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# Research Progress of Rigid Skull Base Reconstruction after Transnasal Endoscopy

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***Abstract:*** *With the rapid development of diagnosis and treatment technology, equipment and instruments in the new era of neurosurgery, [1, 2] endoscope-assisted transnasal skull base surgery technology is becoming increasingly mature, surgical indications show an expanding trend, and the types of treated lesions are increasing day by day under the advantages of less trauma, quick recovery, high total resection rate and clear visual field exposure [3-5]. However, cerebrospinal fluid leakage and severe intracranial infection caused by the defect of skull base bone and dura mater have a great adverse impact on the prognosis of patients. Therefore, how to carry out long-lasting and effective skull base reconstruction after successful tumor resection is particularly important to reduce the occurrence of cerebrospinal fluid leakage after operation. Currently, there is no uniform standard for skull base reconstruction methods, which can be roughly divided into soft reconstruction and rigid reconstruction [6, 7]. There is no doubt about the importance of soft reconstruction in tissue water sealing, but rigid reconstruction of skull base is often ignored or even controversial [6]. In this paper, various techniques of skull base rigid reconstruction are reviewed, and the necessity of skull base rigid reconstruction is expounded.*

***Keywords:*** *Neuroendoscope, Skull base reconstruction, In situ bone flap, Anatomical reconstruction*

## 1. Introduction

How to reconstruct skull base effectively after resection of tumor by endoscope-assisted transnasal approach has always been a challenge faced by neurosurgeons [8, 9]. Skull base reconstruction aims to establish an effective barrier to block intracranial and extracranial space, avoid cerebrospinal fluid leakage and intracranial infection after operation, eliminate dead space and protect normal structure [5, 9-10]. According to the anatomical level of skull base, skull base defects after endoscopic nasal surgery mainly include soft tissue defects (including dura mater and nasal mucosa) and skull base bone defects. Correspondingly, we call its reconstruction soft reconstruction and rigid reconstruction.

In order to achieve the goal of completely separating nasal cavity from intracranial space, providing sufficient support for important peripheral nerves and vessels, eliminating surgical cavity and maintaining normal function of paranasal sinus system, the necessity of combining soft reconstruction with rigid reconstruction must be expounded when the skull base defect is large. Soft reconstruction has always been paid attention to, because its watertightness plays a key role in avoiding cerebrospinal fluid after operation. The main methods include using autologous muscle, fat, fascia, free or pedicled nasal mucosal flap, artificial dura mater or dura mater suture, bio-glue sealant, gelatin sponge and nasal packing materials [5, 11-12]. Currently, there are few studies on rigid reconstruction, and many scholars even say that it is not necessary for rigid reconstruction [6].

## 2. Necessity of Rigid Reconstruction of Skull Base after Endoscopic Sinus Surgery

With the expansion of the application scope of endoscope-assisted transnasal surgery, the larger and more complex skull base defect after operation poses new challenges to skull base reconstruction. Failure of skull base reconstruction will lead to serious complications such as cerebrospinal fluid leakage, intracranial infection or tension pneumocephalus after operation. Although the extensive application of pedicled nasal septum mucosal flap reconstruction technology has greatly reduced the incidence of cerebrospinal fluid leakage after operation, there are still studies that report that the incidence of cerebrospinal fluid leakage after Expended Endoscopic Endonassal Transsphenoidal approach (EETA)

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has an increasing trend [13-15], which results from the fact that when the skull base defect is large and complex, only soft tissue reconstruction cannot provide strong support, and cerebrospinal fluid pulsation will shift the reconstruction materials, especially when the intracranial pressure fluctuates sharply (such as sneezing, coughing hard, emotional excitement). When the skull base lesions are large in volume and hard in texture, the saddle diaphragm is often damaged and high-flow cerebrospinal fluid leakage occurs during operation. Simply using thigh fascia lata, artificial dura mater or nasal mucosa reconstruction cannot effectively resist the pressure caused by high-flow cerebrospinal fluid leakage, so it is necessary to provide sufficient mechanical support by rigid reconstruction [13-14, 16], which can provide support for soft reconstruction and avoid displacement of reconstructed tissue, and the two complement each other. In addition, according to the anatomical level of skull base, the skull base defects caused by endoscope-assisted transnasal resection of skull base tumors mainly include skull base soft tissue defects and skull base bone defects. The goal of endoscopic nasal skull base reconstruction is consistent with that of traditional craniotomy, namely completely separating cranial cavity from nasal cavity and reestablishing watertight and closed tissue barrier; provide effective support for intracranial blood vessels and nerve structures; avoid gas entering the skull; Restore the original anatomical structure as much as possible. In order to achieve the above goals, the necessity of rigid reconstruction is self-evident.

## 3. Common Techniques and Materials for Rigid Skull Base Reconstruction after Endoscopic Sinus Surgery

Esposito put forward Kelly grade of cerebrospinal fluid leakage according to the degree of skull base defect and cerebrospinal fluid leakage in 2007 [17], namely the size of sellar diaphragm and arachnoid defect observed by endoscope can be divided into: cerebrospinal fluid leakage (grade 0) was observed; no obvious sellar diaphragmatic defect but small exudation of cerebrospinal fluid (grade 1); moderate leakage with definite sellar diaphragmatic defect (grade 2); large diaphragmatic sellar defect with high-flow cerebrospinal fluid leakage (grade 3). It is necessary to advocate the corresponding reconstruction methods according to the different grades of cerebrospinal fluid leakage: when the sellar diaphragm is intact or only low and medium flow cerebrospinal fluid leakage occurs during operation, it is sufficient to use artificial dura mater, fat packing, distal fascia lata and even pedicled nasal septum mucosal flap (PNSF) for soft reconstruction [13, 18-20]; however, rigid reconstruction is necessary for high-flow cerebrospinal fluid leakage with open ventricle/cistern [14, 16, 20-22]. However, the bony anatomical structure of sella turcica region of skull base is extremely complex, and the anatomical structures of sella turcica, sphenoid plateau and clival recess are in different planes. The bony structure is irregular and uneven in thickness, which is closely related to the surrounding important neurovascular structures, so it poses a great challenge to the selection of rigid reconstruction materials and methods. In this paper, the methods of rigid skull base reconstruction using various repair materials and their advantages and disadvantages are summarized as follows.

### *3.1 Artificial Repair Materials*

With the rapid development of medical materials science, more and more rigid materials can be used for endoscopic skull base reconstruction. At present, the materials used for rigid skull base reconstruction mainly include titanium mesh, porous polyethylene, collagen-hydroxyapatite, poly-ether-ether-ketone (PEEK), bone cement and others [5, 23-27]. Although with the rapid development of materials research, Various artificial materials have become a reliable substitute material for skull base reconstruction and repair in terms of biological tissue compatibility, toughness and support. However, as allogeneic tissues, artificial materials are still difficult to avoid the risks of tissue rejection, infection, nerve and blood vessel compression, etc. Moreover, the cost of artificial materials is generally high, which increases the economic burden of patients. In recent years, with the rapid development of 3D printing technology, the application scope of artificial materials has been broadened by combining materials science and imaging, and new vitality has been added to the rigid reconstruction of endoscopic skull base surgery [28-29]. After collecting relevant data through neuronavigation before and during operation, the rigid reconstruction material of skull base can be designed individually, and the bone defect site can be reconstructed accurately. However, at present, 3D printing technology has not been extended to clinical practice, and there is a lack of random case data to verify its clinical effect.

### *3.2 Autogenous Bone Graft*

Endoscopic skull base surgery for rigid skull base reconstruction of autogenous bone fragments including ribs, cranial bone, pear bone, sphenoid sinus anterior wall and nasal septum bone. Among them, ribs and cranial bones are seldom used; Some scholars used the anterior wall of sphenoid sinus and vomerosa as bony support, and mucosa as tissue seal to form a "membrane-bone-membrane" sandwich skull base reconstruction technology to restore the anatomical level of skull base [30]; some scholars also used pear bone in "Gasket-seal" technology [31], and later this reconstruction method of combining membrane with bone was widely used. The most widely used artificial bone piece is nasal septum bone [32], including nasal septum cartilage and bony nasal septum, which is mainly composed of part of ethmoid vertical plate, anterior wall of sphenoid sinus and pear bone. This kind of repair material has the following advantages: (1) It is convenient to obtain materials and easy to operate, and it can easily obtain reconstruction materials during endoscopic nasal surgery; (2) It is human body's own tissue and has good biological organization; (3) Using local materials, turning waste into wealth, has less trauma to patients and is more economical. However, in some complex lesions, the sellar floor bone defect is large and complex, and the obtained nasal septum bone cannot meet the goal of "bony reconstruction" in size, thickness and three-position contour. Some patients are also difficult to obtain materials because of their weak or even absent nasal septum bone, and the nasal septum bone is difficult to resist high-flow pressure when high-flow cerebrospinal fluid leaks. At the same time, autologous bone fragments are easy to shift or even fall off, resulting in severe compression of optic nerves or important blood vessels, resulting in serious complications such as decreased vision and even blindness [20, 33].

### *3.3 Gasket-seal Technology*

Gasket-seal technique [31] is a typical skull base reconstruction technique combining soft reconstruction with rigid reconstruction, which can achieve the reconstruction effect of watertight closure of skull base. The main step is to take a piece of fascia lata from thigh to ensure that its radius exceeds the defect of sellar floor bone by at least 1cm. After tumor resection, appropriate thigh fat was used to eliminate tumor cavity to reduce cerebrospinal fluid impact. The prepared fascia lata was placed in the center of sellar floor defect, and then trimmed into the shape and size equivalent to sellar floor defect with hard materials such as pear bone, nasal septum bone, titanium plate and artificial bone, so as to ensure that the hard graft was located in the center of fascia lata, that is, the fascia lata exceeded the edge of hard support by 1cm. In this process, the fascia lata is embedded in the bone defect, forming an impermeable gasket with the rigid support. Finally, fibrin glue was applied to the edge of the reconstructed structure to further ensure the firmness of skull base reconstruction. After that, Garcia-Navarro et al. [20] improved this technique, and proposed the reconstruction method of pedicled nasal septum mucosal flap (PNSF) based on Gasket-seal technique. It was reported that the incidence of cerebrospinal fluid leakage after operation in 46 patients with high flow cerebrospinal fluid leakage was only 4.3% [20]. Gasket-seal technology has the advantages of high tissue sealing brought by fascia lata, support and fixation of hard materials, simple operation without dural suture and so on. However, the use of thigh fascia lata undoubtedly increases the trauma. Moreover, the bony reconstruction materials used in Gasket-seal technology are often difficult to "conformal" anastomose with the irregular bone window at the sella floor. If the embedded materials are displaced, it is easy to compress important structures such as optic nerve and internal carotid artery, which leads to serious complications, and it is even more difficult to ensure that they are closely attached to fascia lata to form a watertight closure effect.

### *3.4 In Situ Bone Flap (ISBF) Technique*

In order to solve the skull base bone repair in the complex plane of sellar floor more reasonably and fully, our team innovatively proposed to use the concept of ISBF [14, 21-22, 34] to improve skull base repair. Among the 47 patients who used in-situ bone flap for skull base reconstruction reported in the early stage, 1 case (1/47, 2.1%) had cerebrospinal fluid leakage after operation, which was significantly lower than that of non-ISBF group (6/38, 15.8%) [14]. From January 2016 to September 2020, a total of 126 patients were followed up with ISBF combined with pedicled nasal septum mucosal flap or free middle turbinate mucosal flap for skull base reconstruction. It was found that the skull base anatomical reconstruction could be realized, the bone flap was in good position, and callus formed 6 months after operation [22]. In this technique, a high-speed grinding drill with a diameter of only 2.5 mm is used to design the bone flap in situ according to the location and size of the tumor, and a complete bone flap is prepared by multi-point cutting, which is put back in situ during skull base reconstruction, thus turning the tissue that would have been "discarded" into wealth. ISBF is a kind of rigid reconstruction material. Compared with Gasket-seal technique, ISBF is taken from the skull base operation area in situ, which has the following advantages [21, 34]: (1) ISBF is taken from the operation site, which is highly consistent with the skull base

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bone window in size and shape, and achieves anatomical reduction in the true sense. (2) Compared with artificial materials, ISBF has better biocompatibility. (3) ISBF, as a rigid support, provides mechanical support for soft reconstruction tissues such as mucosal flap, and avoids the displacement of reconstruction tissues due to cerebrospinal fluid impact pressure. (4) Bone flap can be used as the medium of growth and attachment of mucosal graft, and can fix mucosal flap. (5) The existence of ISBF can avoid adhesion and scar between intracranial tissue and PNSF, which provides a distinct anatomical structure for the second operation of tumor recurrence. (6) After the bone of ISBF gradually healed, the brain tissue could be avoided from shifting downward and bulging due to skull base bone defect. With the maturity of in-situ bone flap technology, PNSF is gradually abandoned due to the great nasal trauma and low quality of life in patients' nasal cavity after operation. Instead, the middle turbinate mucosal flap removed due to exposure of surgical approach is used. Combined with ISBF, skull base reconstruction can also be carried out safely and effectively, and minimally invasive and in-situ anatomical reduction can be achieved in the true sense. However, in-situ bone flap is not suitable for cases with incomplete skull base bone and tumor infiltration of skull base bone.

## 4. Summary and Prospect

With the expanding application scope of neuroendoscopic transnasal skull base surgery and the increasing types of lesions, endoscopic skull base reconstruction technology is facing increasing challenges. At present, there is no uniform standard for skull base reconstruction, but the most ideal reconstruction method is to restore the defect caused by surgical approach to the original normal anatomical level, which includes soft reconstruction of dura mater and nasal mucosa and rigid reconstruction of skull base bone. Soft reconstruction guarantees good tissue sealing, while rigid reconstruction provides mechanical support, which promote each other and complement each other, and provide a safe and reliable way of skull base reconstruction. However, the research on rigid reconstruction is still controversial, and the wide application of in-situ bone flap technology is expected to provide a new idea for endoscopic skull base reconstruction. With the development of endoscopy, materials science and imaging, and the innovation of skull base reconstruction concept, we will eventually move closer to the ultimate goal of anatomical reconstruction and master a more perfect skull base reconstruction method.

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