Review of Contemporary Philosophy
ISSN: 1841-5261, e-ISSN: 2471-089X
Vol 22 (1), 2023
Pp 1513 - 1523

Cubism Graft, in Multilayer Sellar Repair: A Novel Technique

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Abstract

Background: The endoscopic endo-nasal transsphenoidal approach is the best option for the surgical excision of tumors of pituitary. Cubism is a double-layer graft that is made by combining septal cartilaginous dust with platelet-rich fibrin to create a very thin graft. This study intended to determine the effectiveness of cubism graft in reconstructing the sellar region following endoscopic endonasal removal of pituitary tumors. Thirty-four people who had recurrent pituitary tumours were included in this retrospective pilot study. A thorough clinical examination, laboratory investigations, and history were administered to all patients, and imaging studies as computed tomography scan and magnetic resonance imaging. The cases were followed up on every three months up to one year.

Results: The operative time ranged from 2.0 to 2.5 hours with a mean of 2.15±0.85 hours, Blood loss range was from 150 to 300 ml with a mean of 225±10.65 ml, 27 (79.4%) patients had total surgical resection and 7 (20.6%) patients had subtotal surgical resection, 18 (52.9%) had visual improvement. Regarding complications, 4 (11.8%) patients had diabetes insipidus, and 1 (2.9%) patient had acute coronary syndrome. No patients had any cerebrospinal fluid (CSF) leak. There was a significant relation between complications and age, while there was insignificant relation between complications and sex, functioning tumour and surgical resection.

Conclusions: Cubism graft is a material that is both reliable and readily harvested, and it has a high success rate for primary repairs of sellar floor. They can be used as a further technique in the treatment of subsequent or complicated surgical CSF leakage.

Keywords: Cubism Graft; Multilayer; Sellar Repair; Pituitary tumours; endoscopic; endonasal transsphenoidal approach.

Received: 10 october 2023 **Revised:** 24 November 2023 **Accepted:** 08 December 2023

Introduction

The most highly regarded method for surgically removing pituitary tumours is the endoscopic endonasal transsphenoidal technique. which provides the best panoramic vision within the surgical area, enabling surgeons to have a more precise understanding of their position and a more magnified image of the contact between the tumour and the gland, as well as the important anatomical landmarks. [1] However, it has some complications such as carotid artery injury, central nervous system injury, loss of vision, ophthalmoplegia, meningitis, hypopituitarism, diabetes insipidus, death, recurrence rate (10% to 20%), and cerebrospinal fluid (CSF) leak, which may be intraoperative (60%) or postoperative (2%). [2, 3]

A variety of complications are associated with CSF leaks, including intracranial infection, CSF hypotension syndrome, and meningitis. These complications frequently result in substantial morbidity and additional healthcare expenses, as they may necessitate extended hospitalisation, external lumbar drainage. and reoperation. [4]

Reconstruction after endoscopic transsphenoidal approaches to the base of the skull is the most important to avoid leaks of CSF postoperatively. It is acknowledged that the occurrence of postoperative CSF leaks is greatly affected by the effectiveness of the reconstruction technique that is performed after dissection. [5] Reconstruction may be done by autogenous or allogenous grafting. Allogenic grafts include collagen sponge and cadaveric iliac bone, and Fascia. The Autogenous grafts include fat (thigh or abdominal), Fascia Lata, lateral rectus muscle, rectus Fascia, bone (septal, or vomer), and nasoseptal flap. [6]

After the mucosa is removed from the septum of the nose, a substantial defect is left, which is subsequently healed by secondary intention over a prolonged duration. This can lead to severe nasal crusting and the sensation of nasal blockage in the nostril of the same side. Nasal dorsum collapse and septal perforations are examples of significant structural abnormalities of the nose. Moreover, postoperative CSF leaks may still be present. To avoid these complications and to decrease the recurrence of CSF rhinorrhoea we developed a new graft for reconstruction of sella following endoscopic endonasal resection of the pituitary tumour. [7] This graft is called cubism which is formed of septal cartilaginous dust combined with platelet-rich fibrin (PRF) to create a very thin graft that will be used as a double-layer graft. Therefore, we intended to use a novel material to overcome this problem with a cubism graft. [8]

Our research objective was to estimate the efficacy of the cubism graft in sellar reconstruction following endoscopic endonasal pituitary tumours resection.

Patients and Methods

This retrospective pilot study was implemented on thirty-four patients with age ranging from 40 to 65 years, both sexes with recurrent pituitary tumours. This study was carried out after approval of ethical committee of the local University Hospital during the period 2019 to 2022. Patients were asked to sign written informed consent forms before any surgery was performed.

Inclusion criteria were those patients who were suffering from recurrent Pituitary tumours and were available for follow up.

Exclusion criteria were patients unfit for surgery, patients' refusal. The cases were monitored at three-month intervals for a duration of one year.

Every patient underwent a comprehensive assessment, including a thorough clinical examination, medical history, laboratory tests, and imaging studies as computed tomography (CT) scan and magnetic resonance imaging (MRI). The cases were monitored at three-month intervals for a period of one year.

Surgical procedure:

Endoscopes are used for all surgical operations. First, the perforation edges will be de epithelized. The septal cartilage was utilised to procure the graft material. By brushing the scalpel blade no. 11 perpendicular to the cartilage, it will trim it. The scalpel was not subjected to angular alterations. The cartilage convex surface was brushed with rapid and soft scalpel movements. All scalpel movements direction was consistent. In the interim, the scalpel accumulated cartilage dust that resembles dough.

An approximately 400 g venous blood sample was collected in 10-ml sterile containers that are devoid of anticoagulant. The sample was centrifuged at 3000 rpm for 10 minutes. The upper stratum of the tube contains fibrin clot in the form of PRF. The PRF was extracted from the tube and applied to the cartilage particles. Subsequently, the cartilage dust-PRF mixture was pulverised between 2 thick glass slides. The mixture was pulverised once more, and additional dust and PRF were incorporated. This resulted in the formation of a thin, adhesive cubism graft. **Figure 1**

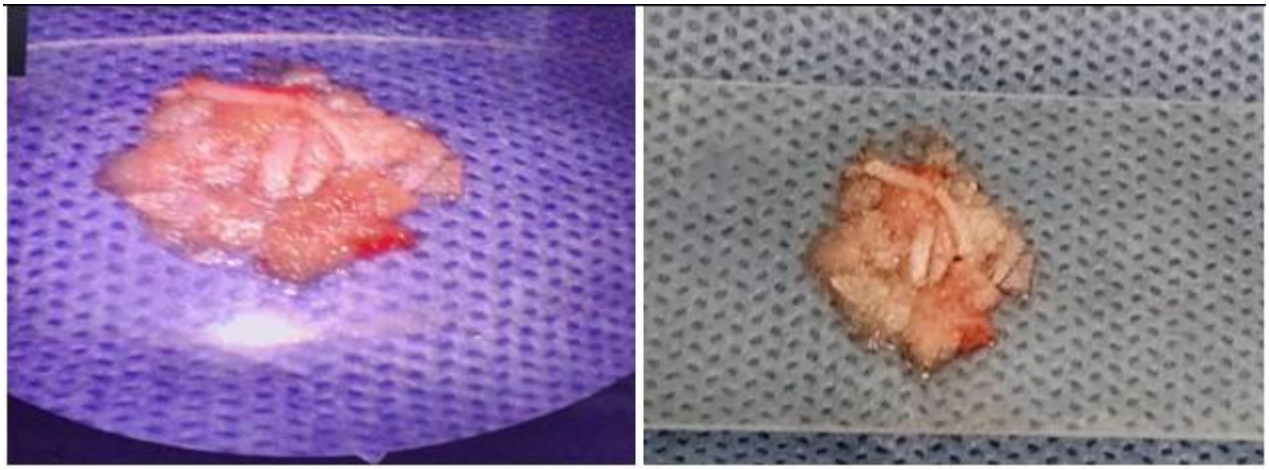

Figure 1: Preparation of cubism graft (Pictures are cropped for better visualization)

Statistical analysis:

The analysis of data was conducted utilizing SPSS software, version 25 (SPSS Inc., PASW Statistics for Windows version 25. SPSS Inc., Chicago). Percentages and numbers were employed to characterise qualitative data. Following conducting a Shapiro-Wilk test to determine normality, quantitative data were described as mean ± standard deviation for normally distributed data. The results were assessed for significance at the "≤0.05" level. The qualitative data was compared between the groups using the Fisher exact test. Normally distributed data was compared between two independent groups using the student t-test.

Results

Regarding demographic data of the studied patients, age ranged from 40 to 65 years with a mean of 52.36± 3.45 years. There was 14 (41.2%) male and 20 (58.8%) female. **Table 1**

Table 1: Demographic data of the studied patients

No. of Patients		n=34
Age/years		52.36± 3.45
Sex	**Male**	14 (41.2%)
	Female	20 (58.8%)

Data presented as mean ± SD or frequency (%).

Among the studied patients, 18 (52.9%) had headache, 15 (44.1%) were non-functioning, 19 (55.9%) were functioning, 10 (29.4%) were adrenocorticotropic hormone (ACTH) producing, 5 (14.7%) were growth hormone producing and 4 (11.8%) were prolactin-producing. Papilledema was present in 17 (50%) patients. Defects of visual field were found in 20 (58.8%) patients. Regarding Preoperative endoscopy, 24 (70.6%) patients had Post septectomy, 6 (17.7%) had Post septectomy and adhesion, 4 (11.8%) patients had Post septectomy and HIT. Regarding MRI findings, 9 (26.5%) patients had Suprasellar tumor, 8 (23.5%) patients had Presellar tumor, 3 (8.8%) patients had Retrosellar tumor, 7(20.6%) patients had Suprasellar and parasellar tumors, and 7(20.6%) patients had parasellar tumors. **Table 2**, **Figure 2**

Table 2: Preoperative manifestation of the studied patients

		N=34	**%**
Headache (n,%)	Present	18	52.9
Main function (n,%)	Non-functioning	15	44.1

	Functioning	19	55.9
	ACTH producing	10	29.4
	Growth hormone Producing	5	14.7
	Prolactin- Producing	4	11.8
Papilledema (n,%)		17	50.0
Visual field defects		20	58.8
Preoperative endoscopy (n,%)	Post septectomy	24	70.6
	Post-septectomy and adhesion	6	17.7
	Post septectomy and HIT	4	11.8
MRI	Suprasellar	9	26.5
	Presellar	8	23.5
	Retrosellar	3	8.8
	Suprasellar and parasellar	7	20.6
	Parasellar	7	20.6

MRI: Magnetic resonance imaging, ACTH; Adrenocorticotropic hormone, HIT: Hypertrophied inferior turbinate

The mean time of operation was 2.15±0.85 hours, with a range of 2.0 to 2.5 hours. Loss of blood ranged from 150 to 300 ml with a mean of 225±10.65 ml, 27 (79.4%) patients had total surgical resection and 7 (20.6%) patients had subtotal surgical resection, 18 (52.9%) had visual improvement. Regarding complications, 4 (11.8%) patients had diabetes insipidus, and 1 (2.9%) patient had acute coronary syndrome. No patients had any CSF leak. **Table 3**

Table 3: Operative and postoperative data of studied populations

		N =34	%
Variable	**Operative time (hour)**		2.15±0.85
	Blood loss (ml)		225±10.65
Surgical resection (n,%)	**Total:**	27	79.4
	Subtotal:	7	20.6
Visual improvement (n,%)	**Yes**	18	52.9
	No	4	11.8
	NA	12	35.3
Complications (n, %)	**None**	29	85.3
	Diabetes insipidus	4	11.8
	Acute coronary syndrome	1	2.9
CSF leak (n, %)	**Yes**	0	0
	No	34	100.0

There was a significant relation between complications and age, while there was insignificant Relation between complications and sex, functioning tumor and surgical resection. **Table 4, Figure 2**

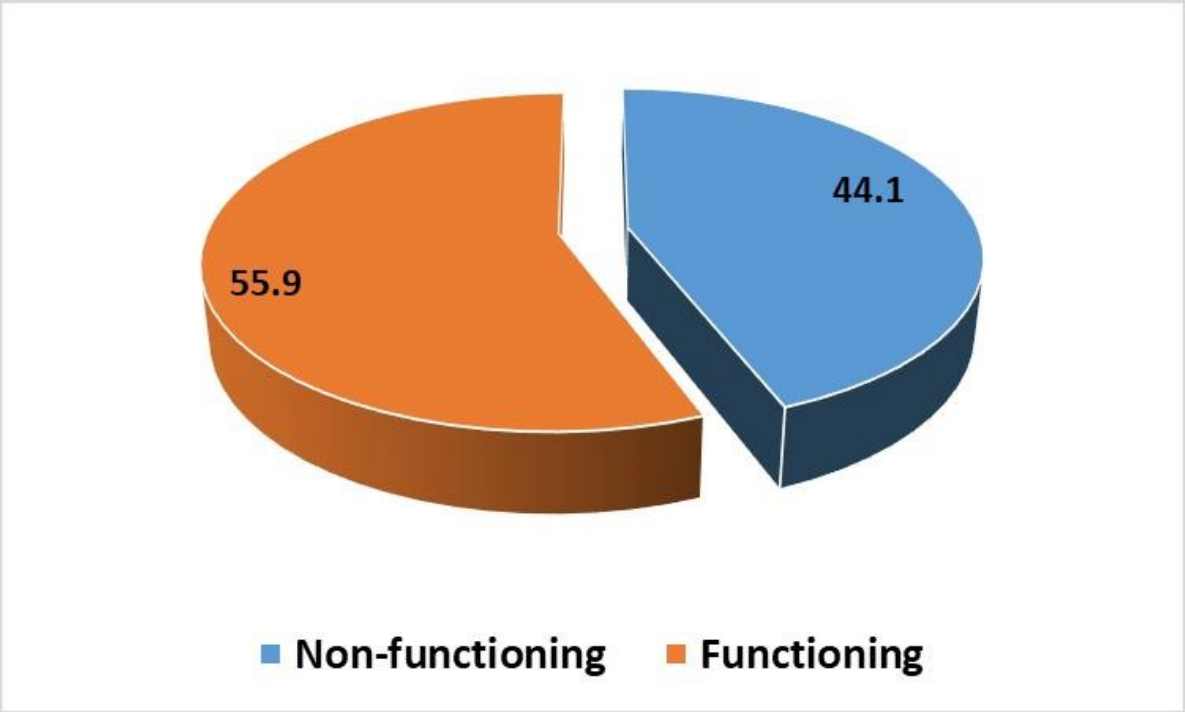

Figure 2: Percentage of functioning and non-functioning tumor

Table 4: Relation between complications and demographic, type of tumor and type of surgical resection among studied cases

	Complications		Test of significance
	None	+ve	
Age/ years	51.22± 2.19	53.69±3.25	t=2.18 **p=0.03***
Sex			
Male	13(44.8%)	1(20%)	χ^{2FET}=1.08
Female	16(55.2%)	4(80%)	P=0.378
Functioning tumor			
None	11(37.9%)	4(80%)	χ^{2FET}=3.06
Functioning	18(62.1%)	1(20%)	P=0.146
Surgical resection (n,%)			
Total	23(79.3%)	4(80%)	χ^{2FET}=0.001
Subtotal	6(20.7%)	1(20%)	P=0.972

t: Student t test, FET: Fisher exact test , *statistically significant

MRI of Pituitary gland large macroadenoma measures 5x5x5.5 cm has iso-intense signal to gray matter in T1WIs & T2WIs with homogeneously enhancement. This mass enlarges the pituitary fossa with supra-sellar extension compresses the optic chiasma. No evidence of cavernous sinus invasion. **Figure 3**

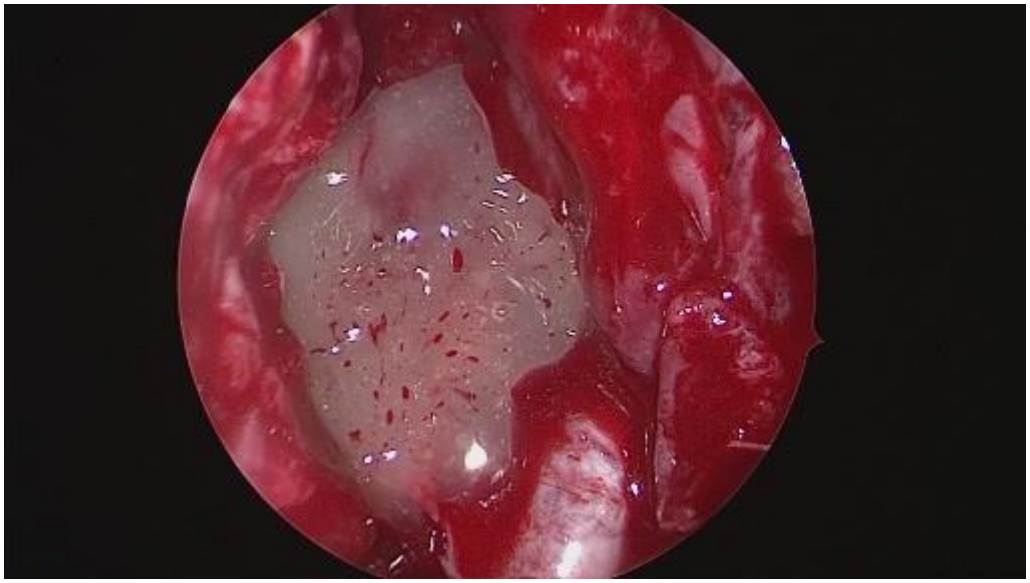

Figure 3: Intraoperative applying cubism graft

Discussion

An enduring reconstruction of the defect in sella and a potential leakage of CSF and are two of the primary challenges of transsphenoidal surgery (TSS). The optimal method of sealing off CSF breaches is still a topic of debate, as they may be the result of the primary erosion of the sellar floor, or surgical procedure, which can be observed in a variety of tumours that affect this region [9].Most authors have documented occurrences ranging from 0.5% to 6.0%, although the occurrence of postoperative CSF leakage after trans-sphenoidal surgery has been reported to range from 0.5% to 15%. [10, 11]

Various restoration approaches for the sellar floor have been suggested to prevent CSF fluid leaks after surgery. [12] Cappabianca et al. [13] showed that it must be inert, simple to shape and fashion to the bone defect, and in harmony within harmony with CT and MRI. These requirements are essential for reducing and simplifying the time of surgery during the endoscopic procedure.

Various autologous materials, including adipose, muscle, fascia, cartilage, mucoperiosteal, and bone grafts, have been employed. [14] Despite the absolute biocompatibility of autologous tissue transplants, they frequently necessitate a postoperative external lumbar drain to reduce the CSF pressure on the graft and maintain its position until the arachnoid heals. [15, 16]

A variety of different reconstructive methods have been proposed to avoid the occurrence of CSF leakage after trans-sphenoidal pituitary surgery. Nevertheless, the method that is most effective has not been fully agreed upon. [17]

Managing CSF leakage during trans-sphenoidal surgery has been relatively standardised through the use of an abdominal adipose graft to pack the Sella. The postoperative CSF fistula is prevented by the obliteration of the sella and sphenoid sinus dead space. Nevertheless, the utilisation of fat may result in complications and issues. [18] The interpretation of the content of sella on postoperative MRI may be impeded by fat. At one year postoperatively, a significant volume of non-resorbed fat may persist in the sella, accompanied by non-enhancing tissue (isointense). [19] Furthermore, the optic chiasm may be compressed, necessitating reoperation. [20] Another technical issue with autologous adipose grafts is that the arachnoid tearing may be exacerbated by inadequate packing, particularly in the case of large tissue grafts. The normal gland is displaced posteriorly when a fat graft is implanted into the intrasellar space. Consequently, postoperative CSF rhinorrhoea may occur, and the tear of the arachnoid and the space between the dura margin and normal gland may be enlarged. [21]

Additionally, in numerous instances, it was proposed to insert a postoperative external lumbar catheter in one layer reconstructions that utilised autologous tissue grafts to reduce the CSF pressure on the graft and maintain its position until the arachnoid heals. [22]

Pneumocephalus, CSF over drainage, or meningitis are potential complications of an external lumbar drain. Additionally, complications may arise as a result of catheter mechanical failure and infection at the insertion site. The nerve root irritation risk has been recorded to be as high as 5%. Furthermore, the nursing staff must possess a high level of familiarity towards the patients with postoperative external lumbar drains care in order to prevent occurrence of complications. [12] Also, abdominal fat graft need another incision which may heals by scar tissue in the abdomen

Some authors recommended the vascularized pedicle flap use to rebuild the cranium base defect following trans-sphenoidal surgery. They suggested that the preserved pedicle's vascularity enables rapid and effective integration with the adjacent tissues. [23, 24]

Gaynor et al. [25] stated that prevention of postoperative CSF leakage ,needed to elevate the nasoseptal mucosal flap. Flaps of vascularized mucosa are highly effective, even in cases of high-flow CSF leakage; nevertheless, they may result in increasing patient distress. Mucosal flaps are not routinely employed on all transsphenoidal patients due to anaesthesia, crusting, and increased process time. In contemporary practice, these flaps are raised at the commencement of the procedure prior to the determination of whether an intraoperative CSF leak will occur, which results in superfluous morbidity in cases where no leak happens. Strategies for preparing a flap having minimal septum morbidity were described for situations in which a CSF escape is unexpected.

Munich et al. [26] stated that a mucoperichondrial nasal septal flap was employed to perform skull base repair in three of 39 primary operations, resulting in postoperative CSF leaks (7.7%). These findings suggest that the use of a vascularized mucoperichondrial flap, along with an autologous tissue graft and a strong dedication to obtaining full coverage of the skull base disease, is linked to a lower incidence of CSF leakage after an improved endonasal surgical operation.

Berker et al. [27] stated that Patients who had the dural flap procedure did not experience any postoperative leakage. However, they detected leakage postoperatively in 12 out of the 120 patients who did not have the dural flap, which accounts for 10% of the total patients ($p = 0.146$). According to their report, the dural flap use decreases the likelihood of a leak occurring after surgery.

Amano et al. [28] stated that there are papers assessing the efficacy of a nasoseptal mucosal flap. This approach is the most effective way to fix or avoid CSF leaking and allow for an extended TSS on the front part of the base of the skull. Overall, the nasoseptal flap is characterised by its increased toughness, thickness, and ability to cover a larger region compared to the sphenoid sinus mucosal (SSM) flap. On the other hand, the distinction between SSM and nasoseptal flaps is in the affection of the normal anatomical structure.

The extended duration needed for integration and resorption of tissue when utilising non-vascularized flaps can result in a postponed occurrence of CSF leak after surgery. Nevertheless, the drawbacks of pedicled flaps include the restricted coverage area caused by the pedicles and the unpredictability of the defect size in dura during the harvesting of the vascularized flap. [29]

Due to these complications, numerous authors have attempted to eliminate autologous tissue grafts. It has been suggested that a variety of synthetic and heterologous materials be used to repair CSF leakage, each with its own set of advantages and disadvantages. [8, 30, 31]

Hard materials, such as pure titanium, ceramic plates, bone cement, silicone blocks, and stainless-steel plates have been employed for sellar reconstruction. Despite their potential to be effective in preventing CSF leakage and forming a strong floor of sella, these foreign bodies may cause a host-tissue reaction, serve as a nidus for infection, or be troublesome when repetitive trans-sphenoidal surgery is necessary. Furthermore, they may be challenging to manipulate and may influence radiological investigations. [12] In

addition, the sluggish attachment of the material to the surrounding tissue causes numerous surgeons to utilise an external lumbar CSF drain after surgery to verify the closure of the floor of sella , particularly in patients with significant leakage of CSF. [32]

The most recent resorbable materials, such as gelatine foam, vicryl patches, fibrin glue, oxidative cellulose, and collagen sponges have shown improved outcomes and fewer problems. [33] Spinal drainage was necessary to avoid leakage of CSF, particularly in cases where there were significant tears. [34] Additionally, some authors have reported the risk of transmitting bovine spongiform encephalitis or viral diseases when bovine collagen or human plasma are combined with these materials. [30, 35] Furthermore, the total expense of the procedure is increased by the use of these synthetic and heterologous materials, which may not be accessible in the event of an arachnoid rupture and leakage of CSF throughout the initial procedure. [33]

El Shazly et al. [12] used autologous composite septal cartilage and muscle grafts for the repair of sellar. They discovered that six patients (26.1%) had a grade 1 CSF leak, ten patients (43.5%) had a grade 2 CSF leak, and seven patients (30.4%) had a grade 3 CSF leak.

Reconstructive surgery's potential was proposed by the biocompatibility, osteoconductive, and osteoconductive properties of biosynthetic bone replacement, as documented in studies. [36, 37] In the clinical setting, there is currently a shortage of clinical data that demonstrates its safety and efficacy. [37]

In order to overcome the difficulties often faced in repairing the sellar floor bony component, we plan to use a cubism graft as a solution. [8]

This substance has demonstrated beneficial attributes in the field of tympanoplasty. Under the endoscopic/microscopic perspective, this novel graft consists of cartilaginous fragments resembling cubic geometric shapes. This graft appearance has resemblance to the artworks created by the cubism art movement artists. As a result, it has been designated as "cubism graft" [38]. The cubism graft will be formed of cartilaginous dust combined with PRF to form a very thin graft which will be used as a double layer graft, which include the following advantages: 1. high graft take rate due to presence of PRF, 2. reducing the rigidity of cartilage graft, so it can be shaped according to the defect, 3. reducing cartilage graft disadvantages such as over-curling, undesirable cartilage fractures, 4. overcome disadvantage of temporalis fascia graft as it lake the elasticity and is resistant to pressure change, 5. It took from local operative field without the necessary of another incision, and 6. No extra cost to the patients. [39]

Conclusions: Cubism graft is a material that is both reliable and readily harvested, and it has a high success rate for primary parasellar and sellar repairs. They can be used as an adjunctive method in the repair of secondary or complex postoperative leakage of CSF.

List of abbreviations:

ACTH: Adrenocorticotropic hormone

CSF: Cerebrospinal fluid

CT: Computed tomography

HIT: Hypertrophied inferior turbinate

MRI: Magnetic resonance imaging

PRF: Platelet-rich fibrin

SSM: Sphenoid sinus mucosal flap

TSS: Transsphenoidal surgery

References:

1. Messerer M, Cossu G, George M, Daniel RT. Endoscopic endonasal trans-sphenoidal approach: Minimally invasive surgery for pituitary adenomas. J Vis Exp. 2018:38-54. doi:10.3791/55896

2. Magro E, Graillon T, Lassave J, Castinetti F, Boissonneau S, Tabouret E, et al. Complications Related to the Endoscopic Endonasal Transsphenoidal Approach for Nonfunctioning Pituitary Macroadenomas in 300 Consecutive Patients. World Neurosurg. 2016;89:442-53. doi:10.1016/j.wneu.2016.02.059

3. Trimpou P, Backlund E, Ragnarsson O, Skoglund T, Hallén T, Gudnadottir G, et al. Long-Term Outcomes and Complications from Endoscopic Versus Microscopic Transsphenoidal Surgery for Cushing's Disease: A 15-Year Single-Center Study. World Neurosurg. 2022;166:e427-e34. doi:10.1016/j.wneu.2022.07.027

4. Shaftel KA, Przybylowski CJ, Little AS. Endoscopic Endonasal Transsphenoidal Approach to Repair Cerebrospinal Fluid Rhinorrhea After an Anterior Clinoidectomy for Aneurysm Clipping: Series of 4 Cases. Oper Neurosurg (Hagerstown). 2023;24:17-22. doi:10.1227/ons.0000000000000430

5. Jolly K, Gupta KK, Egbuji O, Naik PP, Ahmed SK. Endoscopic transsphenoidal surgery reconstruction using the fibrin sealant patch Tachosil(®). Br J Neurosurg. 2024;38:498-502. doi:10.1080/02688697.2021.1905771

6. Thorpe RK, Dougherty MC, Walsh JE, Graham SM, Greenlee JDW. Sellar Reconstruction With a Bioabsorbable Plate After Endoscopic Transsphenoidal Pituitary Adenoma Resection: Safe and Efficacious. Ann Otol Rhinol Laryngol. 2024;133:490-4. doi:10.1177/00034894241233870

7. Thakur JD, Corlin A, Mallari RJ, Yawitz S, Eisenberg A, Sivakumar W, et al. Complication avoidance protocols in endoscopic pituitary adenoma surgery: a retrospective cohort study in 514 patients. Pituitary. 2021;24:930-42. doi:10.1007/s11102-021-01167-y

8. Ramos-Zúñiga R, López-González F, Segura-Durán I. Bilaminar chitosan scaffold for sellar floor repair in transsphenoidal surgery. Front Bioeng Biotechnol. 2020;8:23-45. doi:10.3389/fbioe.2020.00122

9. Conger A, Zhao F, Wang X, Eisenberg A, Griffiths C, Esposito F, et al. Evolution of the graded repair of CSF leaks and skull base defects in endonasal endoscopic tumor surgery: trends in repair failure and meningitis rates in 509 patients. J Neurosurg. 2018;130:861-75. doi:10.3171/2017.11.Jns172141

10. Wang M, Cai Y, Jiang Y, Peng Y. Risk factors impacting intra- and postoperative cerebrospinal fluid rhinorrhea on the endoscopic treatment of pituitary adenomas: A retrospective study of 250 patients. Medicine (Baltimore). 2021;100:e27781. doi:10.1097/md.0000000000027781

11. Graffeo CS, Yagnik KJ, Carlstrom LP, Lakomkin N, Bancos I, Davidge-Pitts C, et al. Pituitary adenoma incidence, management trends, and long-term outcomes: A 30-year population-based analysis. Mayo Clin Proc. 2022;97:1861-71. doi:10.1016/j.mayocp.2022.03.017

12. El Shazly AA, El Wardany MA, Abo El Ezz TA. Sellar repair with autologous muscle and composite septal cartilage grafts for treatment of cerebrospinal fluid leakage following trans-sphenoidal pituitary surgery. Asian J Neurosurg. 2016;11:433-9. doi:10.4103/1793-5482.144157

13. Cappabianca P, Cavallo LM, Esposito F, Valente V, De Divitiis E. Sellar repair in endoscopic endonasal transsphenoidal surgery: results of 170 cases. Neurosurgery. 2002;51:1365-71; discussion 71-2.

14. Galli J, Morelli F, Rigante M, Paludetti G. Management of cerebrospinal fluid leak: the importance of multidisciplinary approach. Acta Otorhinolaryngol Ital. 2021;41:S18-s29. doi:10.14639/0392-100X-suppl.1-41-2021-02

15. Ismail M, Fares AA, Abdelhak B, D'Haens J, Michel O. Sellar reconstruction without intrasellar packing after endoscopic surgery of pituitary macroadenomas is better than its reputation. Ger Med Sci. 2016;14:7-13. doi:10.3205/000234

16. Fang Z, Tian R, Jia YT, Xu TT, Liu Y. Treatment of cerebrospinal fluid leak after spine surgery. Chin J Traumatol. 2017;20:81-3. doi:10.1016/j.cjtee.2016.12.002

17. Baig Mirza A, Boardman T, Okasha M, El-Hariri HM, Al Banna Q, Syrris C, et al. Fat in the fossa and the sphenoid sinus: A simple and effective solution to CSF leaks in transsphenoidal surgery. Cohort study and systematic review. J Neurol Surg B Skull Base. 2023;84:143-56. doi:10.1055/a-1757-3069

18. Roca E, Penn DL, Safain MG, Burke WT, Castlen JP, Laws Jr ER. Abdominal fat graft for sellar reconstruction: retrospective outcomes review and technical note. Oper Neurosurg. 2019;16:667-74.

19. Lee IH, Kim DH, Park JS, Jeun SS, Hong YK, Kim SW. Cerebrospinal fluid leakage repair of various grades developing during endoscopic transnasal transsphenoidal surgery. PLoS One. 2021;16:e0248229. doi:10.1371/journal.pone.0248229

20. Livingston CA, Raviskanthan S, Mortensen PW, Britz GW, Lee AG. Acute bitemporal hemianopsia following transsphenoidal pituitary adenoma resection with fat graft. J Neuroophthalmol. 2023;43:e214-e6.

21. Baussart B, Venier A, Jouinot A, Reuter G, Gaillard S. Closure strategy for endoscopic pituitary surgery: Experience from 3015 patients. Front Oncol. 2023;12:23-65. doi:10.3389/fonc.2022.1067312

22. Kim BK, Kong DS, Nam DH, Hong SD. Comparison of graft materials in multilayer reconstruction with nasoseptal flap for high-flow CSF leak during endoscopic skull base surgery. J Clin Med. 2022;11:1290-6. doi:10.3390/jcm11226711

23. Bowen AJ, Eltahir A, Goates AJ, Rezende N, Leonel L, Graepel S, et al. The posterior septal nasal floor mucosal flap for cranial base reconstruction. Laryngoscope. 2022;132:1561-8. doi:10.1002/lary.30079

24. Strober WA, Valappil B, Snyderman CH. Impact of reverse septal flap on morbidity of nasoseptal flap reconstruction of skull base defects. Am J Rhinol Allergy. 2023;37:470-5. doi:10.1177/19458924231166801

25. Gaynor BG, Benveniste RJ, Lieberman S, Casiano R, Morcos JJ. Acellular dermal allograft for sellar repair after transsphenoidal approach to pituitary adenomas. J Neurol Surg B Skull Base. 2013;74:155-9. doi:10.1055/s-0033-1338263

26. Munich SA, Fenstermaker RA, Fabiano AJ, Rigual NR. Cranial base repair with combined vascularized nasal septal flap and autologous tissue graft following expanded endonasal endoscopic neurosurgery. J Neurol Surg A Cent Eur Neurosurg. 2013;74:101-8. doi:10.1055/s-0032-1330118

27. Berker M, Aghayev K, Yücel T, Hazer DB, Onerci M. Management of cerebrospinal fluid leak during endoscopic pituitary surgery. Auris Nasus Larynx. 2013;40:373-8. doi:10.1016/j.anl.2012.11.006

28. Amano K, Hori T, Kawamata T, Okada Y. Repair and prevention of cerebrospinal fluid leakage in transsphenoidal surgery: a sphenoid sinus mucosa technique. Neurosurg Rev. 2016;39:123-31; discussion 31. doi:10.1007/s10143-015-0667-6

29. Sung KS, Lim J, Na M, Lee S, Kim JS, Hong JB, et al. Anterior skull base reconstruction using nasoseptal flap: cadaveric feasibility study and clinical implication [SevEN-001]. J Otolaryngol Head Neck Surg. 2020;49:67. doi:10.1186/s40463-020-00460-3

30. Yano S, Tsuiki H, Kudo M, Kai Y, Morioka M, Takeshima H, et al. Sellar repair with resorbable polyglactin acid sheet and fibrin glue in endoscopic endonasal transsphenoidal surgery. Surg Neurol. 2007;67:59-64; discussion doi:10.1016/j.surneu.2006.05.049

31. Cho JM, Ahn JY, Chang JH, Kim SH. Prevention of cerebrospinal fluid rhinorrhea after transsphenoidal surgery by collagen fleece coated with fibrin sealant without autologous tissue graft or postoperative lumbar drainage. Neurosurgery. 2011;68:130-6; discussion 6-7. doi:10.1227/NEU.0b013e318207b4ea

32. Ahn S, Park JS, Kim DH, Kim SW, Jeun SS. Surgical experience in prevention of postoperative CSF leaks using abdominal fat grafts in endoscopic endonasal transsphenoidal surgery for pituitary adenomas. J Neurol Surg B Skull Base. 2021;82:522-7. doi:10.1055/s-0040-1712179

33. Chen K, Dai K, Liu Z, Liu J, Yu K, Lu A, et al. Skull base reconstruction using in situ bone flap in patients with pituitary adenomas treated by endoscopic endonasal approach. Front Neurol. 2023;14:1194251. doi:10.3389/fneur.2023.1194251

34. Oh JW, Kim SH, Whang K. Traumatic cerebrospinal fluid leak: Diagnosis and management. Korean J Neurotrauma. 2017;13:63-7. doi:10.13004/kjnt.2017.13.2.63

35. Kelly DF, Oskouian RJ, Fineman I. Collagen sponge repair of small cerebrospinal fluid leaks obviates tissue grafts and cerebrospinal fluid diversion after pituitary surgery. Neurosurgery. 2001;49:885-9; discussion 9-90. doi:10.1097/00006123-200110000-00020

36. Rodríguez-Vázquez M, Vega-Ruiz B, Ramos-Zúñiga R, Saldaña-Koppel DA, Quiñones-Olvera LF. Chitosan and its potential use as a scaffold for tissue engineering in regenerative medicine. Biomed Res Int. 2015;2015:821279. doi:10.1155/2015/821279

37. Vega-Ruiz B, Ramos-Zúñiga R, Duran IS, Ursiel-Ortega Y. Biomaterials and surgical applications: The translational perspective. Transl Surg. 2017;2:85.

38. Kaya İ, Şahin FF, Tanrıverdi O H, Kirazlı T. The new “cubism” graft technique in tympanoplasty: A randomized controlled trial. Laryngoscope Investig Otolaryngol. 2021;6:503-11. doi:https://doi.org/10.1002/lio2.569

39. Kaya İ, Şahin FF, Tanrıverdi O H, Kirazlı T. A novel graft-harvesting technique in tympanoplasty: the cubism graft. Eur Arch Otorhinolaryngol 2021;278:1289-92. doi:10.1007/s00405-021-06646-3