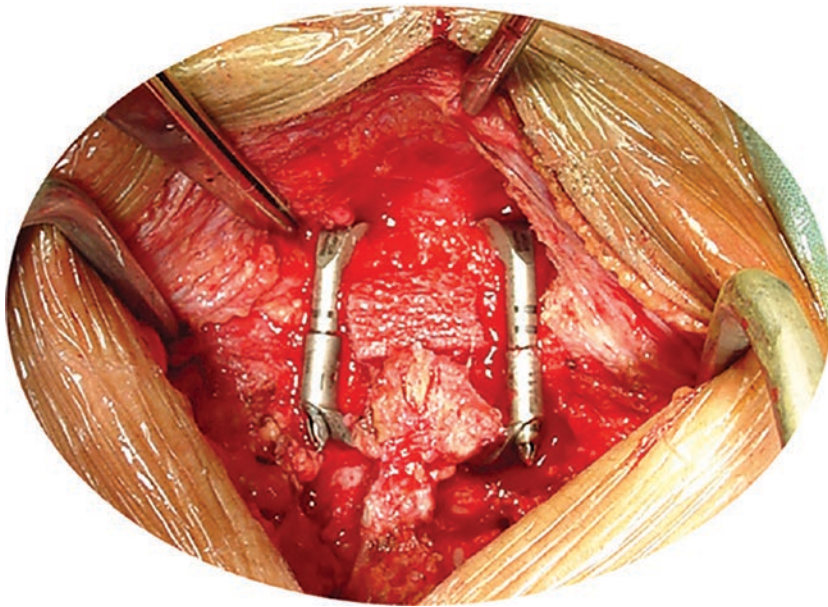
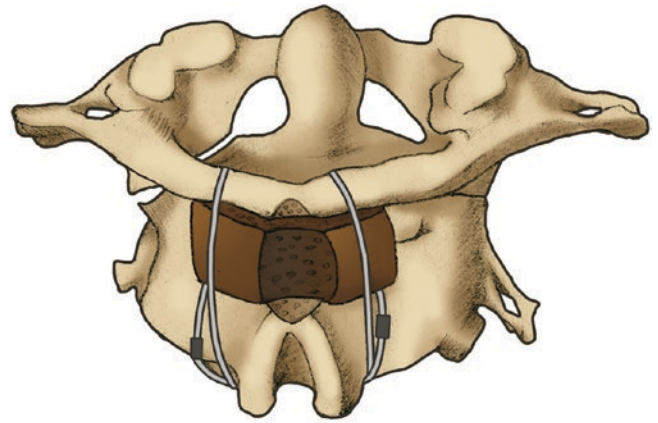


Fig. 1.4 Halifax technique for atlantoaxial fusion

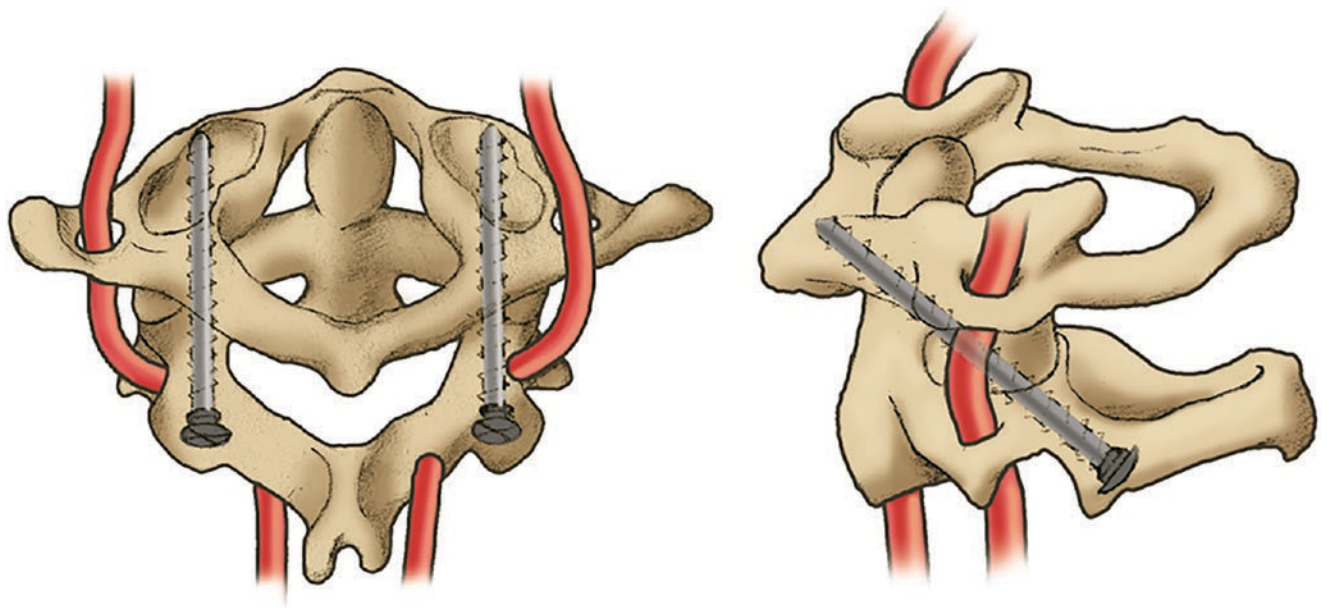


Fig. 1.5 Magerl's transarticular screw technique for atlantoaxial fusion. (Left) Posterior view. (Right) Lateral view

1.2 Atlas Anatomy

The atlas consists of an anterior and posterior arch connected by two lateral articular masses, forming a ring that pivots about the odontoid process. It lacks a vertebral body.

1. Measurement of the transverse section (Fig. 1.9)
2. The anterior view of C1 (Fig. 1.10)
3. The posterior view of C1 (Fig. 1.11)
4. The lateral view of C1 (Fig. 1.12)
5. The sectional view of screw entry site in the lateral mass

Screw entry site via the posterior arch lateral mass (Figs. 1.13, 1.14, and 1.15):

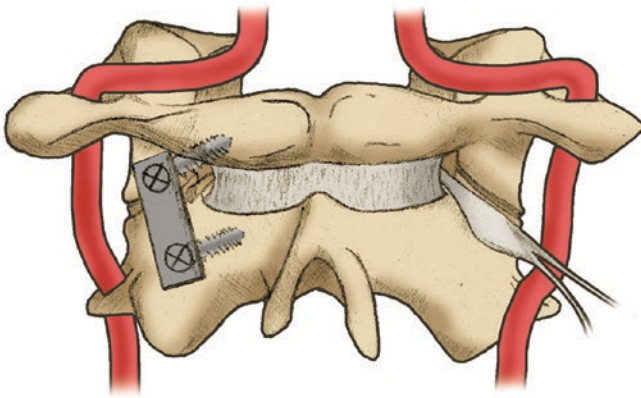


Fig. 1.6 Goel technique for atlantoaxial fusion

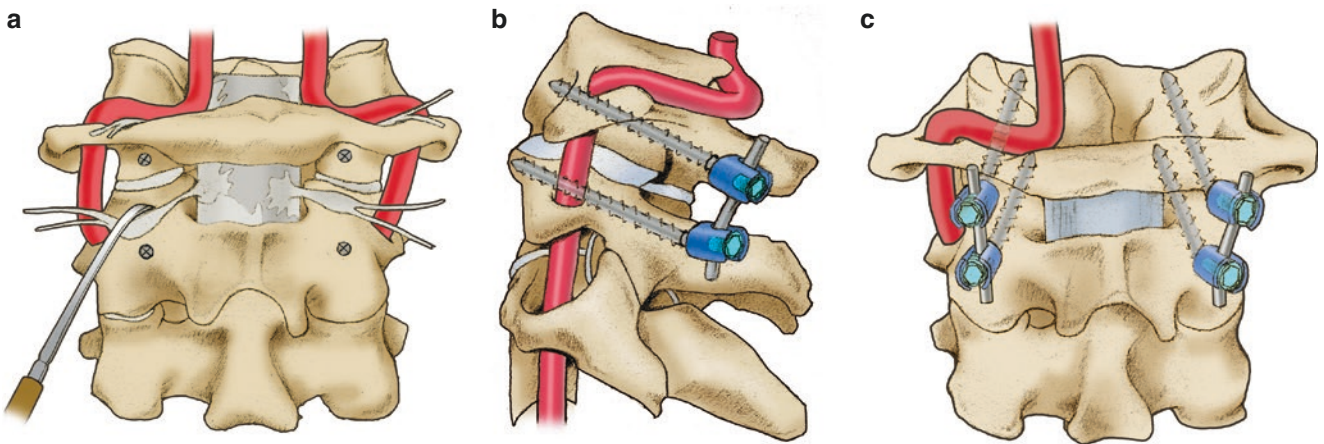


Fig. 1.7 Harms and Melcher technique for atlantoaxial fusion. (a) Posterior view of the upper cervical spine showing the location of the entry points in C1 and C2. (b) Lateral view. (c) Posterior view

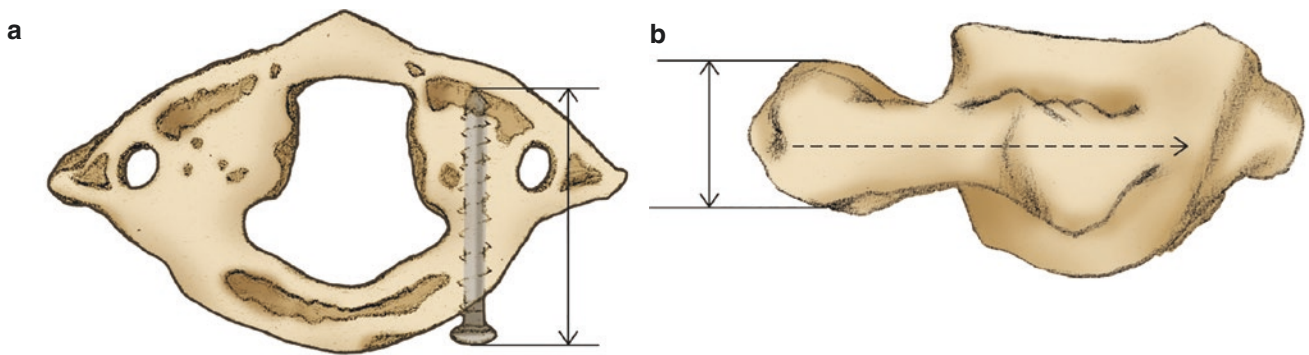


Fig. 1.8 Tan's technique for atlantoaxial fusion. (a) Axial view; (b) Lateral view

Fig. 1.9 The superior view of the atlas. The axial image shows the screw entry site on the lateral mass and direction of screw entry (forming a 5° – 10° angle with the sagittal plane)

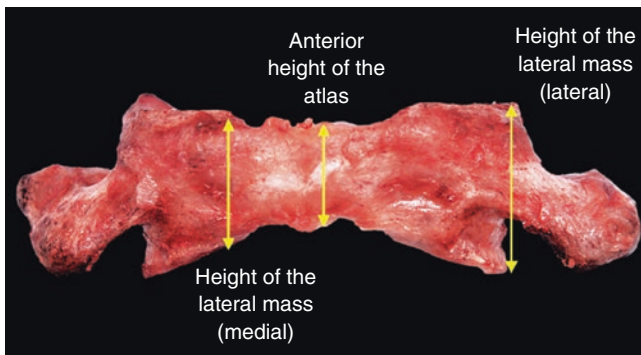
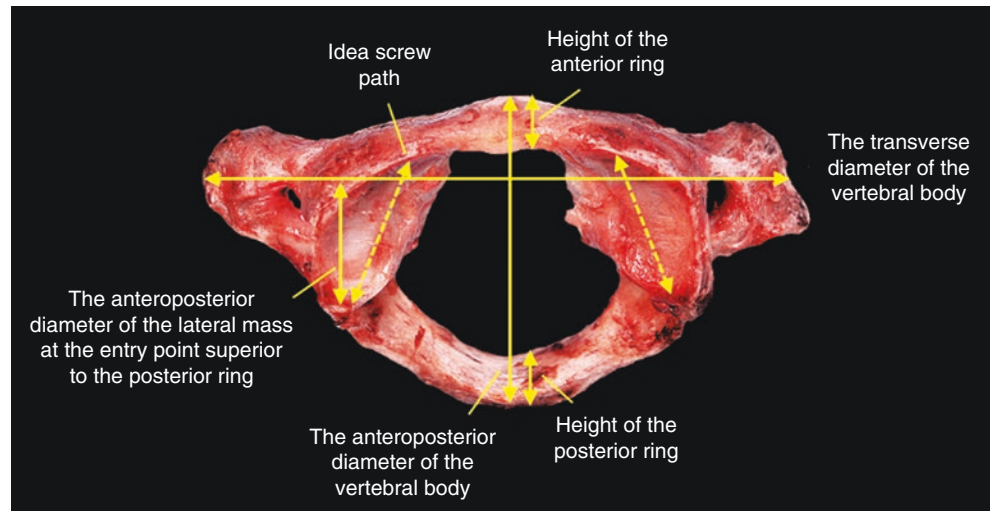


Fig. 1.10 The anterior view of the atlas. The height of the lateral mass in the medial border is 8.81 ± 1.46 mm; the height of the lateral mass in the lateral border is 18.01 ± 2.33 mm [9]

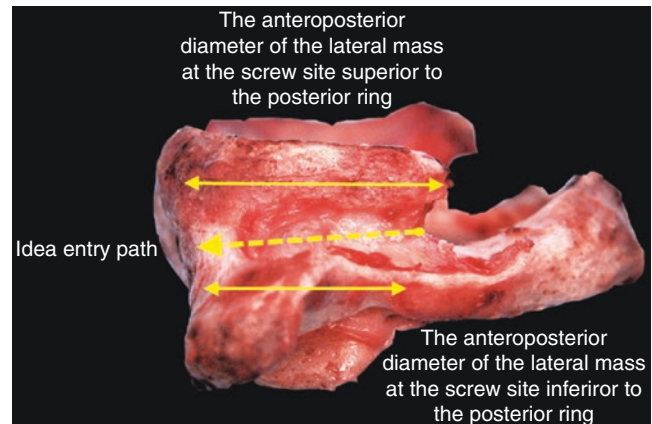


Fig. 1.12 The lateral view of the atlas. The ideal entry path can be seen in the lateral view (at a caudocephalad angle of 10° – 15°). Note that the entry site is located at the junction of the posterior ring and the lateral mass

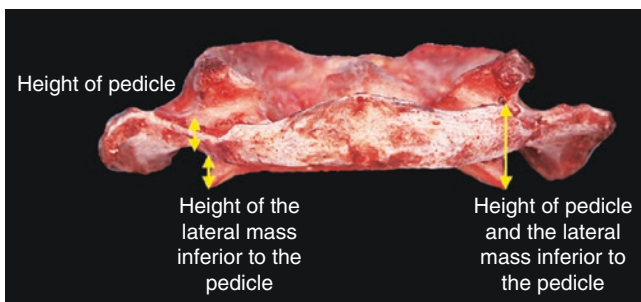


Fig. 1.11 The posterior view of the atlas. The vertebral artery courses through the groove and overlaps with the posterior arch of the atlas in the posterior view. The pedicle height is 4.80 ± 0.93 mm; the pedicle width is 9.82 ± 1.48 mm [9]

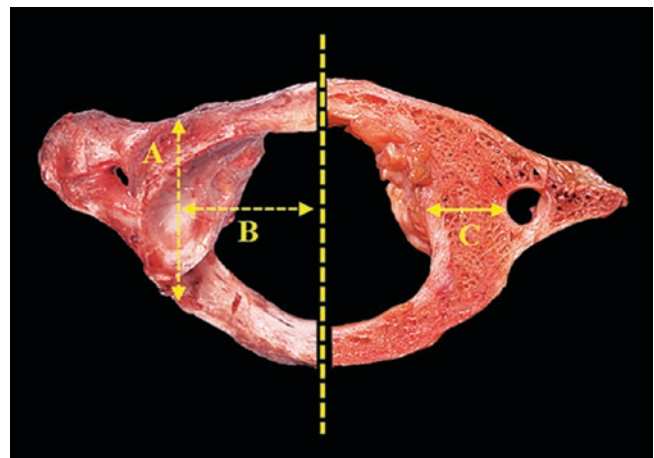


Fig. 1.13 Dimensions of the lateral mass of the atlas. (a) The distance between the entry site and the anterior edge of the lateral mass is 28.01 ± 1.35 mm in the right and 27.98 ± 1.24 mm in the left; (b) The distance between the entry site and the middle line is 13.82 ± 1.05 mm in the right and 13.81 ± 1.06 mm in the left; (c) The width of the lateral mass is 8.27 ± 1.63 mm in the right and 8.24 ± 1.62 mm in the left

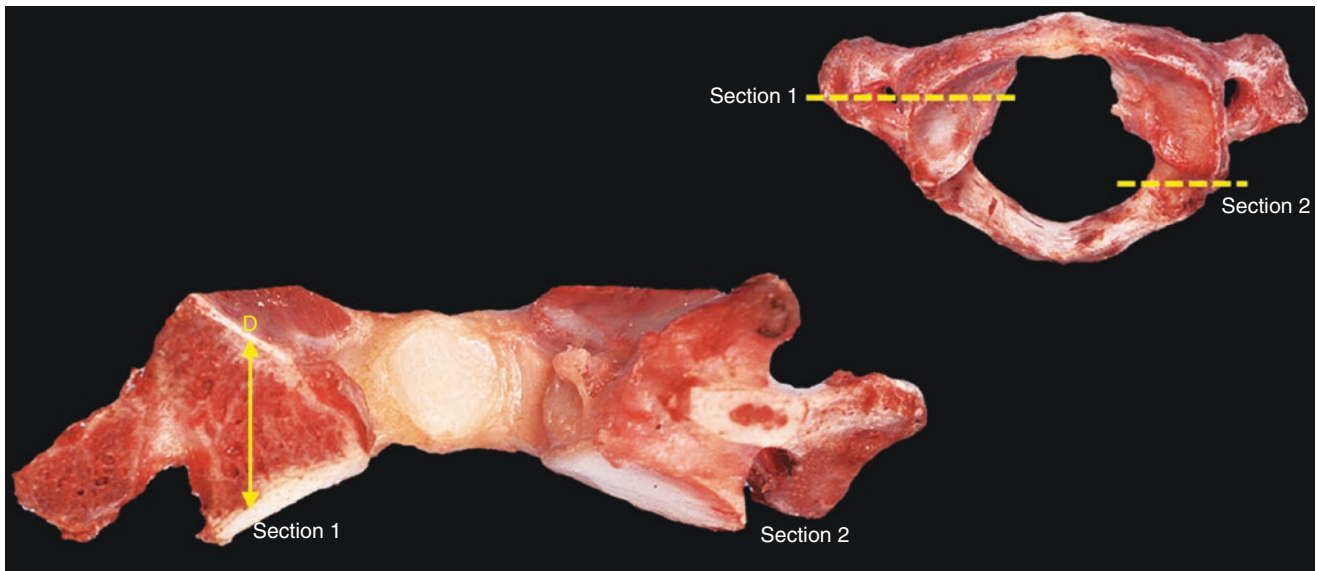


Fig. 1.14 Dimensions of the lateral mass of the atlas. (d) The height of the lateral mass is 10.24 ± 0.80 mm in the right and 10.22 ± 0.80 mm in the left

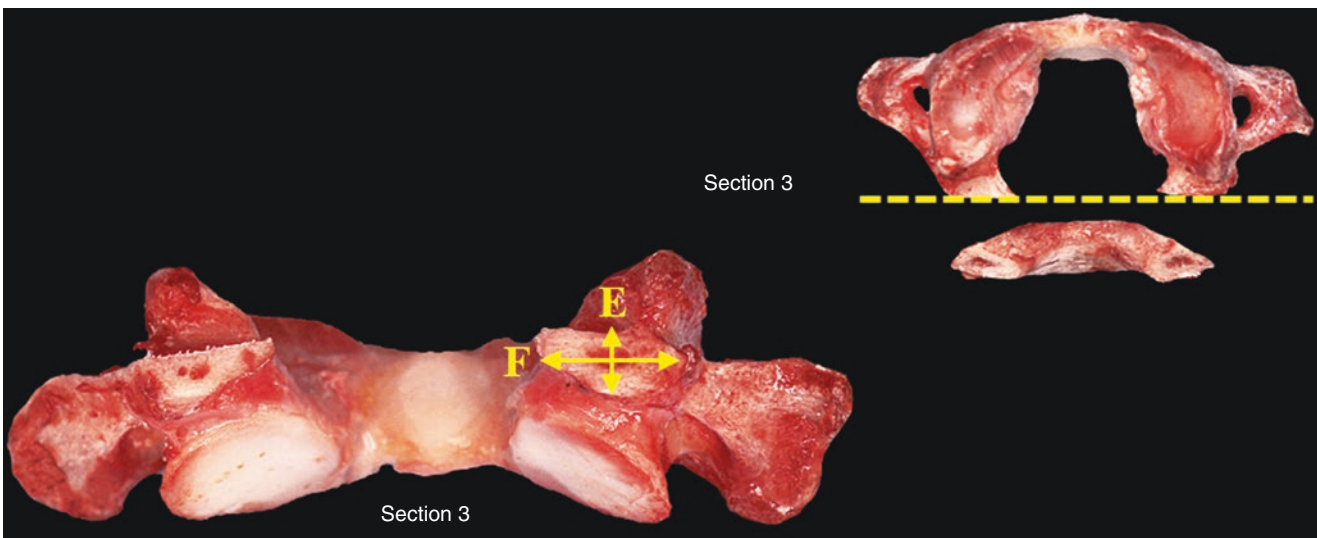


Fig. 1.15 Dimensions of the pedicle of the atlas. (e) The pedicle height is 4.62 ± 1.06 mm in the right and 4.56 ± 1.12 mm in the left; (f) The pedicle width is 9.63 ± 1.51 mm in the right and 9.69 ± 1.36 mm in the left

1.3 Key Points of Atlas Lateral Mass Screw Technique

1.3.1 Determining Screw Entry Points in the Lateral Mass of the Atlas

Anatomically, the atlas is peculiar as it has neither a vertebral body nor a vertebral lamina. Therefore, the vertebral pedicle does not exist anatomically.

There are two entry methods (methods A and B) for screw placement in the atlas (Figs. 1.16, 1.17, and 1.18).

Method A is a clinically commonly used fixation technique for screw entry into C1 lateral mass via the posterior arch and the isthmus.

In **method B**, the screw is directly inserted along the longitudinal axis of the lateral mass of the atlas at the transition zone between the inferior border of the posterior arch and the posterior border of the lateral mass of the atlas. Because the

Fig. 1.16 Two methods of screw entry

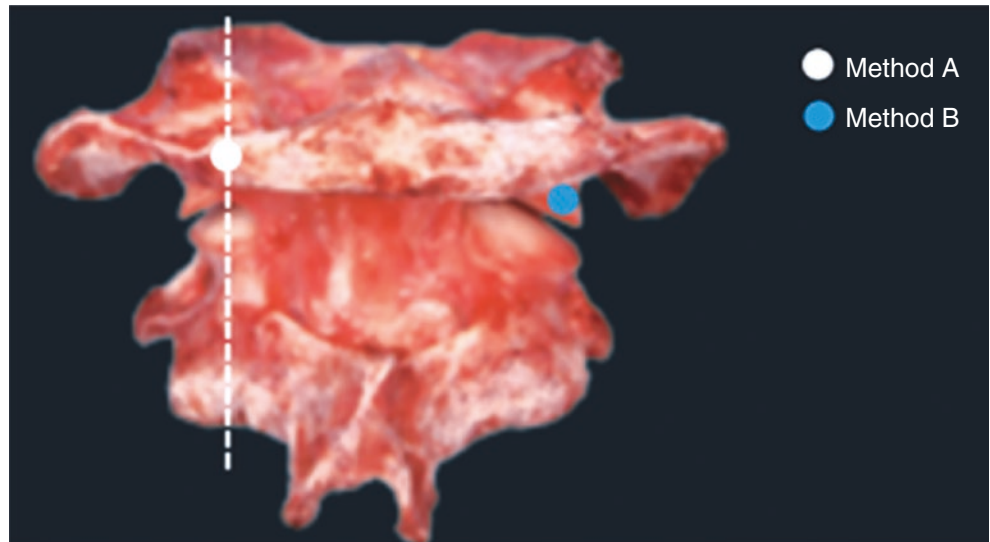


Fig. 1.17 Comparison of two screw entry sites

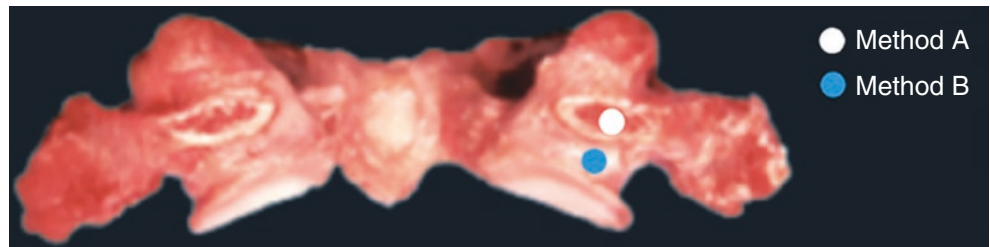
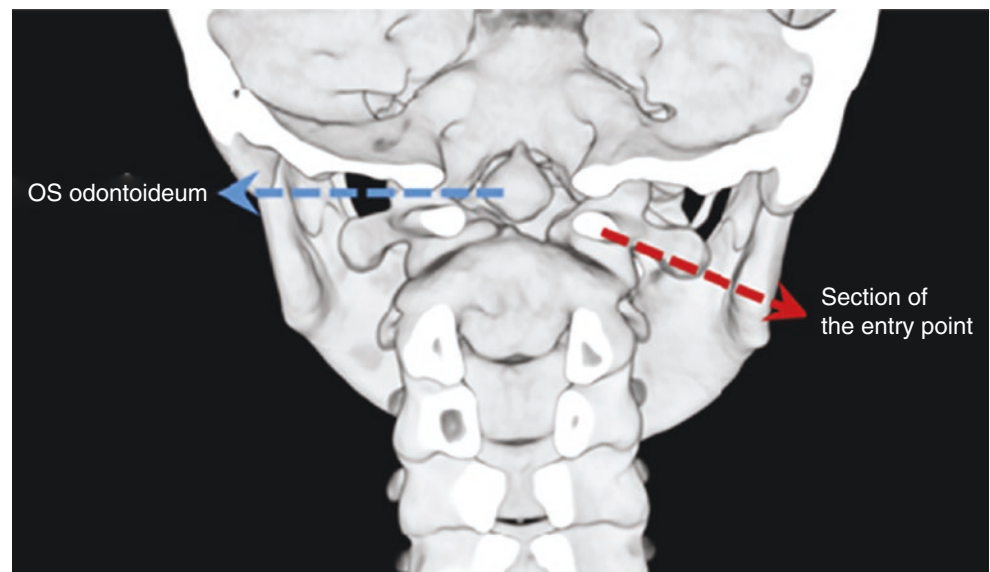


Fig. 1.18 An illustrative case with free dens showing the pedicle section



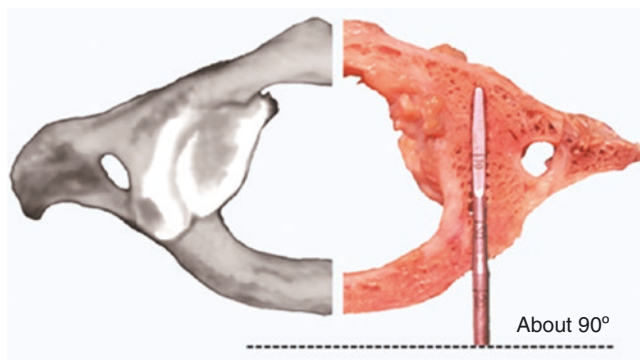
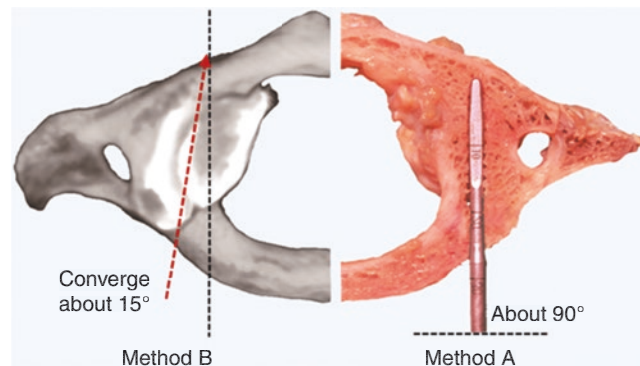
vertebral vein and C2 nerve roots run across the entry path, nerves and blood vessels may be inadvertently injured intra-operatively, leading to profuse bleeding; however, hemostasis is difficult to achieve (Table 1.1).

1.3.2 Entry Angle for a C1 Lateral Mass Screw

6. Method A: The entry angle for a lateral mass screw via the posterior arch of the atlas (Fig. 1.19)

Table 1.1 Comparison of methods A and B

	A	B
Via the posterior arch of the atlas	Yes	No
Exposure of the atlantoaxial venous plexus	No	Yes
Volume of blood loss	Smaller	Larger
Possibility of vertebral artery injury	Higher	Lower
Screw length	Longer	Shorter
Level of difficulty	Greater difficulty in preparation of screw entry path	Greater difficulty in exposure of screw entry points

**Fig. 1.19** Screw entry angle**Fig. 1.20** Screw entry angle

7. Method B: The entry angle for a screw with direct entry into the lateral mass (Fig. 1.20)

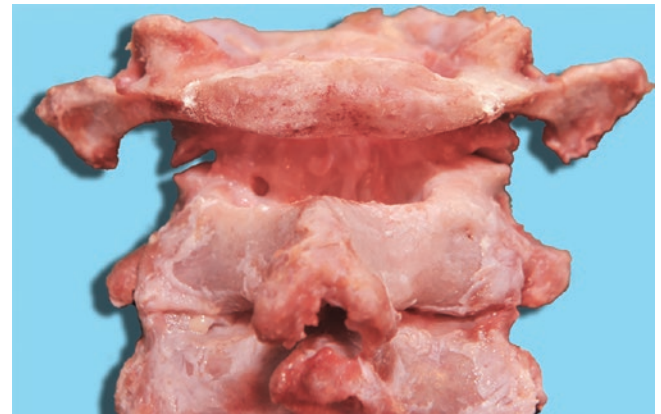
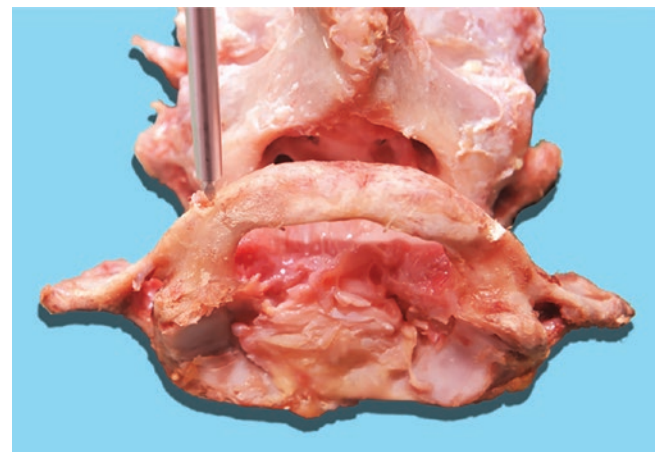
The screw is situated in the lateral mass of the atlas, at a distance of 3–4 mm from the superior facet of C1 with a medial inclination of 15°.

1.3.3 Depth of C1 Lateral Mass Screws

1. The screw is inserted for an approximate depth of 25 mm into the lateral mass of the atlas.
2. Diameter of C1 lateral mass screws: The diameter of the most commonly used lateral mass screws is 3.5 mm.
3. The length of screw inside the bone in method A is longer than that of method B.

1.4 Surgical Steps (Method A)

1. A mill is used to disrupt the cortical bone at the screw entry point (Fig. 1.21).
2. A screw hole is drilled using a drill bit (Fig. 1.22).
3. Drill depth is increased using a 3.5-mm drill bit with drill guide (Fig. 1.23).

**Fig. 1.21** A mill is used to disrupt the cortical bone**Fig. 1.22** A screw hole is drilled using a drill bit

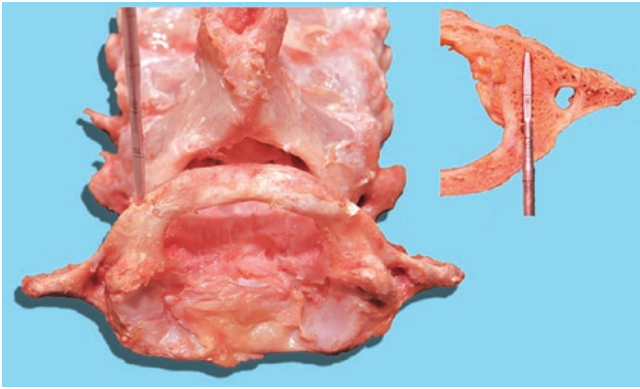


Fig. 1.23 Increasing the drill depth

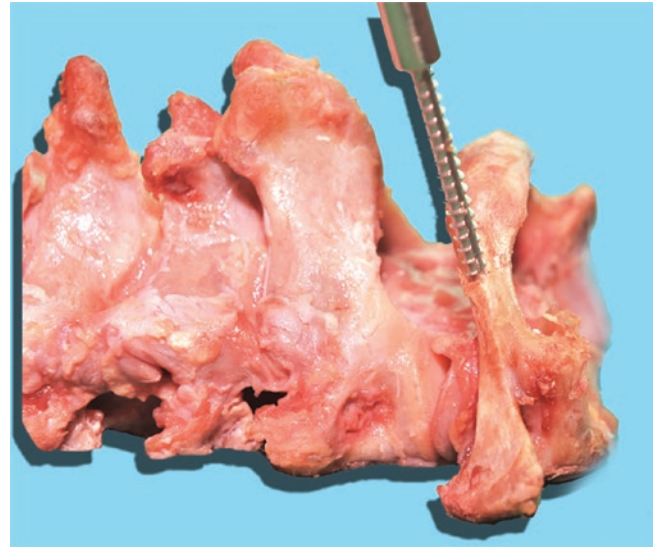


Fig. 1.25 Tapping the screw path

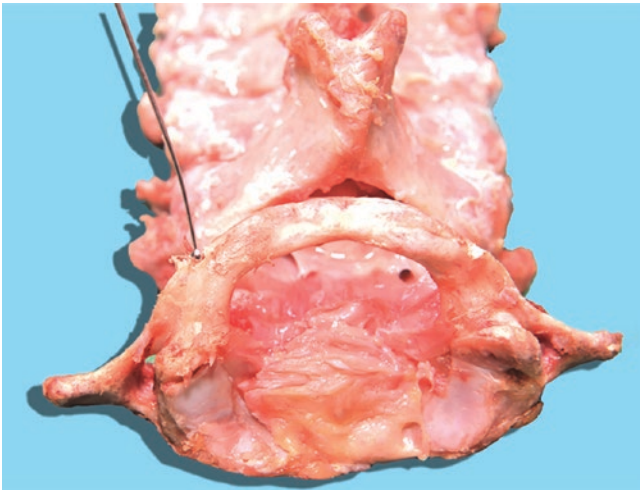


Fig. 1.24 Probing the screw path

4. The screw path is then probed (Fig. 1.24).
5. The screw path is tapped (Fig. 1.25).
6. The screw is implanted (Figs. 1.26 and 1.27).
7. Section at the screw path of a C1 lateral mass screw (Figs. 1.28, 1.29, and 1.30).

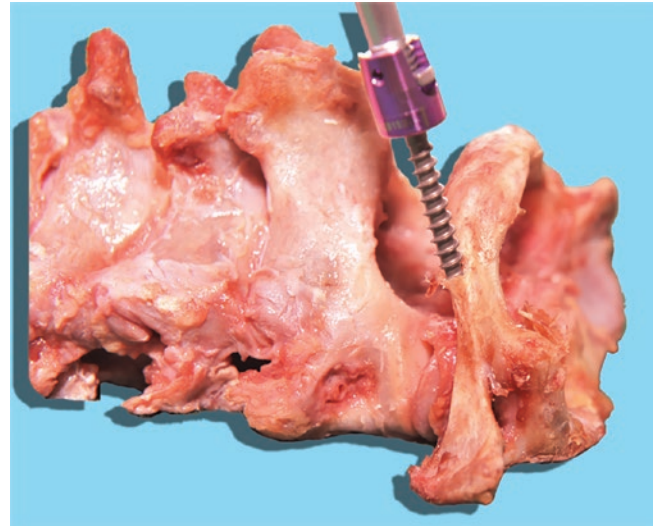


Fig. 1.26 The screw is implanted

Posterior arch of the atlas/section of screw entry site

1.5 Imaging Features of Standard Pedicle Screws of the Atlas (Figs. 1.31, 1.32, 1.33, 1.34, and 1.35)

Case 1

Patient: A 54-year old female complained of traumatic neck pain with limited mobility for 25 days.

Diagnosis: C2 odontoid fracture (Fig. 1.36).

Surgery: VERTEX internal fixation with bone graft and fusion (Figs. 1.37 and 1.38).

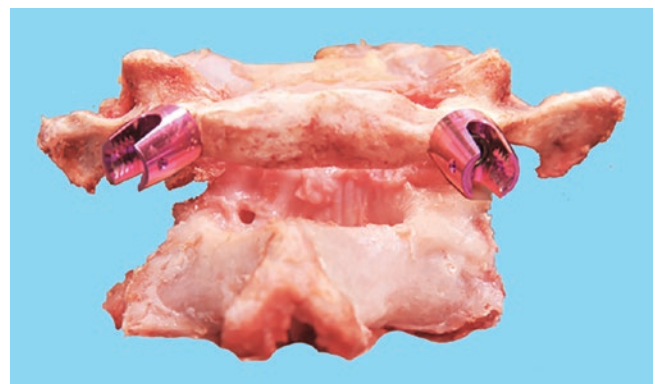


Fig. 1.27 The contralateral screw is implanted

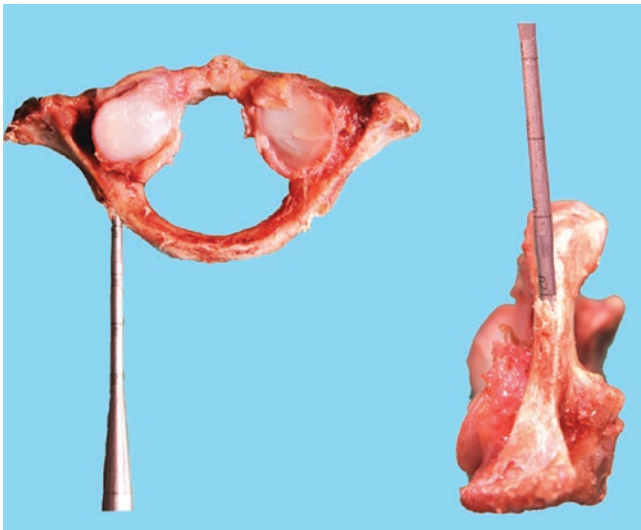


Fig. 1.28 Lateral view of the screw path

Case 2

Patient: A 40-year-old female complained of cervico-occipital pain for 5 years

Diagnosis: Congenital odontoid malformation and C1–C2 dislocation (Fig. 1.39).

Surgery: C1–C3 open reduction via the posterior, VERTEX internal fixation, iliac crest bone graft and fusion (Figs. 1.40 and 1.41).

Caution: Simple instability of C1–C2 only requires stabilization by reduction. When atlantoaxial or foramen magnum decompression is not required, C1 and C2 segments should be chosen for stabilization. In this patient, C3 was stabilized (Fig. 1.41), which is beyond the aforementioned segments to be stabilized. In addition, stabilization should not be extended to the occipital bone.

Fig. 1.29 Sectional view of the screw path

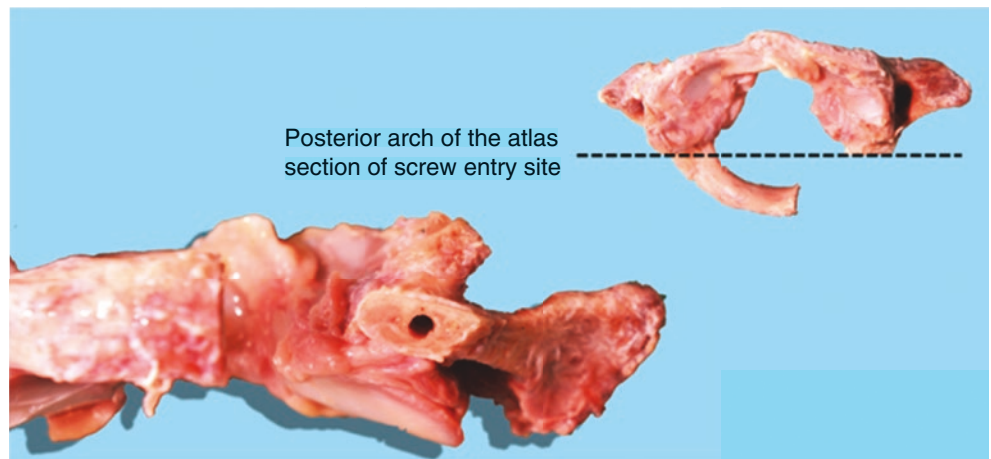
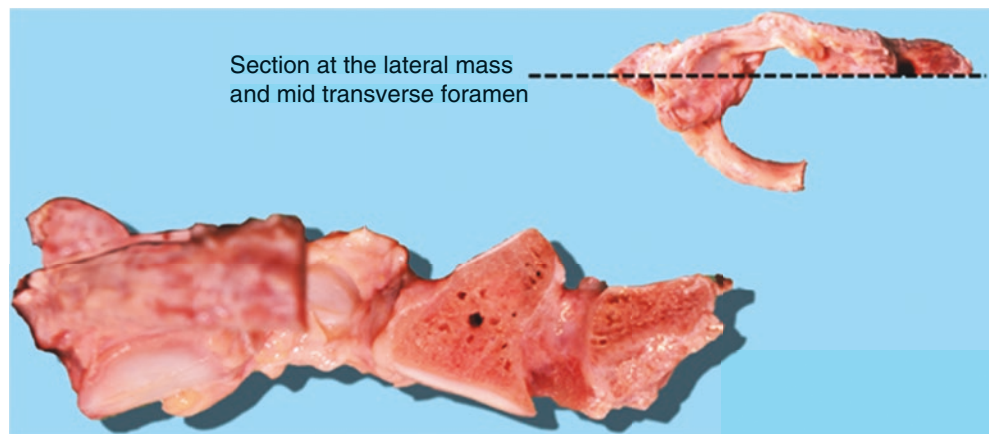


Fig. 1.30 Sectional view of the screw path in the lateral mass



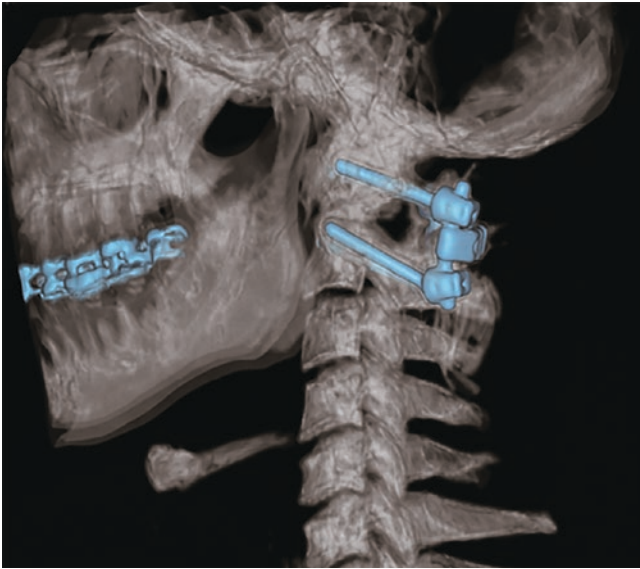


Fig. 1.31 Lateral view of atlantoaxial fixation

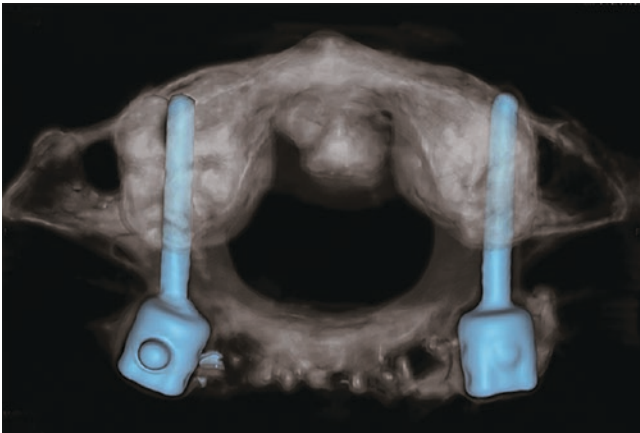


Fig. 1.32 The superior view of C1 lateral mass screw

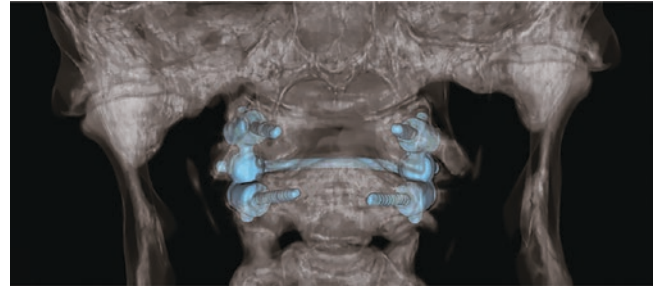


Fig. 1.33 The anterior view of atlantoaxial fixation

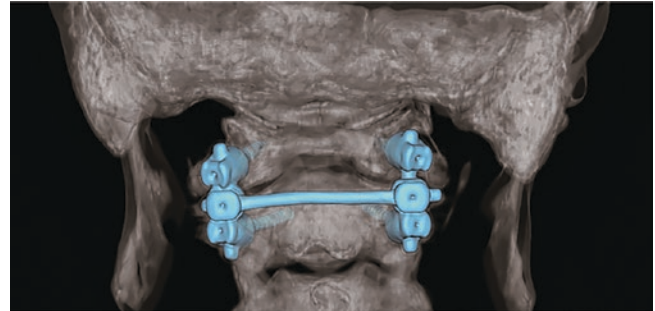


Fig. 1.34 The posterior view of atlantoaxial fixation

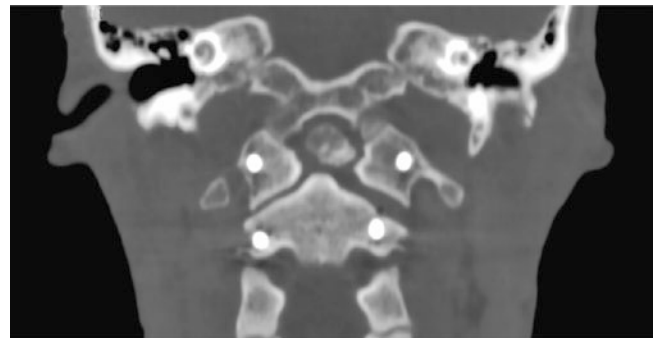


Fig. 1.35 The coronal section view of Atlantoaxial fixation

1.6 Pearls and Pitfalls

1. Caution should be exercised when a C1 lateral mass screw is inserted. The lateral mass of the atlas is approximately 27 mm in length, 8 mm in width, and 10 mm in height, and anatomical studies have demonstrated that a screw of 3.5 mm in diameter is safe.
2. The posterior arch and lateral mass of the atlas have scant cancellous bone and are solid. The screw path should be prepared with caution, and use of a tap is recommended to prevent rupture of the screw path.
3. Lateral to the posterior arch of the atlas runs the vertebral artery, and inferior to the posterior arch travels the venous plexus and inside is the cervical spinal cord. A surgeon should be familiar with regional anatomy and avoid injury to the nerve roots and vessels during operation.

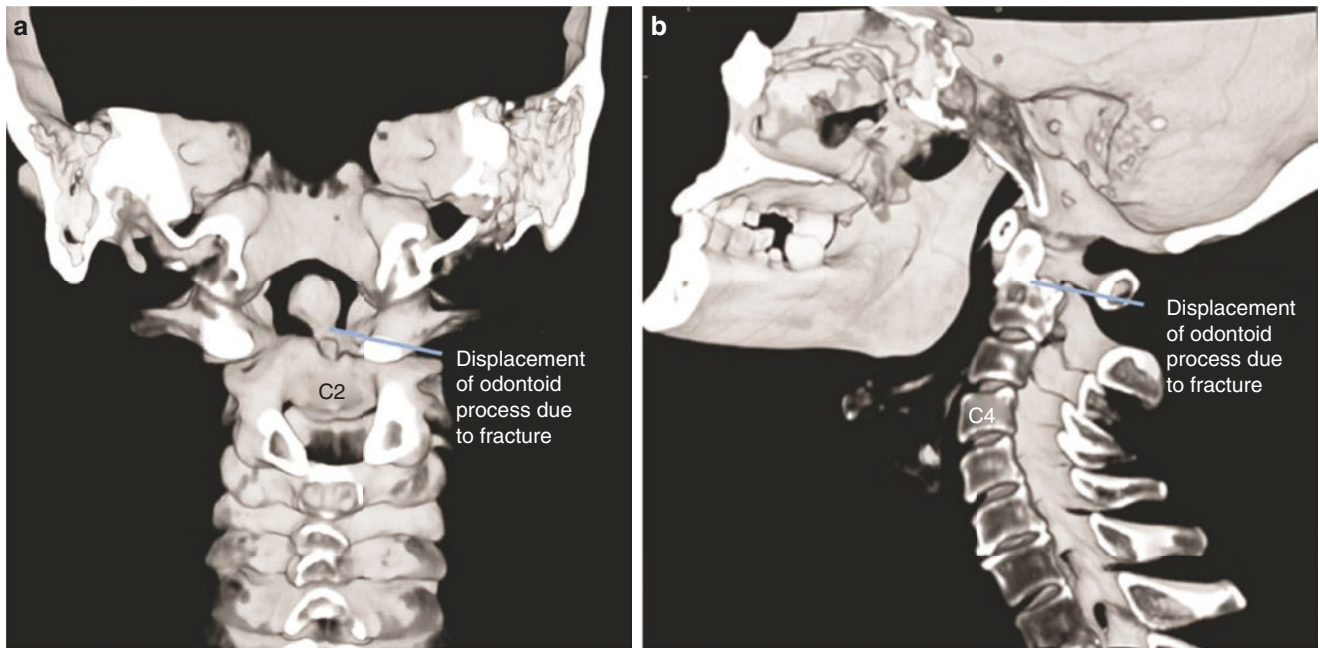
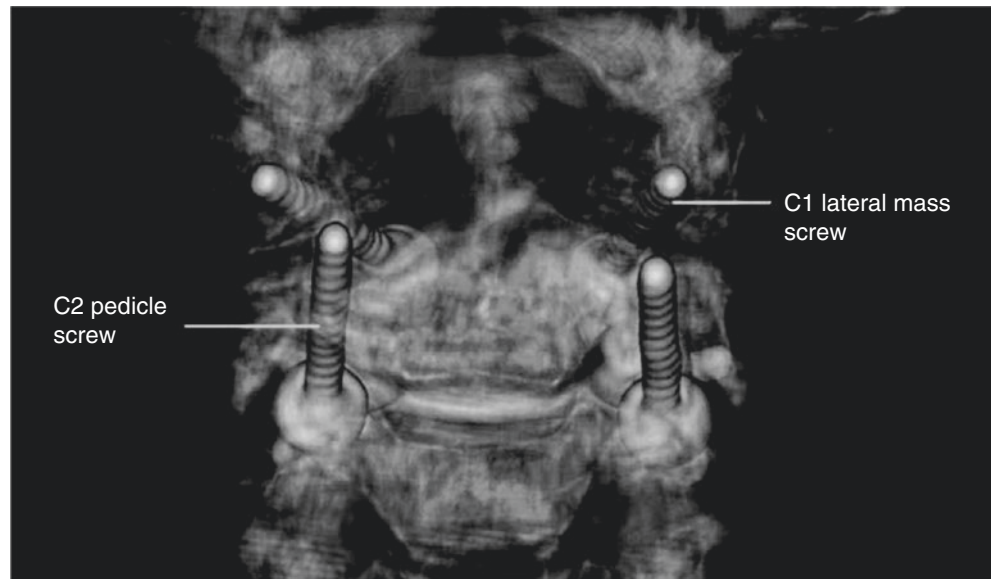


Fig. 1.36 Three-dimensional (3D) CT reconstruction. Split coronal (**a**, *posterior view*) and longitudinal (**b**, *lateral view*) 3D CT reconstruction images of the spinal canal

Fig. 1.37 Location of internal fixation (*anterior view*)



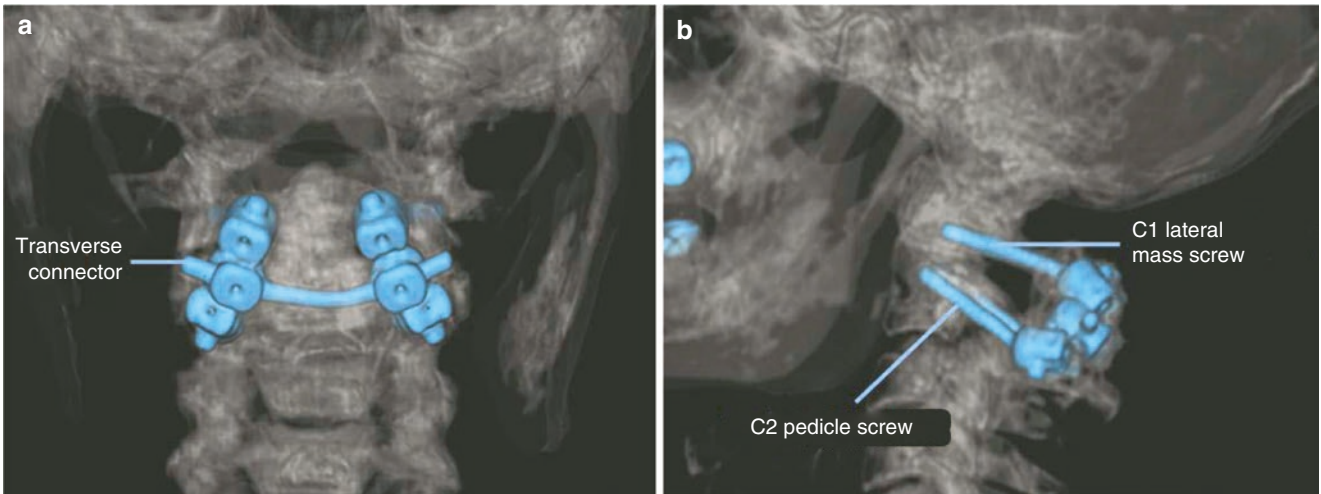


Fig. 1.38 Location of internal fixation. (a) Posterior view; (b) Lateral view

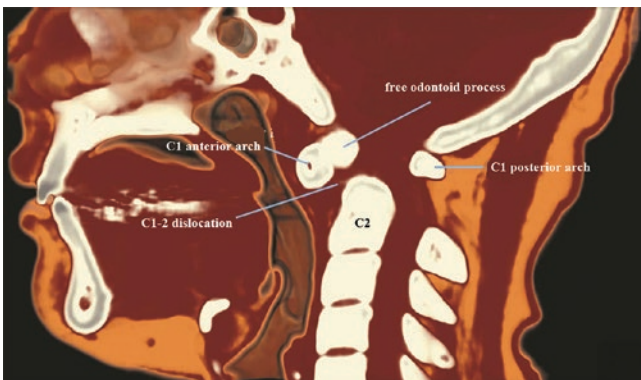


Fig. 1.39 Image of the spinal canal (*sagittal view*). C1 anterior arch; free odontoid process; C1–C2 dislocation; C1 posterior arch

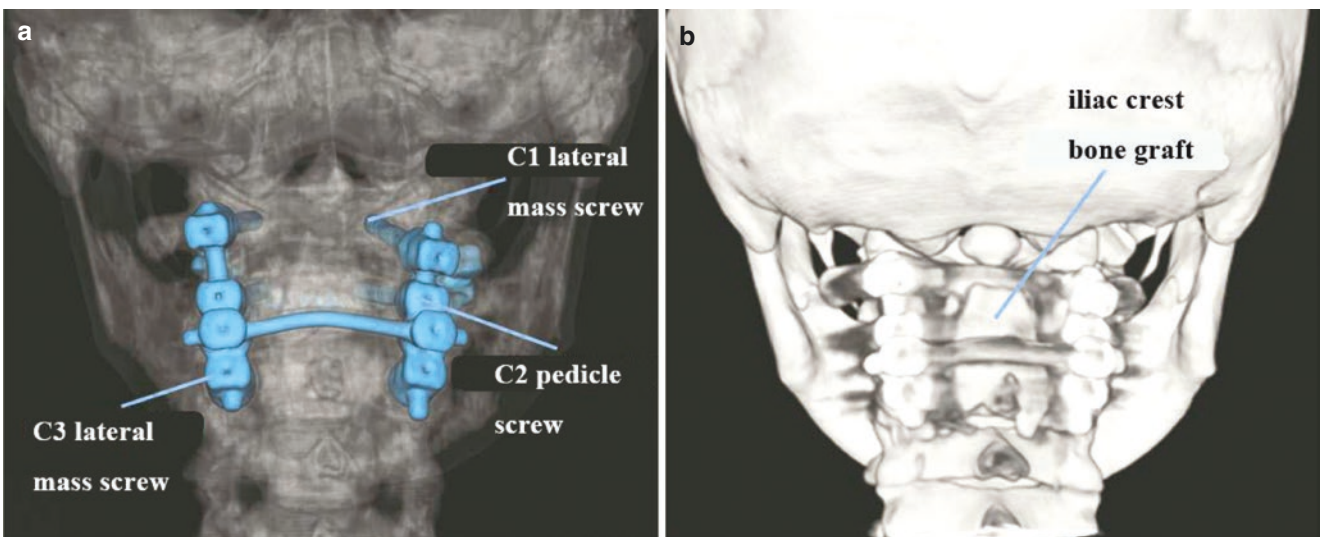


Fig. 1.40 Postoperative 3D reconstruction. (a) Location of internal fixation (*posterior view*); (b) Location of internal fixation (*posterior view*); (c) Position of C1 lateral mass screw (*horizontal view*); (d) Location C2 pedicle screw (*horizontal view*)

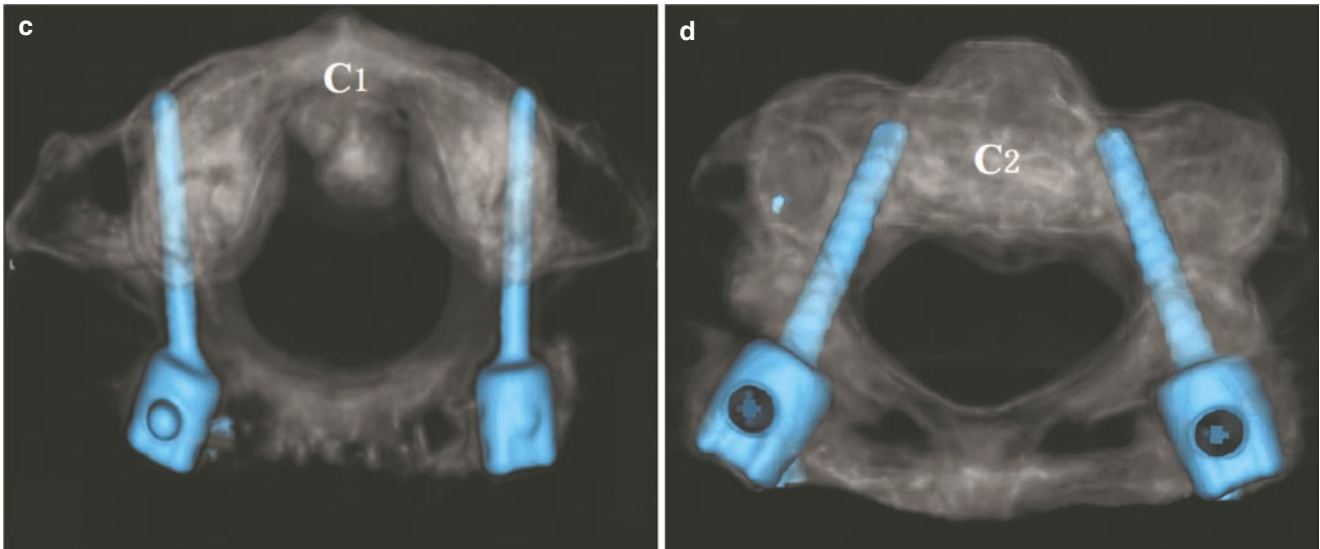


Fig. 1.40 (continued)

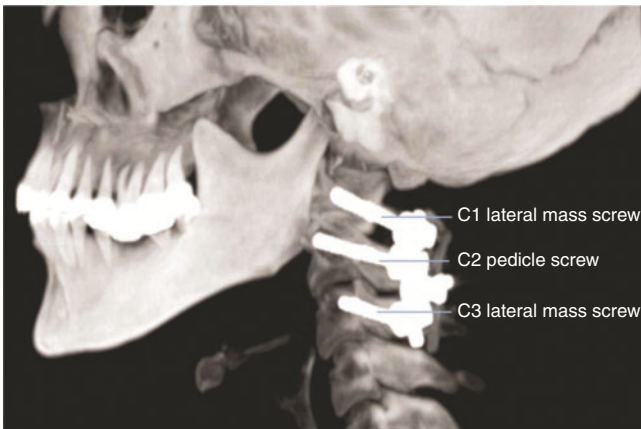


Fig. 1.41 Location of internal fixation (*lateral view*)

5. Jeanneret B, Magerl F. Primary posterior fusion C1/2 in odontoid fractures: indications, technique, and results of transarticular screw fixation. *J Spinal Disord.* 1992;5(4):464–75.
6. Goel A, Laheri V. Plate and screw fixation for atlanto-axial subluxation. *Acta Neurochir.* 1994;129(1–2):47–53.
7. Harms J, Melcher RP. Posterior C1-C2 fusion with polyaxial screw and rod fixation. *Spine (Phila Pa 1976).* 2001;26(22):2467–71.
8. Tan M, et al. Morphometric evaluation of screw fixation in atlas via posterior arch and lateral mass. *Spine (Phila Pa 1976).* 2003;28(9):888–95.
9. Christensen DM, et al. C1 anatomy and dimensions relative to lateral mass screw placement. *Spine (Phila Pa 1976).* 2007;32(8):844–8.

References

1. Gallie WE. Skeletal traction in the treatment of fractures and dislocations of the cervical spine. *Ann Surg.* 1937;106(4):770–6.
2. Brooks AL, Jenkins EB. Atlanto-axial arthrodesis by the wedge compression method. *J Bone Joint Surg Am.* 1978;60(3):279–84.
3. Dickman CA, et al. The interspinous method of posterior atlanto-axial arthrodesis. *J Neurosurg.* 1991;74(2):190–8.
4. Holness RO, et al. Posterior stabilization with an interlaminar clamp in cervical injuries: technical note and review of the long term experience with the method. *Neurosurgery.* 1984;14(3):318–22.