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# CROSS LAMINAR SCREW FIXATION OF THE AXIS

## *AKSİSİN ÇAPRAZ LAMİNAR VİDA İLE FİKSASYONU*

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**SUMMARY:**

Cross C2 laminar screwing is a potentially safe and effective technique for both initial and salvage applications of craniocervical and atlantoaxial fixation as well as for incorporation of C2 into subaxial fixations especially in cases having unsuitable anatomy for pedicle screw fixation. However, a careful preoperative radiologic evaluation is essential to determine the suitability of laminar anatomy for the screw placement on an individual basis. Our purpose of this study is to review previous literature on the anatomical, clinical and radiological basis and to create a useful guidance for C2 translaminar screw fixation.

**Keywords:** Lamina, anatomy, radiology, laminar screw, axis, fixation

**Level of Evidence:** Review Article, Level V

**ÖZET**

C2 çapraz laminar vidalama özellikle pedikül vida fiksasyonu için uygun olmayan anatomiye sahip olgularda kraniyoservikal ve atlantoaksiyel fiksasyon uygulamalarının hem başlangıç hem de kurtarma ameliyatlarında, aynı zamanda C2'nin subaksiyel fiksasyonlara dahil edildiği durumlar için potansiyel olarak güvenli ve etkin bir tekniktir. Bununla birlikte, bireysel bazda vida yerleştirilmesi için laminar anatominin uygunluğunun saptanmasında dikkatli bir ameliyat öncesi radyolojik değerlendirme önemlidir. Bu çalışmadaki amacımız anatomik, radyolojik ve klinik bazda daha önceki literatürü gözden geçirmek ve C2 translaminar vida fiksasyonu için kullanışlı bir klavuz oluşturmaktır.

**Anahtar Kelimeler:** lamina, anatomi, radyoloji, laminar vida, aksis, fiksasyon

**Kanıt Düzeyi:** Derleme Düzey V

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## INTRODUCTION:

A variety of techniques have been described for C-2 fixation since the initial wiring technique describing by Gallie, including the use of laminar hooks, posterior and anterior transarticular fixation, transpedicular screws, ishtmus screws, and, more recently, laminar screws[9,11,14,29]. All these techniques have been aimed to provide safe and solid fixation.

Initially, numerous wiring techniques had been used safely[6,8-9]. However, they have been associated with high pseudoarthrosis rate despite the use of halo or brace immobilization after surgery. Therefore, many types of screwing methods had been developed for C-2 fixation because of their higher biomechanical stability. Firstly, transarticular screwing proposed by Magerl and Seeman in 1987, was used for C-2 fixation with high rate of fusion[21]. However, it was technically demanding and carries a risk for fatal neurovascular injury. Afterwards, the C-1 lateral mass and C-2 pedicle screw insertion suggesting by Harms and Melcher was become a widely accepted screw-based technique as a safer method, but it was still technically demanding due to the danger of vertebral arter injury[11].

The ideal instrumentation technique for cervical screwing should provide both solid fixation as well as higher biomechanical stability, while reducing the risk of neurovascular injury. Crossing laminar screw fixation method described recently gained an increasing popularity among the C-2 screw fixation techniques due to providing excellent stability with eliminating the risk of vertebral artery injury[29]. In addition, it does not require the use of intra-operative navigation, because all relevant structures are directly visualized during surgery. However, careful preoperative planning using fine-cut computed tomography is necessary to determine the feasibility of laminar screw placement due to intra and interindiviual variations of C-2 laminar anatomy.

## PREOPERATIVE PLANNING:

Despite several modifications and advances in surgical technique since the first description by Wright in 2004, first stage in the laminar screw placement is a careful preoperative planning. The first step in the planning is to define whether lamina is intact and its anatomy is suitable for screw placement, using imaging method. The most advantageous method for preoperative planning is thin-slice tomography which provides high resolution in the bony structure. Information required for laminar screw placement is collected through 3D reformation of the images that are obtained from thin-slice tomography (Figure 1). At this stage, the thinnest laminar width, shortest laminar height and length and spinous process height should be assessed with the reformatted images to determine the suitable screw dimension and avoid screw collision along the ideal screw trajectory. At the same time, spinolaminar angle, the angle formed by the C2 spinous process and a line parallel to the longitudinal axis of the lamina, should be determined. So that, ventral violation into the spinal canal can be prevented. Only direct radiogram study regarding laminar screwing has been conducted by Lehman et al. on cadavers. Despite it is an intraoperative available and practical method, c-arm fluoroscopy was reported to be insufficient in showing ventral or dorsal violations[8].

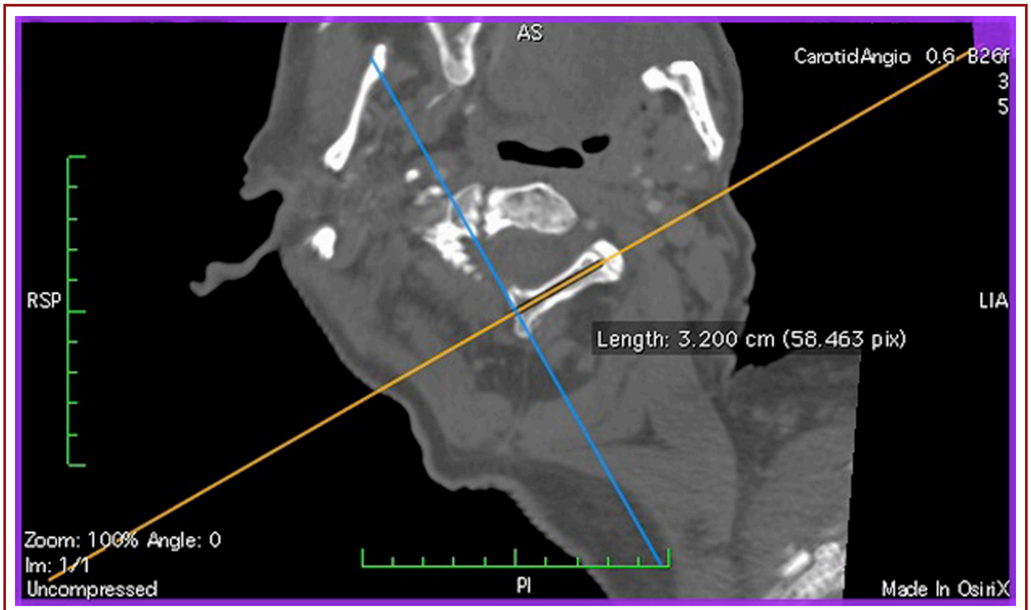


**Figure-1.** The reformatted axial CT images by using OsiriX imaging software (version 3.8.1, Pixmeo, Geneva, Switzerland) for preoperative planning.

## AXIS TRANSLAMINAR SCREWING TECHNIQUE (WRIGHT TECHNIQUE) AND ITS MODIFICATIONS:

In the Wright technique, first a high-speed drill was used to open a small cortical window at the junction of the C2 spinous process and lamina on one side, close to the rostral margin of the C2 lamina. With a hand drill, the contralateral (left) lamina was carefully drilled to a depth of 30 mm. It is slightly directed toward posterior in order to prevent violation from the cortical bone into the spinal canal. It is checked, whether or not there is a violation into the spinal canal through the drilling depth, with using a small probe. Polyaxial screw is then carefully inserted along the same trajectory. Whereas in placement of contralateral screw a small window, which was opened on the rostral half of the lamina spinous process junction at the beginning, is opened close to the caudal half in order to prevent a collision. Then the screw is placed by the same way[29]. Herein, the most important issue at the planning stage is to define whether or not the height of the spinous process is sufficient in order to prevent collision. The second important issue is that; although whether the penetration into the spinal canal was checked with a probe, ventral cortical breach into the spinal canal is yet likely to occur. The third important issue is challenge in insertion of the bone graft after translaminar screw placement. Therefore, several modifications were developed in the Wright technique for reduce complications and facilitate application of C-2 laminar screw placement.

Firstly, Jea et al. opened an exit cortical window at facet-lamina junction in addition to the entry hole at the junction of spinous process and the lamina. They used pedicle finder instead of high-speed drill in order to increase the sensitivity in disjunction of the cancellous and cortical bone. By this way, they carried out C-2 translaminar screwing by directing from entry hole of the spinous process-lamina junction to exit window at the facet-lamina junction without a need for fluoroscopy and preventing ventral violation into the spinal canal[13].

Secondly, Kabir et al. placed a unilateral laminar screw after removing of the upper part of the spinous process of C2 [15]. With this modification, laminar screw application combined with a unilateral pedicle screw was achieved in the presence of unilateral high riding vertebral artery. Additionally, bone graft can be inserted in the surgical site and cortical breach can be prevented. As a disadvantage, this method is not suitable for bilateral screw placement.

Finally, in their study with computerized images of the population under 18 years of age, Xia et al. reported that, violation into the spinal canal can be avoided using an entry window more ventral from the junction of spinous process and lamina, and an exit window more dorsal from the junction of facet-lamina. Disadvantage of this modification was found to be requirement of using shorter screws[30].

## COMPUTERIZED TOMOGRAPHY STUDIES:

In their study with 42 patients (23 male, 19 female) Nakanishi et al. reported that 80% of the male and 63% female patients have laminar width sufficient for 3-mm diameter screw placement, while only 50% of the male and 24% of female patients have laminar width sufficient for 4-mm diameter screw placement. In addition, the thinnest laminar width measured in the males and females was found as 0,8 mm and the largest laminar width as 8,4 mm. In conclusion, they emphasized that, the left-right distinction and height of the lamina is not effective in screw placement, while gender and individual differences are quite important[22].

In their study on 102 patients (60 male, 42 female, mean age 48.4) aged between 20 and 81 years, Kim et al. reported that, half of the patients have not laminar width sufficient for placement of 3.5 mm diameter laminar screw unilaterally. In their study, 68% of the male and 38% of female patients have laminar width sufficient for placement of 4 mm diameter laminar screw unilaterally, while only 50% of the male and 24% of female patients have laminar width sufficient for placement 4 mm diameter laminar screw bilaterally. Male population was reported that have a larger laminar width, although this was not of statistical significance. In addition, all the patients had a laminar length that been able to tolerate 22mm screw without foramen transversarium penetration. They emphasized that the importance of careful preoperative radiological evaluation, because of the thinner laminar width in Korean society than the western societies[16].

In a computerized tomography study performed with the 100 cadavers axis (50 male, 50 female), Yue et al defined a drilling entry point on the 5–6 mm posterior to the post-edge of the spinal canal of the C2 spinous process, and they reported that it was the more feasible and safer entry point for guiding a crossing laminar screw placement. The screw pass ratio from this entry point is 85%. Furthermore, they found the mean angulations in the coronal plane in this entry point as 9.57±4.36 degrees, the widest screw length as 21.74±2.44 mm and spinolaminar angle between 49.68±4.64 and 59.19±4.70 degrees. In conclusion the authors suggested that, preoperative radiological evaluation is necessary because of the individual differences in screw angulations[31].

Bhatnagar et al compared the suitability of C2 pedicle versus laminar screws in 50 patients using CT angiograms. They reported that 24% of patients having anatomy that would preclude 3.5-mm C2 pedicle screw fixation and more than 90% of patients having anatomy that could tolerate 3.5-mm C2 laminar screw fixation. They stated that C2 intralaminar screw fixation is a suitable option in cases having a vertebral artery anatomy precluding C2 pedicle screw fixation[2].

In a study with 113 pediatric patients (61 boy, 52 girl), Xia et al. reported that all the patients could tolerate longer than 30-mm-screw length in at least one side of the lamina. Of the patients, 95.6% could tolerate 4.5-mm diameter screw placement in at least one side of the lamina. Height of the spinous process was sufficient in 72.6% of the patients for bilateral screw placement. In addition, a marked shortening in the screw length and increase in the spinolaminar angulation were observed through measurements performed using modified Wright technique, and it was reported that shorter screws should be preferred in laminar screw placement when using modified Wright technique[30].

## CADAVER STUDIES:

In their study with 420 adult cadavers (118 black female, 85 white female, 100 black male and 117 white male) Casinelli et al. reported that, 92.6% of the axis bones have a lamina wider than 4mm and more than 99% were able to tolerate a screw length longer than 20 mm. Although race, height and weight were not of statistical significance, gender was found to be effective on all the parameters measured. In conclusion, the authors mentioned importance of the preoperative planning for safe screw placement[4].

In a study on axis samples of 38 cadavers, Wang reported that 16 sides of 14 samples (37%) were not suitable for placement of 3.5-mm diameter laminar screws, assuming the need for a 0.5 mm space for safety margin around the screws and, 32 sides of 18 samples (47%) were not suitable for placement of 4-mm diameter laminar screws. In this study, the average maximal screw length was found as 31.6 mm[27].

In a study on 84 adult cadavers by Dean et al using CT revealed that 97% of the axis samples could tolerate 3.5-mm diameter laminar screw and all could tolerate 20-mm long laminar screw. They found a poor correlation between direct measurements of the spinolaminar angle and computerized tomographic measurements in the axis samples, but they attributed this to the measurement variability. In conclusion, they emphasized that preoperative planning to be performed through computerized tomography is necessary for safe crossing laminar screw placement[7].

In a study by Hu et al. on 28 adult cadavers (18 male, 10 female, mean age: 52), axial laminar screws with the length of 24-27 mm were safe in fixation. Furthermore, the authors argued that pedicle screwing is the most suitable method for C-2 fixation even in the presence of abnormal vertebral artery, as long as pedicle anatomy is sufficient for screwing. They suggested that laminar screwing would be reliable approach in the presence of hypoplasic or unilaterally occluded vertebral artery in which asymmetric vertebral artery is clearly seen. They stated that however, surgical experience and status of the patients are the most important factors in selection of the surgical technique[12].

## BIOMECHANICAL STUDIES:

In their study with 6 fresh human cadavers, Gorek et al. compared fixation with bilateral C-2 translaminar screwing, Harms technique, unilateral pedicle and contralateral laminar screw and, reported that an equal stability was achieved[10].

In a study on 8 fresh human cadavers, Lapsiwala et al. compared flexion, extension, axial rotation and lateral bending motion of the neck after atlantoaxial fixation through 3 different methods with non-instrumented intact cervical spine. Furthermore, they added fixation by cable to the posterior fixation methods. Flexion, extension and axial rotation obtained with the atlantoaxial fixation which was performed through C-1 lateral mass and C-2 intralaminar screwing was found to be equal with the atlantoaxial fixation biomechanically obtained using transarticular and pedicle screws. Whereas resistance to lateral bending was lower in the first method than in other two methods[17].

In a study on 8 fresh human cadavers, Reddy et al. compared the methods of posterior cervical fixation with C-3 lateral mass in addition to C-2 pedicle screwing and posterior cervical fixation with C-3 lateral mass in addition to C-2 translaminar screwing with the intact spine. They found that both the instrumentation methods provided a significant stiffness compared to intact spine. Although C-2 pedicle screwing method was seen to cause more restricted motion, no statistically significant difference was observed between both methods in terms of biomechanical stability[25].

In their study on 11 fresh human cadaveric samples, Lehman et al. proposed that C-2 laminar screwing provided the strongest fixation both in the initial and salvage operations. In addition they reported that C-2 laminar screwing provided a stronger fixation compared to lateral mass screwing[19].

In a study on 6 fresh cadaveric cervical spines, Benke et al. compared flexion, extension, axial rotation and lateral bending motions of the neck following the posterior cervical fixation with C3-6 lateral mass screwing in addition to C-2 pedicle screwing and posterior cervical fixation with C3-6 lateral mass screwing in addition to C-2 intralaminar screwing with the intact spine. They reported that, laminar screws were more rigid in all the motion planes when compared to intact spine. In addition, they reported that laminar screws were less rigid in lateral bending, equal strictness in flexion-extension and more rigid in axial rotation when compared to the pedicle screws[1].

## CLINICAL STUDIES:

Wright described C-2 crossing laminar screwing technique for the first time in 10 patients (8 male, 2 female) presenting with trauma. Postoperatively all patients had used cervical collars for 6 weeks and only one patient died at the postoperative second month due to cardiac problems. Wright proposed that, although biomechanical results are not available, this technique would gain increasing popularity and would be used in a greater number of patients without risk of vertebral artery injury[29].

Wang used the crossing laminar screws for axis fixation in 30 patients (12 male, 18 female, mean age:55) with various pathologies. None of the patients developed intraoperative complication. Dorsal laminar breach was seen in 11 patients and ventral violation (into the spinal canal) in 1 patient, but no neurological symptom was observed. Hardware fracture was seen in 2 patients in the early period. The author reported that intralaminar screws were under increased stress and strainn due to the unique position of the screw heads and therefore recommended use of the larger diameter screws or additional fixation points at the adjacent levels[28].

Rhee et al. prevented screw collision in a 81 years old female patient who had low profiles of C2 lamina with modification of trajectory of inferior laminar screw by drilling the bifid inferior base of C2 spinous process at two points on the entry side. They also reported that simple modifications provide stability of fixation in patients with low profiles C2 laminas. In addition, they stated that the importance of careful preoperative evaluation (26).

In their study with 167 patients, Parker et al. compared C2 translaminar and C2 pedicle screwing for axial (n=31) and subaxial (n=136) cervical fusions. Revision surgery was required in 4 patients undergone subaxial fixation with translaminar screwing due to pseudoarthrosis or screw loosening at the first year follow-up. The authors reported that C2 translaminar screws were equally effective as C2 pedicle screws for axial fixation at the one-year follow-up, but durability was lower in C-2 translaminar screwing than in C-2 pedicle screwing for subaxial fixation (24).

Chaumon et al. used C-2 translaminar screwing for axial and subaxial fixation in 7 pediatric patients (4 boy, 3 girl) and reported this method is safe with high fusion rates[5].

Ma et al. retrospectively examined 35 patients (19 male, 16 female, mean age: 45) underwent atlantoaxial fixation with C-2 translaminar screwing in addition to C-1 lateral mass screwing, and found on computerized tomography that partial dorsal laminar breach occurred in 10 patients at mean follow-up of 29 months (6-54 months). However, none of the patients required revision due to pseudoarthrosis or screw loosening, and fusion was observed in all the patients at the end of the follow-up period. The authors reported that, C-2 fixation with translaminar screws is a straightforward and efficient method in cases of the unilaterally occluded vertebral artery or if the pedicle anatomy is not convenient for screw placement[20].

Bransford et al. retrospectively examined 383 patients who underwent axis fixation using different screwing techniques (pedicle, pars, isthmus and laminar) and laminar screws were placed for C-2 fixation in 63 of them in a four-year period. No complication regarding to C-2 laminar screwing was observed in their series of 58 patients except for 5 patients whom without having a CT in follow-up period[3].

Park et al. followed 14 patients (8 male, 6 female) who underwent posterior fixation with C2 translaminar screws for various pathologies, during mean follow-up 11.6 months. They observed radiographically bony fusion in 11 (91.7%) patients at the end of the 6 months follow-up, and five of them demonstrated improvement in initial neurological deficit. The authors stated that, fixation using C-2 translaminar screws is a quite practicle method with preoperative planning and, stress and strain of the laminar screws could be reduced by additional connectors[23].

## CONCLUSION:

Consequently, translaminar screwing technique is a method that could be confidently preferred and readily applied both in the initial and salvage operations in case of need for axis fixation. As it is seen in all above mentioned studies, preoperative planning is the most important consideration for determination of the length and diameter of the screws.

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