# Study on the application of a new type of vertebral plate nail guide

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# Abstract

**Objective** :To explore the safety and accuracy of the novel C2 laminar staple guide through in vitro experiments.

**Methods** 40 cases of cervical spine 3D CT data were selected to produce the same two sets of 3D printed specimens (groups a and b), and the self-made guide was used to assist nail placement on group a specimens (group A: guide nail placement group), and group b Laminate nails were placed free-hand on the specimens (group B: free-hand nailing group), and a three-dimensional modeled simulated nailing was reconstructed on the computer (group C: 3D simulated nailing group). Simultaneously measure the danger level, the position of the needle exit point and the inclination angle of the screw placement position of each group.

**Results :**In group A, 75 screws were acceptable and 5 were dangerous. The acceptable rate was 93%, and the double cortical rate was 92%. There were 62 position-acceptable screws in group B, and 18 positions were dangerous, with an acceptable rate of 77% and a double cortical rate of 32%. There was a statistically significant difference between the two groups ($P < 0.05$). There was no significant difference in the accuracy of the needle point and the inclination angle of the nail channel between group A and group C (ideal nail channel). There was no significant difference between groups A and C (ideal nail channel). The comparison of the inclination angle of the nail channel is statistically significant ($P < 0.05$). The results show that the screw assisted by the guide is closer to the ideal nail channel, which is safer than the manual nail placement, and can effectively improve the double cortical rate.

**Conclusion:** The guide is universal, with stable structure, accurate guidance, and easy operation. It can be placed with bilateral lamina screws at the same time, shortening the time of nail placement, avoiding the collision of two-way cross screws, increase the rate of double cortex. Ultimately, efficiency and security can be improved.


# Introduction

C1-2 fractures and dislocations are more common in upper cervical spine trauma. This type of disease often requires posterior cervical spine internal fixation. The fixation methods are more diverse, and the choice of fixation methods is still controversial in clinical practice. At present, the main techniques of posterior C1-2 fixation include posterior atlantoaxial transarticular process and atlantolateral mass fixation, and atlantoaxial bilateral pedicle internal fixation. Although both of these techniques can obtain strong biomechanical properties, the surgeon has high requirements on the operation technique and experience, and it is easy to damage the vertebral artery [1]. The vertebral artery injury rate reached 4% during arthroscopic screw operation [2]. Lgarashi et al.[3] related autopsy studies have shown that about 20% of the specimens have significantly narrower pedicle diameters (less than 3.5 mm), and 25% of the specimens have C2 lateral mass development deformity with high-hanging tortuous vertebral artery deformity. For this situation, C2 laminar cross screw internal fixation technology has certain advantages[4, 5]. Wright[6] proposed that the axial lamina nail based on the large lamina structure can provide stable biomechanics, and can avoid the vertebral artery, and its practicality has also been clinically confirmed [7].

# 1 Structure Principle And Use Method Of Guide

## 1.1 The structure principle and use method of the new pivotal lamina screw guide

There are three main indicators to determine the accuracy and safety of the placement of the axial lamina nail, namely, the needle entry point, the needle exit point and the inclination angle, as long as the appropriate needle entry point and needle exit point are locked during the nail placement process Obtain a safe and effective nail path, and it is easy to determine the proper needle entry point during the nail placement process, and the needle exit point is often difficult to control. During the guiding process, the guide takes the needle point of the axial lamina as the marking point, and locks the needle point first, but because of the difference in the anatomy of the vertebrae of different patients, the needle insertion point of the axial lamina needs to be adjusted accordingly. In order to achieve a proper needle entry point, in order to solve this problem, the guide sleeve of this guide must always take the needle exit point as the center of the guide sleeve during the adjustment process and point to the needle exit point. The main body of the guide is provided with an arc-shaped slide rail. The guide sleeve can be finely adjusted to the center of the slide rail to ensure that the guide sleeve always takes the needle exit point as the center and points to the needle exit point (Fig. 1-a). A three-dimensional model was reconstructed on the computer to simulate nail placement. After the distal end of the screw was locked out of the needle point, under the premise that the screw did not penetrate the medial and lateral cortex of the axis, the movable angle of the tail of the screw in the lamina was simulated to obtain a fine-tuned angle (Fig. 1-b). In order to avoid the cross nail friction, at the same time, the optimal cross screw angle is simulated through 3D simulation, combined with the fine adjustment angle of the guide and the principle of the slide rail centripetality, a 3D model of the guide is modeled in the MedCAD module, and the main frame model of the guide is designed It is printed with the eos m400 laser metal 3d printer, and the guide sleeve and slide rail connecting ring are printed using polylactic acid material. A new type of axial laminar screw guide (Fig. 1–5) designed to assist in the placement of axial laminar screws is designed by 3D printing technology. The guide includes a fixed frame body, a bidirectional guide sleeve, and an arc-shaped centripetal slide, The slide rail connecting ring and other parts; the main body of the fixing frame includes an arc-shaped bidirectional fixing frame: the upper end is a spinous process locking sleeve, which can be inserted into a Kirschner wire to fix the guide on the spinous process, and the central part is an arc-shaped centripetal slide rail. The guide can be connected and fixed inside the slide rail through the slide rail connection ring to ensure the centripetality of the sleeve. At the same time, the guide barrel is a three-stage sleeve structure, which can complete all nail placement operations; at the same time, in order to obtain better stability, The main body of the guide adopts a metal structure to reduce the deformation during the operation (Fig. 1-c).

# Instructions

The postoperative mid-medial approach reveals the structure of the posterior segment of the intended operation, and then fixes the outlet sleeve of the new axis laminar nail guide at the position of the needle outlet, and adjusts the position of the guide sleeve of the slide rail through the slide rail. Lock at the ideal nail entry point, insert the 1.5 mm Kirschner wire into the spinous process locking sleeve and fix it to the spinous process of the vertebra, then place the Kirschner needle in the guide sleeve, and place the Kirschner needle in the direction of the sleeve The electric drill is used to drill a 1.5 mm Kirschner wire through the navigation hole of the biaxial slide guide of the vertebral lamina screw, and the hollow screw is placed after the position is satisfactory.

# 1.2 In Vitro Safety And Accuracy Analysis

# Specimen preparation

Select 40 random three-dimensional CT data from January 2018 to June 2018, 19 female patients, including 21 male patients, with an average height of (172.9 ± 9.5 cm) and an average age of (51.1 ± 12.8). Exclude patients with axial lamina defects and hypoplasia. All are provided by the Imaging Department of the Affiliated Hospital of Xuzhou Medical University. The parameters of the selected cases are uniformly scanned at a window width of 1000, a tube current of 280 mA, a distance of 0.938, a thickness interval of 1 mm, a scanning distance of 0.5 mm, a tube voltage of 120 kV, and a window 300. The selected three-dimensional CT and other image data of the cervical spine are transferred to the 3D reconstruction medical image processing software (Mimics 10.01 Belgium) in the form of medical image data. The original mask of the upper cervical spine was obtained by image thresholding and segmentation threshold. Use the three-dimensional area growth technology to repair the space loopholes, fill in the hole filling technology, and separate and construct the three-dimensional model of the upper cervical spine specimen through the model editing tool to obtain the defect-free model data; save the model data in STL format. Convert the designed guide sleeve and slide rail connection ring model data and connect it to a 3D printer (FDM-3000, Stratasys) and use a fully transparent polyethylene material to print out cervical spine specimens. The 3D printed cervical spine specimens are made of fully transparent materials, and the transparent polyethylene materials are used to print out the cervical spine specimens of groups a and b. The 3D printed cervical spine specimens are fully transparent. Group a (40) applies to the guide group, and group b (40) applies to the free-hand nail set.

# Methods

Uniform operation is performed by spinal surgeons who do not have experience in the placement of intervertebral laminar screws. Using a group of specimens, a 3.5 mm Kirschner wire was inserted with the help of a new type of axial laminar screw guide (group A: guide set nail group, experimental group) (Fig. 2 2-a), and the fully transparent cervical spine was 3D Place the printed specimen on the operating table with the back side facing upwards, and then fix the outlet sleeve of the new pivotal lamina screw guide at the position of the outlet point. Adjust the position of the slide guide sleeve through the slide rail to lock it in the ideal position. Nail point position (upper laminar nail: spinous process at the vertex of the lamina junction, 5 mm from the upper edge of the lamina. Lower laminar screw: spinous process at the vertex of the lamina junction, 9 mm from the upper edge of the lamina. From the center of the inferior articular process Pierce); fix the Kirschner wire into the spinous process locking sleeve and fix it to the spinous process of the vertebrae, and then insert the Kirschner wire into the guide sleeve (2) to pass the Kirschner wire out of the dorsal cortex of the outer edge of the lamina, Get the distance between the needle point and the inferior mass on the axial lamina (L1: The distance between the upper laminar nail and the outer edge of the lateral mass. L2: The distance between the upper laminar nail and the upper edge of the lateral mass. L3: The distance between the lower laminar nail and the outer edge of the lateral mass. L4: the distance between the lower laminar nail and the lower edge of the lateral mass).

Nail specimens are made of transparent materials, and the relationship between the screw and the anterior and posterior cortex of the axial lamina can be evaluated by visual aided vernier calipers (Grade 1–5: 1–2 is acceptable, 3–4 is dangerous for location, and 1 is screw Located in the middle of the lamina or causing only slight cortical shape changes, grade 2 is the screw through the cortex <□ screw diameter, grade 3 is the screw through the cortex between □ to ½ screw diameter, and grade 4 is the screw through the cortex> ½ screw Diameter, grade 5 is the rate of screw penetration through the cortex (the entire screw diameter) and double cortex.

Using an electric drill to freely place the axis lamina nails on the group b specimens according to the standard cross nail placement direction (group B: freehand nail placement group, control group) (Fig. 2 2-b). Put the Kirschner wire through the dorsal cortex of the outer edge of the lamina, measure the screw risk level, double cortical rate and the location of the needle point.

Reconstruct the same 40 specimen data on the computer into a three-dimensional model and simulate nail placement (Group C: 3D simulated nail placement group, ideal group) (Fig. 2-2c). Import the specimen data into the MedCAD module for reconstruction, replace the screw with a 3.5 mm diameter cylinder, use the standard cross nail placement direction to simulate nail placement, and pass the simulated laminar nail out of the dorsal cortex of the outer edge of the laminae to obtain the ideal needle point data, To measure the ideal inclination angle of the ideal needle point.

Three sets of anatomical data were statistically analyzed to determine accuracy.

# 2 Research Purpose And Significance

The accuracy and safety of the C2 lamina screw will be affected by factors such as the operator's operating experience, fluoroscopy effect, intraoperative position, and other factors. In some cases, the screw invades the spinal cord due to the error in the direction of the nail placement, causing high spinal cord injury [8,9, 10]. Nail placement by the auxiliary guide can effectively reduce this complication and improve the efficiency of nail placement. Most of the existing vertebral guides are individual models [11,12,13], which need to be customized in advance, which is expensive and requires a long time to prepare before surgery. At the same time, it must be closely fitted with the lamina to ensure accuracy. Improper cleaning of soft tissue or damage to the lamina structure will affect the accuracy of the guide. In addition, the lack of hardness of polyethylene and other materials will lead to structural instability. The error of 3D simulation and the lack of fixed points will affect the accuracy of the guide. There is a clinical need for a guide device that is simple in operation, stable in structure, accurate in guidance, safe in use, and reusable.

In order to insert the laminar screw more accurately and safely, this experiment takes the needle point of the axial laminar nail as the marked point, and uses the arc slide centripetal principle combined with the anatomical structure of the axial lamina and spinous process, through 3D printing Technology designed a bidirectional slide rail guide for the insertion of the axial laminar nail. The accuracy test of the nail placement was performed in vitro to verify its safety and accuracy, in order to provide a more convenient and safe for the clinic Auxiliary equipment to improve the safety and efficiency of surgery.

# 3 Statistical Methods

Using SPSS21.0 statistical analysis, the non-positive distribution data is expressed by the median, and the measurement data data is expressed by ——x±s, $\chi^2$ test was used for the comparison of percentages, and the independent sample t test was used for the comparison of the mean between the two groups. *P*< 0.05 was considered statistically significant.

## Results

In group A, 80 vertebral lamina nails were acceptable in 75 cases through the observation position in the transparent specimen. The positional risk was 5 cases. The acceptance rate was 93%. Among them, 74 had double cortex, and the rate of double cortex was 92%.. In group B, the 80 vertebral lamina nails can be accepted in 62 cases through the observation position, the positional risk is 18 cases, and the acceptance rate is 77% (Table 1), of which 26 have reached the double cortex, double The cortical rate was 32%, and the difference between the two groups was statistically significant (P < 0.05). The accuracy of the needle exit point and the inclination angle of the nail path in Group A and Group C (ideal nail path) (Table 2), the difference was not statistically significant (P > 0.05), the needles in Group B and Group C (ideal nail path) The accuracy of the points and the comparison of the inclination angle of the nail path (Table 3), the difference is statistically significant (P < 0.05), the results show that the screw assisted by the guide is closer to the ideal nail path, and the safety is higher than that of the free hand nail. And can effectively improve the rate of double cortex.

Table 1

Comparison of Risk Grade and Double Cortical Rate between group A and group B ($\bar{x}$±s, mm,n=80)

| Group | Number of nails | Location acceptable | Location dangerous | Acceptable rate | Dual cortex rate |
|---|---|---|---|---|---|
| Group B | 80 | 62 | 18 | 77% | 26(32%) |
| Group A | 80 | 75 | 5 | 93% | 74(92%) |

Note: There was significant difference in the acceptable rate of the nail track position between the two groups (p□0.05), and the difference between the two groups was statistically significant (p□0.05

Table 2 Comparison of needle point position and inclination angle between group A and group C (ideal group)

($\bar{x}$x±s, mm,n = 40)

| | Group A | Group C | *P* |
|---|---|---|---|
| L1(mm) | 6.55 ± 0.75 | 6.44 ± 0.52 | □0.05 |
| L2(mm) | 7.61 ± 1.05 | 7.05 ± 0.84 | □0.05 |
| L3(mm) | 3.86 ± 0.84 | 3.55 ± 0.75 | □0.05 |
| L4(mm) | 4.97 ± 0.68 | 5.09 ± 0.74 | □0.05 |
| Inclination(°) | 55.73°±1.54° | 55.51°±1.62° | □0.05 |

Note: There was no significant difference in the position of needle point and the angle of inclination between the two groups (*p*>0.05).

Table 3

Comparison of needle point position and inclination angle between group B and group C (ideal group)(x$\bar{x}$±s, mm,n = 40)

| | Group C | Group B | P |
|---|---|---|---|
| L1(mm) | 6.44 ± 0.52 | 4.71 ± 0.84 | □0.05 |
| L2(mm) | 7.05 ± 0.84 | 6.03 ± 0.79 | □0.05 |
| L3(mm) | 3.55 ± 0.75 | 5.11 ± 0.83 | □0.05 |
| L4(mm) | 5.09 ± 0.74 | 6.13 ± 0.58 | □0.05 |
| Inclination(°) | 55.51°±1.62° | 51.92°±3.11° | □0.05 |

Note: There were statistically significant differences between the two groups in the position of needle point and the angle of inclination($p$>0.05)

# Discussion

# 5.1 The Choice Of Internal Fixation Of The Vertebrae

The fixation of the pivotal vertebrae is essential in cervical spine fixation surgery. There are mainly C1 / 2 joint screws and transpedicular fixation techniques. Wright and Lauryssen [14] found in clinical that the vertebral artery injury rate in the clinical application of transatlantoaxial joint fixation technology can reach 4.1%. According to anatomy of cadaveric specimens, it was found that 20% of the C2 vertebral artery foramen region had a tortuous deformity of the vertebral artery, which invaded the isthmus and lamina [15]. Yan Ming [7] and other researchers found that 5% of patients had a cavity deformity in the vertebral pedicle, which increased the risk of axial pedicle screws. The cross-screw technique can effectively reduce the arterial injury rate, and its wide and thick laminae can ensure the effective biomechanical stability of laminar nails [16, 17, 18]. Cassinelli et al. [19] found that the thickness of the vertebral lamina of the axial vertebrae exceeds 5 mm to reach 70%, and the thickness of the vertebrae exceeds 4 mm to reach 92%. The actual feasible length of the lamina is 24 mm, and the specimens exceeding 20 mm reach 99%. This indicates that The fixation of axial lamina screws on the anatomical structure is practical and feasible for most people. Ma Xiangyang et al [20] found that the average thickness of the proximal end of the axial lamina exceeds 3 mm, the average thickness of the middle segment exceeds 5.9 mm, the average thickness of the distal lamina exceeds 5.59 mm, and the spinous process The average height of the base is more than 12.1 mm, the height of the lamina is more than 12 mm, and the average length of the lamina screw is more than 25 mm; this shows that most people's vertebral structures can accommodate adequate diameter and length of vertebral lamina nails. Considering the limitation of the spinal process of C2 on the angle of the laminar screw channel, Kabir and Casey [21] can remove the laminar cross screw directly in the direction of the laminar by biting off the spinous process of C2 and exposing the cancellous bone. The risk of penetrating the lamina cortex due to the angle deviation of the screw placement, but this technique has a certain effect on the stability of the inserted screw.

Spinal lamina nails are a reliable way to fix the posterior cervical route. Wright [6] suggested that based on the large vertebral lamina, it can provide stable biomechanics and avoid vertebral arteries. Confirmed clinically [7]. The biomechanical effect can achieve the same effect as pedicle screw and transarticular screw fixation [22, 23, 24]. Jea [25] improved the single cortical screw fixation method in clinical application. Under the condition of choosing the same nail insertion method, the screw penetrated the lateral cortex of the axial lamina, and the needle exit point was located at the connection between the articular process and the lamina At the outer edge of the lamina, an ideal double cortical fixation is formed to achieve greater emphasis on biomechanical stability.

### 5.2 The Clinical Significance of Guide Assist in C2 Laminar Screw Internal Fixation

During C2 laminar screw fixation technique, the accuracy and safety of nail placement will be affected by the operator's operating experience, fluoroscopy effect, intraoperative position and other factors. The existing relevant clinical data shows that some cases have caused screws to invade the spinal cord due to the wrong orientation of the nail, causing high spinal cord injury [26, 27]. In addition, improper grasp of the screw length or direction during screw placement may also damage the vertebral artery [17]. Notmell et al. [10] and rajasekaran et al. [28] assisted with the intraoperative fluoroscopic three-dimensional navigation system during clinical surgery, and completed a considerable number of lamina nail insertion surgery. Clinical follow-up results showed the accuracy of surgical nail placement Satisfaction greatly improves the success rate of the placement of the axial lamina nail. And some clinical data analysis results show that with the precise assistance of the intraoperative fluoroscopic 3D navigation system, the diameter of the inserted screw can be increased to 4 mm. However, this navigation system also has some shortcomings, such as the high cost of the entire 3D navigation system, which leads to increased surgical costs. At the same time, similar 3D navigation systems often require professional and technical personnel to operate, which increases the complexity of the operation, and most hospitals do not meet the configuration and application. condition.

Based on the application of three-dimensional data simulation and synthesis technology in orthopedics, some researchers have applied three-dimensional digital simulation modeling technology to the internal fixation of C2 lamina screws. By extracting the three-dimensional CT data of the cervical spine, a personalized guide device for assisting the placement of C2 laminar screws is established, which plays a certain role in improving the accuracy of the placement of axial laminar screws [15]. Lu et al. [20] obtained the complete structure and nail path of the original data, and reconstructed the model and nail path from the thin-layer CT scan data. On the computer, the spiral track plate was locked and reconstructed by UG Imageware software. The structure of the posterior spine, reconstruction of the positioning track and the virtual screw mold, and finally the use of light curing rapid prototyping technology, using photosensitive resin as the material, to make customized guides. Through the analysis of ascending corpse accuracy and clinical application analysis, the customized guide based on this technology can effectively increase the efficiency of C2 intralaminar screw implantation [29]. However, there are still some shortcomings with this technology [30]: In the design process of the navigation template, there are many softwares that need to be used, and the data transmission conversion process is easy to be missing, which affects the accuracy of the final modeling. In addition, the requirements for software operation and professional spine surgery knowledge are extremely high, resulting in a long learning curve for design and operation. Because the principle of SLA technology is to use laser or ultraviolet radiation to irradiate the liquid photosensitive resin layer by layer, it has a higher working environment, and the liquid resin is easy to condense, which is not conducive to molding. The resin is easy to shrink and deform during the curing. In addition, higher design and production costs limit the development of this technology. At the same time, due to the complexity of the computer simulation design process and the time consuming process, it has hindered its application in emergency surgery. Furthermore, because the material is resin, its thermal decomposition products are biotoxic, and there are potential safety hazards in clinical application. And after molding, the position of the guide tube on the template cannot be changed, and the guide error caused by the material deformation is very easy.

Nail placement by the auxiliary guide can effectively reduce this complication and improve the efficiency of nail placement. Most of the existing vertebral guides are individual models [11, 12, 13], which need to be customized in advance, are expensive, and require a long time to prepare before surgery. Improper cleaning of soft tissue or damage to the lamina structure will affect the accuracy of the guide. In addition, the insufficient hardness of polyethylene and other materials will lead to structural instability. Errors in 3D simulation and insufficient fixed points will affect the accuracy of the guide. Therefore, this study aims to develop a guide device that is simple in operation, stable in structure, accurate in guidance, safe in use, and reusable for clinical application.

In order to insert the laminar screw more accurately and safely, this experiment takes the needle point of the axial laminar nail as the marked point, and uses the arc slide centripetal principle combined with the anatomical structure of the axial lamina and spinous process, through 3D printing The technology designed a new type of lamina screw guide for the insertion of lamina screws. The accuracy test of nail placement was performed in vitro, and the clinical application analysis was performed to verify its safety and accuracy.

### 5.3 Structure principle of bidirectional slide rail guide system for vertebral lamina nail

There are three main indicators to determine the accuracy and safety of the placement of the axial lamina nail, namely, the needle entry point, the needle exit point and the inclination angle, as long as the appropriate needle entry point and needle exit point are locked during the nail placement process Obtain a safe and effective nail path, and it is easy to determine the proper needle entry point during the nail placement process, and the needle exit point is often difficult to control. During the guiding process, the guide takes the needle point of the axial lamina as the marking point, and locks the needle point first, but because of the difference in the anatomy of the vertebrae of different patients, the needle insertion point of the axial lamina needs to be adjusted accordingly. In order to achieve a proper needle entry point, in order to solve this problem, the guide sleeve of this guide must always take the needle exit point as the center of the guide sleeve during the adjustment process and point to the needle exit point. The main body of the guide is provided with an arc-shaped slide rail, and the guide sleeve can be finely adjusted to the center of the slide rail to ensure that the guide sleeve always takes the needle point as the center of the circle and points to the needle point. The guide consists of a fixed frame body, a two-way guide sleeve, an arc-shaped centripetal slide rail, a slide rail connection ring and other parts; the fixed frame body includes an arc-shaped two-way fixed frame: the upper end is a spinous process locking sleeve, which can penetrate into the Kline The needle fixes the guide on the spinous process, and the middle is an arc-shaped centripetal slide rail. The guide can be fixed to the inside of the slide rail through the slide rail connection ring to ensure the centripetality of the sleeve; at the same time, in order to obtain better stability The main body of this guide adopts a metal structure to reduce deformation during operation.

### 5.4 The accuracy of C2 laminar staple bidirectional slide-type guide system

In vitro experiments and clinical application studies have shown that the new axis laminar nail guide assisted nail placement has higher safety than free hand nail placement, and locks the needle entry point and the needle exit point to ensure a higher double cortical rate, Effectively increase the mechanical strength of the inserted screw, and at the same time, in terms of accuracy, the new pivotal laminar screw guide assists the placement of the needle and the inclination angle is closer to the ideal nail path, because the guide can lock the needle The point and the needle out point can lock the safety nail path more effectively, with higher accuracy and safety.

The guide is a metal frame structure with high hardness and low deformation rate, which greatly improves the structural stability. The bidirectional slide rail guide does not require repeated fluoroscopy during navigation operation, which can greatly reduce the operation time and reduce the amount of radiation. Because it can be reused, it is superior to custom guides in cost. By guiding the positioning of the nail entry point and the needle exit position at the same time, this guider improves the double cortex rate, and then assists the two cross-fixation brackets to fix the guider on the spinous process, which can firmly stabilize the guider and avoid guiding errors. The guide tube needs to be in contact with the laminar line point, and it can be effectively and accurately guided when the soft tissue is left or the laminar structure is damaged. The entire operation is completed under visual inspection. The experimental results also show that the guide is accurate and reliable. The great clinical value provides an economical and reliable auxiliary method for the placement of axial lamina screws.

## Declarations

# Ethics approval and consent to participate:

Not applicable.

### Consent for publication:

Not applicable

### Availability of data and material:

The authors declare that the data and material are true and effective.

### Competing Interest:

The authors declare that they have no conflict of interest.

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## Authors’ contributions:

Maji Sun and Qiuan Wang contributed equally to this work. Maji Sun and Qiuan Wang designed research, performed research, analyzed data, and wrote the paper. Xingchen Zhang helps Maji Sun and Qiuan Wang complete the research. Kaijin Guo and Feng Yuan designed research and provided financial support. all authors contributed to the writing and revisions.

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# Figures

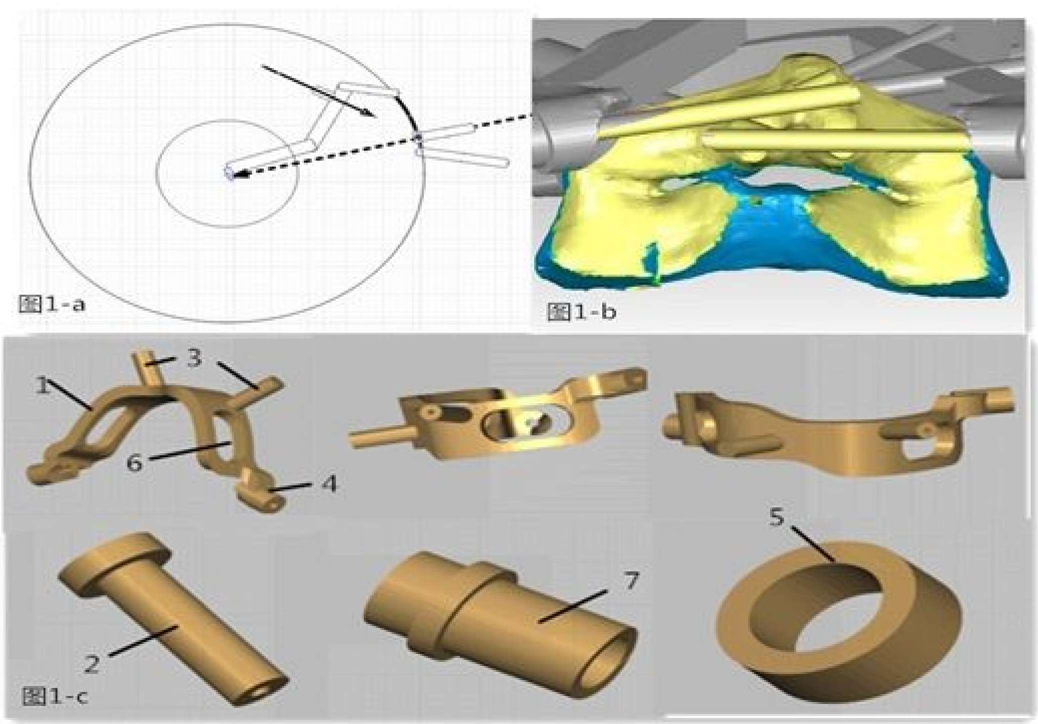


**Figure 1**

1-a：design principle: the concentricity principle of slide rail, 1-b：3D simulation to fine-tune the angle of nail channel. 1-c： Schematic diagram of separation of auxiliary parts of two-way slide rail guide (1) fixing frame main body (2) three-stage guide sleeve (3) spinous locking sleeve (4) pin point interface (5) slide rail connection ring 1(6) arc concentric slide rail (7) slide rail connection ring 2

## Figure 2

2-a：Group A (Guide assisted nail); 2-b：Group B (Unarmde nail placement)；2-c：Group C (3D Simulated Nail Set, Ideal Nail Track)