Odontoid Screw Fixation and Anterior C1-C2 Fixation Techniques

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Andrea Brunori, Daniele Marruzzo, Valentina Russo, and Alberto Delitala

12.1 Introduction

The axis (C2 vertebra) is the strongest cervical vertebra while the dens is the superior process of C2, articulating the anterior arch of C1 and providing about half rotation in the cervical spine. Strong ligaments, including the transverse, alar, and apical, hold the odontoid in close approximation with the atlas (Fig. 12.1). Odontoid fractures have been classified according to the fracture line by Anderson and D'Alonzo in 1974 [1] and represent about 12% of cervical fractures.

Anderson and D'Alonzo provide three fractures typologies (Fig. 12.2):

- Type I fracture line is commonly located in the apex of odontoid process (above the level of the transverse band of cruciform ligament).
- Type II fracture line occurs at the base of odontoid process (below the level of transverse band of cruciform ligament); type II A is a result of a fracture due to a splinters detachment on dens base.
- Type III fracture line is extended through the body of the axis (C2).

Type II fractures are usually unstable, at high risk of nonunion especially in elderly patients, and furthermore, they can be associated with the atlas fracture, influencing prognosis and therapeutic titer. Fractures involving both vertebrae can cause atlanto-axial instability. This can be managed by a variety of different techniques in order to achieve stability of the C1-C2 junction: among them the anterior C1-C2 transarticular fixation has proved safe and successful as the posterior fixation approaches, although less used by most spine surgeons. The supine vs prone positioning and minimal soft

A. Brunori · D. Marruzzo (✉) · V. Russo · A. Delitala
Neurosurgery, Department of Neuroscience "G.M. Lancisi", San Camillo-Forlanini Hospital, Rome, Italy
e-mail: delitala@sinch.it

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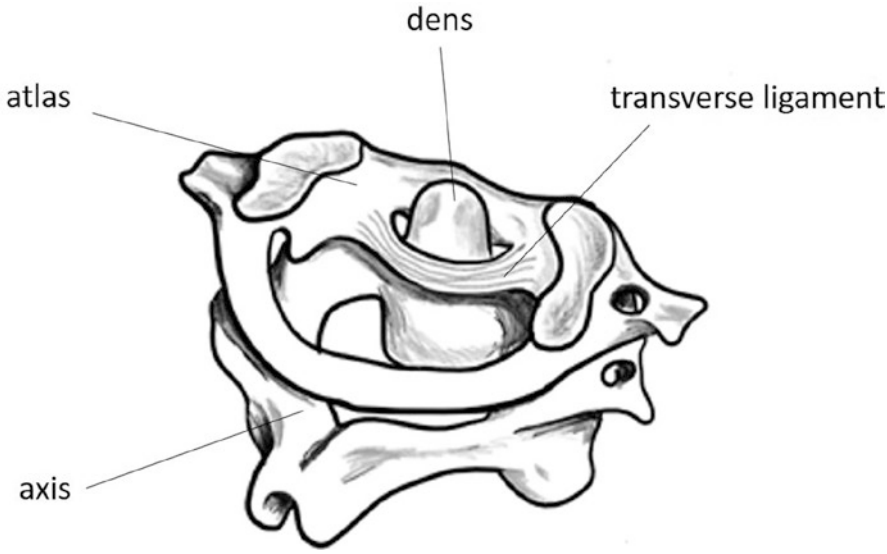

Fig. 12.1 Atlas-axis complex. Transverse ligament holds the dens to the anterior arch of the atlas

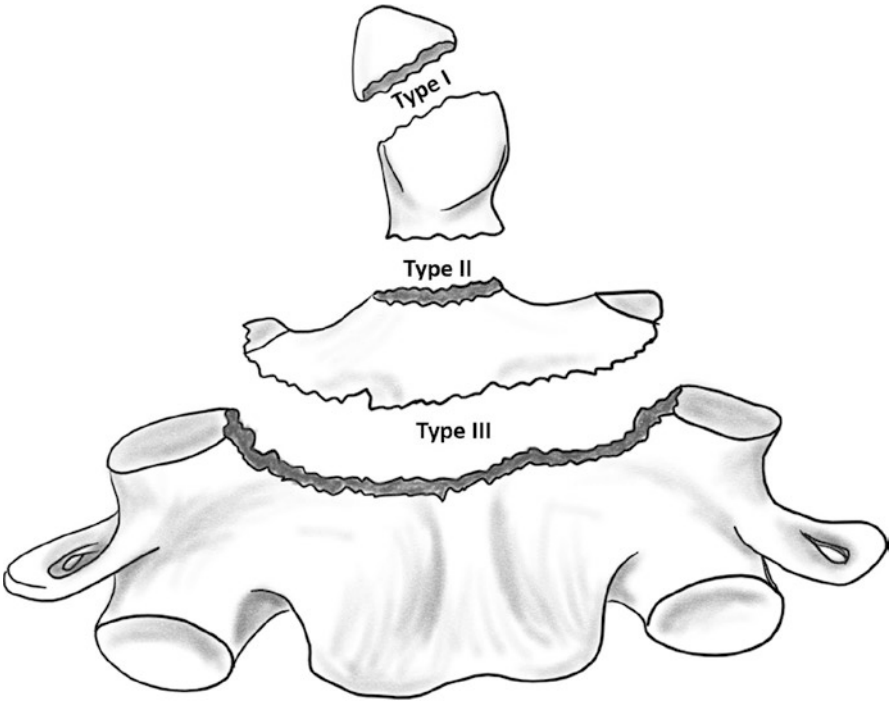

Fig. 12.2 Fractures of C2 according to Anderson and D'Alonzo classification. Type I fracture line is commonly located in the apex of odontoid; type II fracture line occurs at the base of odontoid process (below the level of transverse band of cruciform ligament); type III fracture line extends through the body of the axis (C2)

tissue dissection make the anterior approach less traumatic. In this chapter we describe two surgical techniques that can be performed through an anterior approach: odontoid screw fixation and C1-C2 transarticular fixation.

12.2 Odontoid Screw Fixation Technique

12.2.1 Treatment Indications

External cervical orthosis immobilization may be considered as a starting recourse in all types of mentioned fractures of odontoid. Type I and III fractures can be stabilized through cervical collar or Halo-Vest stabilization, obtaining notable results and the recovery in the following 12 weeks. Type II fractures (Fig. 12.3) are generally treated using surgery as considered unstable due to the high probability of the dens dislocation and the consequent cervical spine injury. The Halo-Vest initial treatment may be unable to fully stabilize the C1-C2 spine, and it may be associated, especially in elderly population, with pins' infection or loosening, while external orthosis may lead to pressure sores in occipital region related to dorsal recumbency [2].

Imaging studies are warranted on evaluating the fracture, the dens dislocation rate and the ligament complex integrity (CT scan with multiplanar reformatting and MRI with T1- and T2-weighted and STIR sequences). CT scan enables to measure the odontoid peg diameter and length in order to choose the appropriate screw dimension (Fig. 12.4).

Anterior odontoid screw placement for type II fractures was first introduced by Bohler in 1981 [3]. The mentioned treatment yields better results on increasing the final recovery outcome and healing time and reducing myelopathy onset.

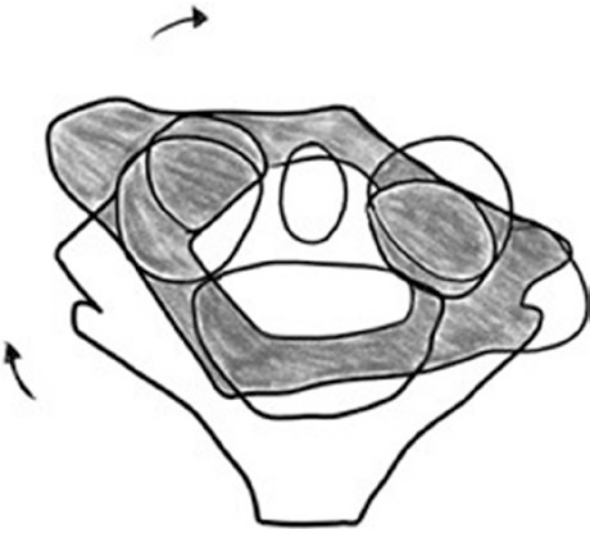

Fig. 12.3 Type II fractures have been reproduced by axially rotating the head and force in the lateral or oblique directions

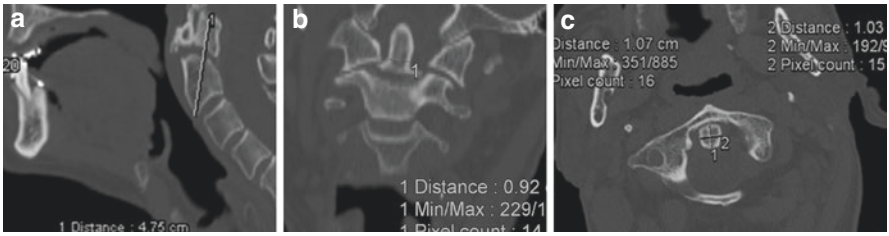

Fig. 12.4 (**a**, **b**, **c**) Preoperative CT scan allows to plan the right screw, measuring in sagittal the length (**a**) and the diameter of the screw (**b**, **c**)

Advantages of anterior screw fixation technique:
- Improved fracture alignment
- Preservation of atlantoaxial rotation
- Immediate fragments stabilization through a cannulated screw
- Easy access to the surgical site
- Reduction in length of stay
- Faster mobilization compared to Halo-Vest
- Improved quality of life

Indications:
- Transversal atlantal ligament (TAL) integrity
- Odontoid dislocation fracture >5 mm
- More than 10° angulation
- Failure of closed reduction and orthosis treatment

Contraindications:
- Unfavorable fracture line obliquity (oblique anterior line) (Fig. 12.5) [4]
- Osteoporosis/osteopenia
- Comminuted fractures
- Diastasis of the fragments, non-reducible fractures
- Prominent thorax (Barrel's chest)
- Cervical kyphosis

12.2.2 Surgical Technique

12.2.2.1 Patient Positioning

We routinely place the patient in the supine position. Due to the commonly advanced age of the patient, special care is paid to proper padding of an X-ray transparent surgical bed; legs are slightly flexed at the knee to avoid stretching of sciatic nerve. Correct positioning of the head is the key for a successful odontoid screwing: a pad at the inter-scapular region and the occiput resting in a gel donut allow for a suitable extension of the neck. The head is secured in a sharp neutral 0° position by lateral

Fig. 12.5 When the fracture line obliquity is unfavorable (oblique anterior line), the anterior screwing of the dens is not recommended: the figure shows how the screw carries the fragment forward

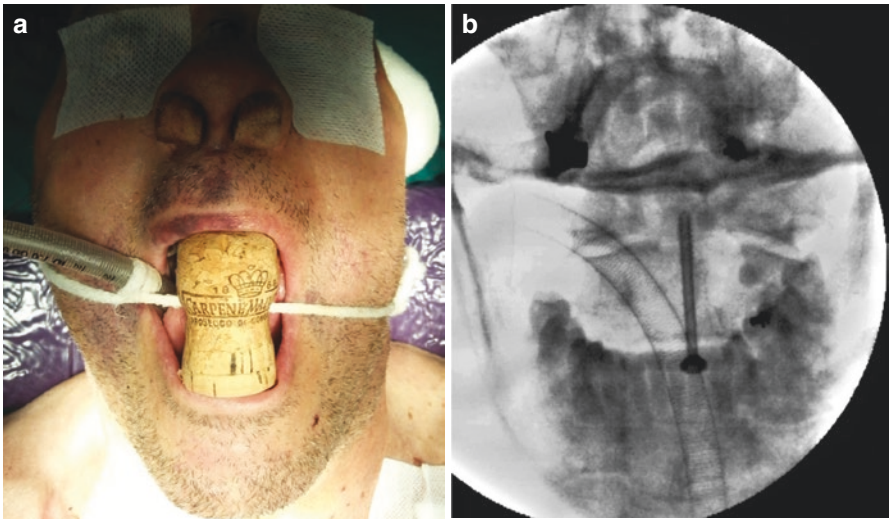

Fig. 12.6 (**a**, **b**) The mouth is kept opened with a guttered cork (**a**) to facilitate the visualization of the dens in intraoperative X-ray AP view (**b**)

pads if available or by soft bandaging of the forehead. Based on our experience we consider a transparent Mayfield headrest as unnecessary, time consuming, and invasive. The endotracheal tube is displaced laterally based on the surgeon's hand dominance an italian Prosecco sparkling wine guttered cork has just the right size and consistency to allow mouth opening; X-ray being transparent, AP views are not affected by any means (Fig. 12.6).

12.2.2.2 Operating Theater Set-Up

Extreme importance is attributed in this process to machines equipment in relation to the surgical team location (surgeons, anesthesiologist, and scrub nurse). This is especially true when the theater room is small.

A double fluoroscopy for simultaneous AP/LL projections is not an option and should be the standard for two reasons: (a) length procedure is reduced by at least 50%; (b) manual rotation of "C arm" requires a trained and compliant technician during whole procedure; even variation of a few degrees to compliance with the initial adjustment implied and repeated AP to LL projections changes could result an unfortunate surgical failure. Figure 12.7 shows the recommended theater setup. The two fluoroscopies are positioned at 45°, respectively, where fluoroscopy monitor must be in the vision line of the main surgeon, i.e., at 30–40° with respect to the main axis of the surgical bed, slightly rotated. It is very important that both pedals are operated by the surgeon himself, virtually setting to zero the dependency from the radiology technician.

The theater setup for odontoid screwing can be depicted, as a clock dial being the bed on the 12/6 axis, C-arm 1 on the 9/3, C-arm 2 on the 10/4, the scrub nurse at 7, surgeon at 8, anesthesiologist and respirator at 12, and monitors at 2. A scrubbed assistant is stand by and ready to join the procedure in case of need.

Being an image-guided procedure, a clear visualization of the odontoid process is mandatory. The AP view is usually more difficult to set because of the

Fig. 12.7 Operating room setup: a double fluoroscopy for simultaneous AP/LL projections; the fluoroscopy monitor must be in the surgeon's line of view

superimposition of occipital plane and inferior dental arch; therefore, obtaining the best angle to outline the profile and odontoid tip is worth it. Lateral images are more valuable to observe the base, a correct alignment of fragments and the crossover line fracture by screw.

12.2.2.3 Incision and Exposure

We use a right transverse incision in a neck crease at the C4-C6 level running from the anterior sternocleidomastoid muscle up to the midline. A different approach can be performed by using a K-wire on lateral radiological monitoring to simulate the screw's path on the patient skin. Muscle planes are dissected in a blunt fashion as usual in the upper spine pre-carotid/retropharyngeal approach; a good application is visualizing directly the C3 body such as the longus colli insertion keeping strictly the midline, from both sides. Odontoid process visualization is not easy to achieve nor useful, but palpation with the fingertip is possible; in elderly patients, dissection is easier due to tissues laxity. A trocar retractor/cannula with pinned tip is then adopted to point the entrance of the K-wire guide, target estimated just few millimeter behind the anteroinferior tip of the C2-body where the C2-endplate is softer and there is less slippery of the anterior cortical layer. Sometimes drilling of the upper anterior portion of C3 vertebral body is necessary in order to obtain the right obliquity of the screw. Failure on breaching cortical layer and K-wire slipping guide could result as injury of the pharynx; moreover, at the end of this procedure, the screw head will rest in a niche preventing soaring on the pharynx and possible dysphagia.

12.2.2.4 Odontoid Screw Insertion

Dens Access system from DePuy-Synthes and a K-wire mounted on a Colibri drill are adopted (Colibri drills are very light and comfortable to handle). In patients with prominent chest, it is advised to hold it in reverse fashion (i.e., grip upwards), avoiding bumping on the sternum. Drill's buttons (clock/counter clockwise rotation and K-wire release) can be operated with a single hand. Once planned trajectory is found by AP/LL, the guide wire is frequently advanced checking the direction. As K-wire is placed in the correct position, the appropriate screw length is chosen by using a similar K-wire and the sterile ruler. Cannulated screw inserted through the K-wire is screwed up to the cortical tip of dens. Supervision must be done, during screwing and after passing fracture line, avoiding possible caudocranial displacement of distal fragment; therefore, pressure onto the drill must be dosed, and drill speed needs to be homogeneous.

12.2.2.5 End of Procedure

Once the optimal positioning screw is obtained, K-wire is removed and screw head is checked by palpation. The procedure is usually bleeding less, and monitoring hemostasis at the end is granted by direct vision. Muscle and skin layers are then sutured, and cervical Philadelphia-like collar is put in position for 8–12 weeks to avoid stress on the fusion line (Fig. 12.8).

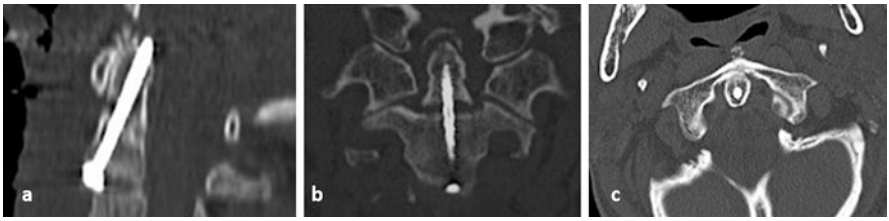

Fig. 12.8 (**a**, **b**, **c**) Postoperative CT scan in sagittal, coronal, and axial view (**a**, **b**, **c**) the screw is in the center of the dens in the three projections

12.3 Anterior C1-C2 Fixation Technique

12.3.1 Treatment Indications

Fractures of the axis are often associated with ligamentous injuries or other cervical fractures. C1 fractures in combination with odontoid fracture type II are considered unstable and it has to be managed with surgical stabilization and fusion. Surgical anterior techniques include C1-C2 fixation with transarticular screws and anterior odontoid screw fixation. This technique was first performed in 2003 by Reindl et al. [5, 6] as an alternative to posterior approaches technique known before.

Advantages:
- Prone positioning.
- Feasible in the presence of a thoracic kyphosis which would create problems for the posterior approach.
- Ideal for patients with severe trauma which may not tolerate the prone position.
- Reduces the trauma of muscles that normally occurs in posterior approaches.
- This technique can be performed with the standard Smith-Robinson approach.
- The possibility of vertebral artery damage is reduced because the vertebral artery foramen is close to the screw entry point; therefore, the artery can be well controlled.

12.3.1.1 Patient Positioning

The patient is in a supine position on a carbon fiber radiolucent operating table. Two image intensifiers are used to identify the dens in the AP and LL projections. The fracture is reduced under X-ray visualization meanwhile the patient's head is positioned in the extended position; this enables correct alignment and facilitates the screw insertion.

12.3.1.2 Incision and Exposure

A standard approach to the anterior cervical spine is performed, with a unilateral horizontal incision placed in correspondence with the projection of the intended direction of the screw and viewing on the image intensifier. Projection generally corresponds to the vertebral C4-C5 level.

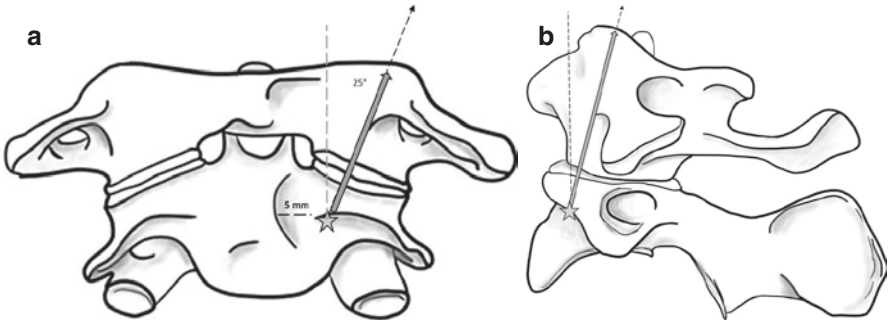

Fig. 12.9 Entry point. Anterior-posterior view (**a**) and lateral projection (**b**): At 5 mm from the lateral border of the base of C2, the screw follows a trajectory 25° cranially and laterally to target the lateral mass of C1

12.3.1.3 C1-C2 Screwing

Preoperative measurements on CT scan are strictly required to determine the correct screw length. The entry point, assigned for each side, is on the overhanging lip surface of C2 lateral mass: 5 mm laterally to the base of the dens and 25° lateral head oriented to it, in order to locate the screw in the C1 lateral mass (Fig. 12.9). As the entry point is identified on the C2 vertebra, an access is created to insert with a drill, the appropriate screw with the angled cannulated screwdriver. The use of tissue protectors is safely recommended, to avoid damaging vital structures, while drilling and tapping. It is essential to observe these procedures on the lateral image intensifier to ensure that guide wire does not advance cranially.

12.4 Risks and Complications

Besides the well-known risks and complications of anterior approach to the cervical spine (i.e., damage of neck vessels, laryngeal and autonomic nerves, upper respiratory and digestive tracts), most failures are due to screw malpositioning, injury of critical vascular, and neurological structures. In some cases screw loosening can occur especially in elderly patients due to poor quality of porotic bone [7, 8, 10, 11]. In a minority of cases, when dislocation is symptomatic, a surgical revision is recommended. Some studies report dysphagia following these procedures [7–9] probably related to impinging of the screw head on pharyngeal soft tissues.

12.5 Conclusions

In this chapter, the authors describe two surgical techniques performed for the treatment of odontoid fractures and C1-C2 vertebrae instability. The treatments of the mentioned pathologies, for a while, were approached with the posterior cerclage wiring [10, 11]. Afterwards with a better knowledge of anatomy and the coming of

biomechanics principles, applied to the spinal column, surgical strategies have boosted, both with anterior approach and with posterior access, revising the treatment of mentioned pathologies. Anterior approach techniques avoid muscles trauma typical of posterior ones, and they guarantee an immediate stabilization of the odontoid process and C1-C2 functional segment. Fractures of the dens and C1-C2 vertebrae instability can be encountered in patients with severe trauma (as sternum or rib fracture, respiratory distress because of lung contusions or pelvic fractures) and with higher surgical risks in prone position.

The discussed techniques fundamentally changed the fractures approach for elderly patients. Type II fractures of the odontoid treated with immobilization represent, in patients over 50 years old, a high risk of nonunion 21 times greater than in younger patients [2]. Therefore, odontoid screw fixation is recommended for type II odontoid fractures in patients over 50 years.

Extreme importance is attributed to the theater room setup and to the imaging studies warranted during intervention, on evaluating the fracture and the visualization of the anatomic landmarks. Fluoroscopy projections have to be the standard routine before surgical incision to keep away from intraoperative complications.

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References

1. Anderson LD, D'Alonzo RT. Fractures of the odontoid process of the axis. J Bone Joint Surg Am. 1974;56:1663–74.
2. TC R, Hadley MN, Aarabi B, Dhall SS, Gelb DE, Hurlbert RJ, Rozzelle CJ, Theodore N, Walters BC. Management of isolated fractures of the axis in adults. Neurosurgery. 2013;72(Suppl 2):132–50.
3. Bohler J. Screw-osteosynthesis of fractures of the dens axis (author's transl). Unfallheilkunde. 1981;84:221–3.
4. Roy-Camille R, de la Caffinière JY, Saillant G. Les traumatismes du rachis cervical supérieur. Paris: Masson et Cie; 1973.
5. Reindl R, Sen M, Aebi M. Anterior instrumentation for traumatic C1-C2 instability. Spine. 2003;28:E329–33.
6. MK S, Steffen T, Beckman L, Tsantrizos A, Reindl R, Aebi M. Atlantoaxial fusion using anterior transarticular screw fixation of C1-C2: technical innovation and biomechanical study. Eur Spine J. 2005;14(5):512–8.
7. Andersson S, Rodrigues M, Olerud C. Odontoid fractures: high complication rate associated with anterior screw fixation in the elderly. Eur Spine J. 2000;9(1):56–9.
8. Josten C, Jarvers JS, Glasmacher S, Heyde CE, Spiegl UJ. Anterior transarticular atlantoaxial screw fixation in combination with dens screw fixation for type II odontoid fractures with associated atlanto-odontoid osteoarthritis. Eur Spine J. 2016;25(7):2210–7.
9. Osti M, Philipp H, Meusburger B, Benedetto KP. Analysis of failure following anterior screw fixation of type II odontoid fractures in geriatric patients. Eur Spine J. 2011;20(11):1915–20. https://doi.org/10.1007/s00586-011-1890-7.
10. Gallie WE. Fracture and dislocations of the cervical spine. Am J Surg. 1939;46:495–9.
11. Brooks AL, Jenkins EB. Atlantoaxial arthrodesis by the wedge compression method. J Bone Joint Surg Am. 1978;60(3):279–84.