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PERSONALIZED 3D-PRINTED IMPLANT FOR THORACIC VERTEBRA BODY REPLACEMENT AFTER EN BLOC RESECTION OF A TUMOR WITH FIVE-YEAR FOLLOW UP PERIOD

Objective: *This study aims to evaluate the application of 3D-printed individual vertebral prostheses for reconstructing the spine following thoracolumbar Total En-bloc Spondylectomy (TES) in patients with benign spinal tumors. The primary objectives include assessing the feasibility of 3D-printed prostheses in various reconstruction scenarios and determining their impact on spinal stability and neurological function in the short term.*

Methods: *A retrospective analysis was conducted on four patients who underwent TES between 2019 and 2020. Patient data, including demographics, tumor characteristics, and surgical details, were collected. Customized 3D-printed vertebral prostheses were created based on computed tomography (CT) and magnetic resonance imaging (MRI) scans. Surgical procedures were performed, and clinical outcomes were assessed using the Visual Analog Scale (VAS) for pain and the Oswestry Disability Index (ODI) for functional status. Mechanical strength testing of the implants was conducted, and statistical analysis was performed using ANOVA ($p<0.0001$).*

Results: *Preliminary results indicate that 3D-printed individual vertebral prostheses are suitable for anterior column reconstruction following TES. VAS and ODI scores showed significant improvements post-surgery, reflecting reduced pain and enhanced functional outcomes. Mechanical testing revealed the implants' robustness, with no signs of deformation or failure even at maximum loads.*

Conclusions: *The integration of 3D printing technology into spinal surgery holds promise for optimizing patient-specific reconstructions. Customized vertebral prostheses offer benefits such as improved surgical planning, reduced procedure duration, and minimized perioperative blood loss. While challenges, including the need for specialized software and limited long-term data, exist, this study underscores the potential of 3D-printed implants in enhancing patient outcomes. Further research with a larger patient cohort and longer follow-up periods is essential to confirm the effectiveness of personalized implants in spinal surgery.*

Keywords: *3D implant, vertebrae, tumor, prosthesis, total en bloc spondylectomy.*

Introduction:

The application of 3D printing technology for crafting implants to replace affected vertebrae marks a groundbreaking and progressive stride within the realm of personalized medicine. Nevertheless, the journey of implementing this cutting-edge technology necessitates meticulous scrutiny and analysis to overcome the challenges it presents. At present, the predominant employment of 3D printing lies in the domain of spinal surgery, predominantly within the preoperative planning phase. This strategic utilization of a full-scale, three-dimensional model of the affected region brings forth invaluable insights, enabling the assessment of preoperative risks while honing surgical skills tailored to each unique case. As a natural consequence, this approach translates into tangible benefits, encompassing a notable reduction in surgical procedure duration and the minimization of perioperative blood loss [1].

The realm of oncology grapples with an immediate and pressing concern: the absence of specialized implants for post-tumor resection reconstruction. Within this context, there is a resounding demand for implants that find their genesis in 3D printing technology, a demand well-reflected in the literature [2-5]. Notably, this demand is more pronounced in cases of tumor resection, while instances of degenerative changes and congenital anomalies of the spine witness a lesser extent of such utilization [5, 6]. In such instances, the recommendation leans towards the use of individual prostheses crafted from

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titanium alloy (TiV6Al4), largely due to their inherent biocompatibility and their ability to optimize porosity in a manner that mirrors the trabecular structure of vertebral cancellous bone. Multiple clinical and biomechanical studies attest to the suitability of titanium implants for vertebral body replacement. This technology's pinnacle lies within the realm of spinal neurosurgery at the preoperative planning stage. Among the numerous advantages conferred by 3D printed implants, one can cite the ability to preemptively assess preoperative risks, skillfully tailor surgical interventions, and consequently reduce the duration of the surgical procedure itself, alongside the associated perioperative blood loss. The precision intrinsic to 3D printing ensures a seamless fit of implants onto prepared surfaces of neighboring vertebrae, bolstering implant stability while simultaneously minimizing complications such as osteolysis and the subsidence of otherwise healthy bone tissue [2-4]. However, it is essential to acknowledge the flip side – negative aspects reminiscent of those encountered in various applications of 3D printing in spinal surgery. The creation of these specialized implants mandates additional investments of time and resources [6]. The intricacies of the software and hardware prerequisites further add to the barrier of wide-scale implementation [7-12]. Furthermore, the dearth of comprehensive long-term data concerning the efficacy of these prostheses poses a challenge [6]. Nonetheless, as previously elucidated, the trajectory of these methods points towards a promising future, particularly in the realm of complex spinal prostheses.

The versatility inherent to 3D printing extends to the generation of previously unattainable geometries, including the remarkable capacity to replicate the interconnected structure of cancellous bone. By exerting control over porosity and surface roughness, the optimization of osseointegration becomes a feasible prospect [13]. This, when combined with an open architectonics that maximizes bone graft volume, results in the creation of implants that harness the complete potential of 3D printing sans the encumbrance of setup-related planning. This technology is particularly advantageous in terms of customization, offering a spectrum of implant sizes encompassing variables such as width, height, length, and angles. This versatility translates to the practical utilization of spinal implants, all while minimizing complications such as migration and protection against osteolysis [14-16]. Moreover, in conditions demanding such implants, the employment of 3D printing proves to be cost-effective, thereby addressing the demand with an economically viable solution.

Peering into the future, one can discern the impending arrival of innovative features, most notably porous matrices. This innovation brings forth the intriguing prospect of variably adjusting the density, pore diameter, and mechanical properties in different sections of the implant [14]. As the trajectory of 3D printing technology is guided by factors such as cost-effectiveness, speed, and precision, its seamless integration into spinal surgery appears inevitable. The landscape becomes further enriched with the potential advent of affordable desktop 3D printers, catering to everyday usage. This impending reality is poised to revolutionize the landscape, ushering in real-time model creation and implants that align meticulously with personalized surgical requirements [3, 5]. Furthermore, as the range of available materials widens, new opportunities beckon, promising enhanced biocompatibility, osseointegration, and biodegradability [5, 17-19]. Amidst these promising horizons, the crescendo of advancement finds its apex in the concept of bioprinting. Within this paradigm, cells, growth factors, and biomaterials coalesce to generate living tissue, potentially culminating in the 3D printing of complex organs and facilitating direct tissue repair [20].

Beyond the sphere of surgical procedure optimization, the advantages of 3D printing extend into domains such as reduced fluoroscopy time, enhanced team cohesion, and superior rates compared to conventional imaging methods within the preoperative phase. Despite these advantages, the dearth of research featuring control groups hampers the establishment of conclusive evidence substantiating the advantages of 3D technology in surgical preparation.

In pursuit of spinal column restoration, various methodologies have been proposed. Among these, we advocate for the implementation of personalized implants that mirror the contours of the endplates of adjacent vertebrae. This ingenious approach promises to distribute loads more effectively, mitigating the risk of a stress-shielding effect and ultimately improving overall implant performance.

Methods:

The study received approval from the institutional ethics committee. A retrospective evaluation was conducted on patients who underwent en bloc spondylectomy for benign spinal tumors using

individual implants between the years 2019 and 2020. A total of four patients underwent this procedure within the period of January to December 2019. Specifically, two patients were diagnosed with aggressive hemangiomas of the T9 and T10 vertebrae, presenting with epidural invasion, spinal cord compression, and requiring surgical intervention. Additionally, two other patients were diagnosed with giant cell tumors of the Th7 vertebra, necessitating replacement of the affected vertebrae with individual implants. All surgical interventions were performed with the informed consent of the patients.

Clinical Data Collection:

Comprehensive clinical data was collected and evaluated for analysis. This data included patient characteristics such as age and gender, neurological findings assessed using the ASIA scale, localization of the spinal tumor, pathological diagnosis, pre- and post-operative patient conditions, pre- and post-operative pain assessed through visual analogue scores (VAS), Oswestry Disability Index (ODI) for functional status, time of operation, intraoperative blood loss, and any postoperative complications. Preoperative CT and MRI scans were conducted to establish baseline conditions, while postoperative CT scans were performed at 3 days, 3, 12 and 24 months after the surgical procedure.

Selection Criteria:

The study population was not distributed based on sex. Participants were required to be over 18 years of age and have different nationalities, reflecting the diverse demographic of the region. Inclusion criteria consisted of patients with isolated tumor lesions of the thoracic spine meeting the following criteria:

a) Tumor Classification: Tumors were classified based on Enneking's classification of spinal tumors, with classification not exceeding type 4.

b) Spine Instability Neoplastic Score (SINS): Patients were included if they had a SINS index indicating instability, with a threshold value of ≥ 7 points.

Exclusion Criteria:

a) Pregnant women, patients with severe immunodeficiency, severe somatic pathology, exacerbation of chronic diseases, and those who underwent chemoradiotherapy within 3 months prior to surgery were excluded from the study.

b) Patients assessed on the ASIA scale at a level less than C were not included in the study cohort.

Surgical Technique

A median incision was made, exposing two levels above and below the affected vertebra, while under C-arm control. A lateral dissection revealed the bilateral costovertebral joints. Standard transpedicular fixation technique was employed to secure two levels above and below the affected vertebra. Vertebrectomy was executed using a bilateral costal-transversectomy approach, following the Tomita Method. The process involved removing approximately 6-8 cm of the rib's posterior portion, exposing the parietal pleura. Sequentially, the arch pedicles of the affected vertebra were cut at their base using a Gigli saw. Subsequently, the entire posterior element of the vertebra was removed. The excised tissue was sent for histopathological analysis. The individualized 3D implant was positioned between the healthy vertebrae proximally and distally. After proper placement, gentle compression was applied, and fixation was achieved using a transpedicular structure. Post-surgery, the pathologist meticulously examined the surgical margins of the tumor. Based on evaluation, all four cases were categorized as Tomita 3, with none displaying vertebral endplate involvement.

Postoperative Control

Comprehensive clinical and radiological evaluations were conducted both preoperatively and during postoperative follow-up periods (Fig. 1). Clinical outcomes were gauged using the Visual Analog Scale (VAS) for back pain and the Oswestry Disability Index (ODI) scores [4]. Neurological function alterations before and after surgery were assessed using the Frankel Scale. Patient outcome scores were collected at multiple time points: preoperatively, 1 week postoperatively, and at 3, 12, and 24 months post-surgery. Preoperative CT and MRI scans were performed for all patients. Subsequent follow-up CT scans were utilized to measure any subsidence of the prosthesis into the adjacent vertebral body. By employing this meticulous surgical technique and closely monitoring clinical and radiological outcomes, the study ensured a comprehensive evaluation of the proposed approach for vertebral body replacement.

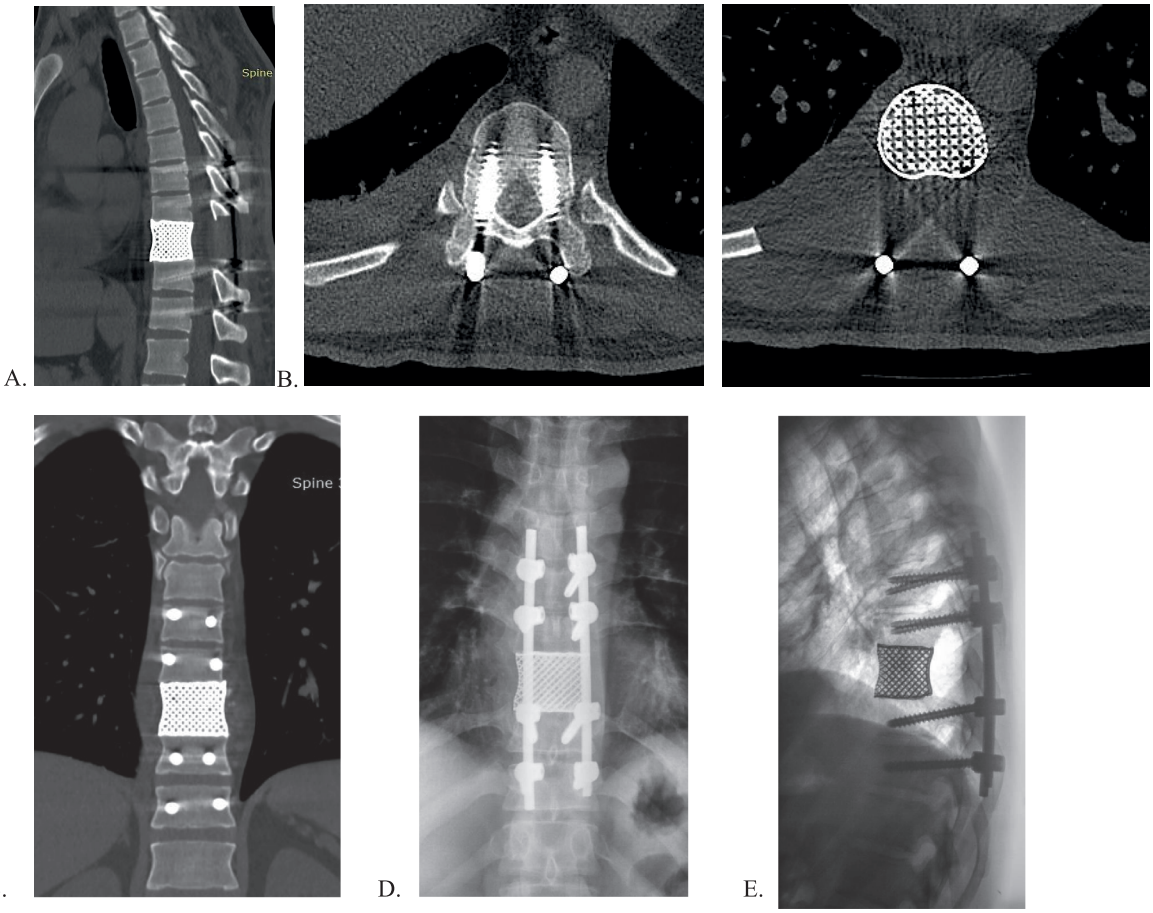

Figure 1 – Case 2. 37-year-old man presented with tumor of the T9 vertebra. Surgical resection and reconstruction was performed in combination with a 3D printed, patient-specific implant. Custom design features included porous titanium endplates, corrective angulation of the implant to restore sagittal balance. In addition, the customized features of the patient specific implant eliminates the need for fixation the 3D implant to the transpedicular construction. A: Postoperative sagittal section. B: Postoperative axial section. C: Postoperative frontal section CT scans and X-ray at 60 months. D: Frontal. E: Sagittal

Implant Planning and Testing

The development of a secure implant involved a three-step process. In the initial phase, the design engineer employed a computer-aided design (CAD) system to craft a 3D model of the affected spinal body. This model was generated using finite element analysis (FEA) based on computed tomography (CT) and magnetic resonance imaging (MRI) scans of an actual patient's thoracic spine. From several tested forms using the FEA method, the implant structure was chosen as hexagonal cells due to its superior strength and stress resistance under varying loads.

The subsequent step entailed subjecting the implant to an experiment using a press machine to simulate a static uniaxial axial load. This was done to evaluate the mechanical strength of the implant .

Finally, in the third step, the impact of the custom 3D printed vertebra prosthesis on the biomechanics of the thoracic spine was explored through biomechanical testing on cadaveric samples. These tests were conducted at the Institute of Traumatology and Biomechanics in Ulm, Germany. Initially, CT scans of the thoracic spine were performed on six cadaveric preparations. Subsequently, based on mathematical models, six implants were 3D printed from a titanium alloy Ti6Al4V (powder) with a chemical composition conforming to ASTM F136-02a (ELI Grade 23) standards. This cutting-edge 3D printing technology was employed by "Galam" LLP.

The implant insertion process was executed with precision by experienced spine surgeons to ensure reproducibility. The device was inserted, and posterior fixation was achieved using pedicle screw-rod instrumentation from T4 to T8. This procedure was carried out in the upright specimen position without distraction, and the posterior instrumentation was secured without compression. For the T4 and T5 vertebrae, pedicle screws with dimensions of

5.0 mm diameter and 40 mm length were employed. Meanwhile, for T7 and T8, 5.0×45 mm pedicle screws were selected and joined by rods with a diameter of 5.5 mm.

The data collected during the load-displacement phase of the spinal tester were integrated with the information from the optical motion tracking system. This amalgamation facilitated the generation of volume of motion data for each segment, using an established Matlab script (Matlab 2014, MathWorks Inc., Natick, USA). These results underwent post-processing using Microsoft Excel (Microsoft Corp., Redmond, USA) and underwent rigorous statistical analysis using Rstudio (R Core Team (2021) [21].

Results:

Mechanical Strength Evaluation:

The assessment of mechanical strength for the proposed implants revealed no instances of deformation or structural damage even at maximum loads. The analysis of static axial compressive strength for the vertebral body implant demonstrated that all samples withstood testing up to a machine limit of 20 kN. The average stiffness was measured at 30.458 N/mm with a standard deviation of 5.5. None of the samples exhibited visible irreversible deformation or mechanical failure. Notably, plastic deformation (F out, 2%) and alternative output load (F out, 0.2%) could not be determined due to the absence of deformation. The analysis underscored that the implant provided reliable segment stabilization while maintaining superior stress resistance compared to standard implants [21, 22].

Surgical and Clinical Outcomes:

All patients underwent thoracic en bloc spondylectomy (TES) under general anesthesia, with follow-up period from 56 to 60 month (57.25 on the average). Other characteristics of patients related to gender, age, diagnosis, and time of surgery are highlighted in Table 1. The surgical operation lasted 310-535 min (mean 386.25) with blood loss of 1,200-3,100 ml (mean 2,375 ml). The main preparative indicators such as VAS and the ODI mean were 6.75 and 67. The average reduction of the pain syndrome according to the VAS of 1.5 points (from 2 to 1) after 3 month and 0.75 points (from 1 to 0) after 12 month. The same trends were also observed using ODI score 18.5 (from 14 to 22) after 3 month and 13 (12 to 14) after 12 month (Table 2). ANOVA ($p<0.0001$) suggests that there are significant differences in VAS and ODI scores among the different time points (Before, 3 Months, and 12 Months) (Table 3).

Table 1

PATIENTS' DATA AND TEST RESULTS BEFORE AND AFTER SURGICAL PROCEDURES

№	Gender	Age	Diagnosis	Level	Blood loss (ml)	Time of surgery (min)	Adjuvant therapy	Frankel scale before surgery	Frankel scale after surgery	Frankel scale after 3 month	VAS before surgery	VAS after surgery	VAS after 3 month	VAS after 12 month	ODI before surgery (%)	ODI after surgery (%)	ODI after 3 month (%)	ODI after 12 month (%)
1	F	59	heman gioma	T7	2,500	360	No	E	E	E	8	4	2	1	72	44	20	14
2	M	37	heman gioma	T9	1,200	310	No	E	E	E	6	3	1	1	66	32	18	14
3	F	64	giant cell	T10	2,700	340	No	D	D	E	5	2	1	0	62	40	14	12
4	F	48	giant cell	T6	3,100	535	No	E	E	E	8	4	2	1	68	36	22	12

Table 2

PATIENT AND SURGICAL CHARACTERISTICS (N=4). MEDIAN (INTERQUARTILE RANGE) AND MEAN (STANDARD DEVIATION)

Variables	Median (IQR)	Mean (SD)
Age	53.5 (15)	52 (12.02)
Blood loss	2.600 (625)	2.375 (822.09)
Surgery Time	350 (71.25)	386.25 (101.27)
VAS score before surgery	7 (2.25)	6.75 (1.5)
VAS after surgery	3.5 (3.25)	3.25(0.96)
VAS After 3 months	1.5 (1)	1.5 (0.57)
VAS after 12 months	1 (0.25)	0.75 (0.5)
ODI score before surgery	1 (4)	67 (4.16)
ODI after surgery	38 (6)	38 (1.15
ODI After 3 Months	19 (3.25)	18.5 (3.41)
ODI After 12 Months	13 (2)	13 (1.15)

Table 3

ANOVA FOR VAS AND ODI SCORES BY TIME POINTS

VAS score					
	Df	Sum Sq	Mean Sq	F value	P value
Time	3	85.69	28.563	30.47	6.8e-06 ***
Residuals	12	11.25	0.938		
ODI score					
Time	3	7145	2381.6	167.1	4.73e-10***
Residuals	12	171	14.3		
***Significance level = 0.05** **df = degrees of freedom, F=between-group/within variables**					

At the outset of the study, the mean ODI score before surgery stood at 67 (±4.16), indicating a considerable degree of disability and functional limitations among the patients in our cohort. Post-surgery, there was a pronounced reduction in ODI scores, with a mean of 38 (±1.15), reflecting a 43.28% decrease in disability. The same striking finding in our study was the substantial reduction in ODI scores observed at the 3-month assessment, with a mean score of 18.5 (±3.41), representing an impressive 72.39% reduction. This rapid and substantial improvement within just three months post-surgery underscores the transformative impact of the surgical intervention on patients' lives. Our long-term assessment, conducted at the 12-month mark, demonstrated that the benefits of surgery were not transient but persisted over time. The mean ODI score further decreased to 13 (±1.15), indicating that the improvements in functional outcomes were sustained and durable, amounting to a 80.60% reduction (Fig. 2).

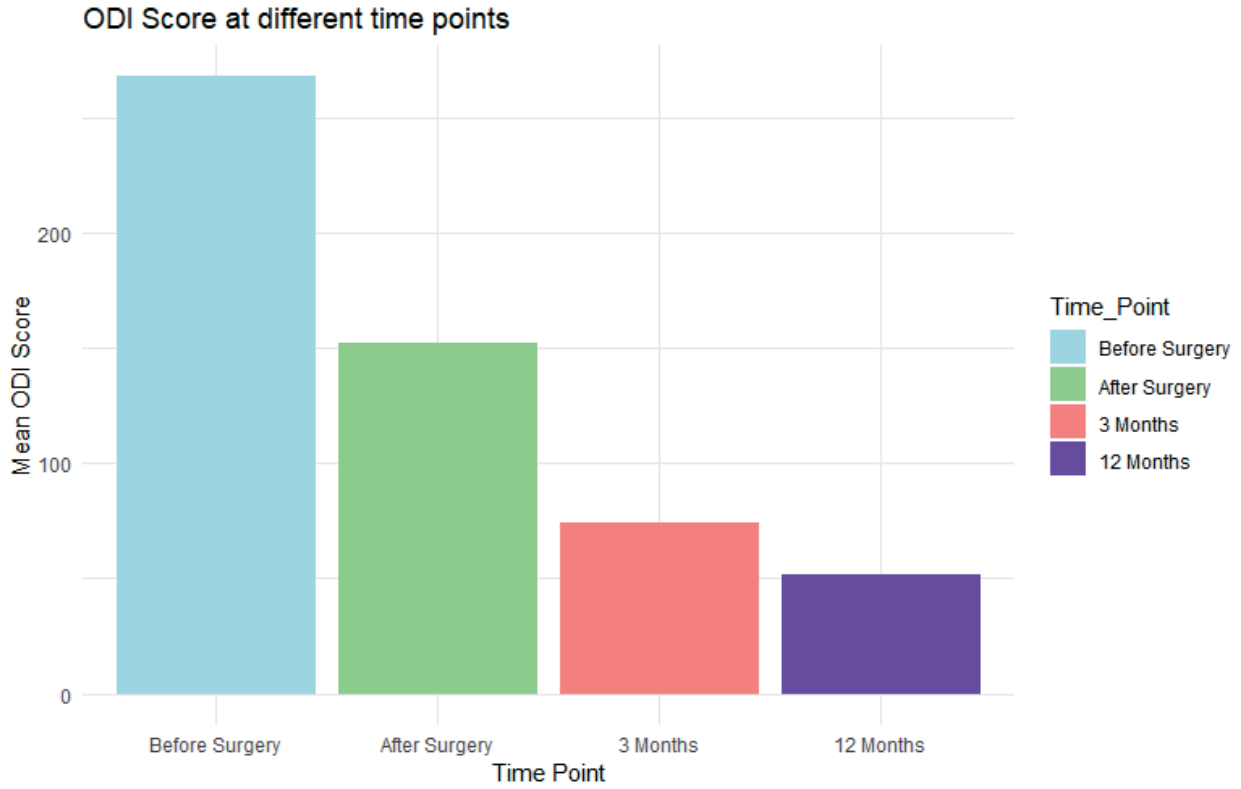

Figure 2 – Comparison ODI score

Significant improvements in Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores were observed postoperatively. The mean VAS score before surgery was 6.75 (±1.5), indicating a considerable level of pain and discomfort among the patients in our cohort. Immediately after surgery, patients experienced a significant reduction in pain, as reflected in the mean VAS score of 3.25 (±0.96). This marked improvement shortly after the procedure is a testament to the effectiveness of the surgical intervention and the relief it provided to our patients. The most striking observation in our study was the substantial reduction in VAS scores at the 3-month mark. Patients reported a mean VAS score of 1.5 (±0.57), signifying a remarkable 77.78% reduction in pain and discomfort levels. The positive trend continued in our long-term assessment, with the mean VAS score dropping to 0.75 (±0.5) after 12 months, representing an 88.89% reduction (Fig. 3). This extended follow-up period allowed us to conclude that the benefits of the surgical intervention were not only immediate but also sustained over time.

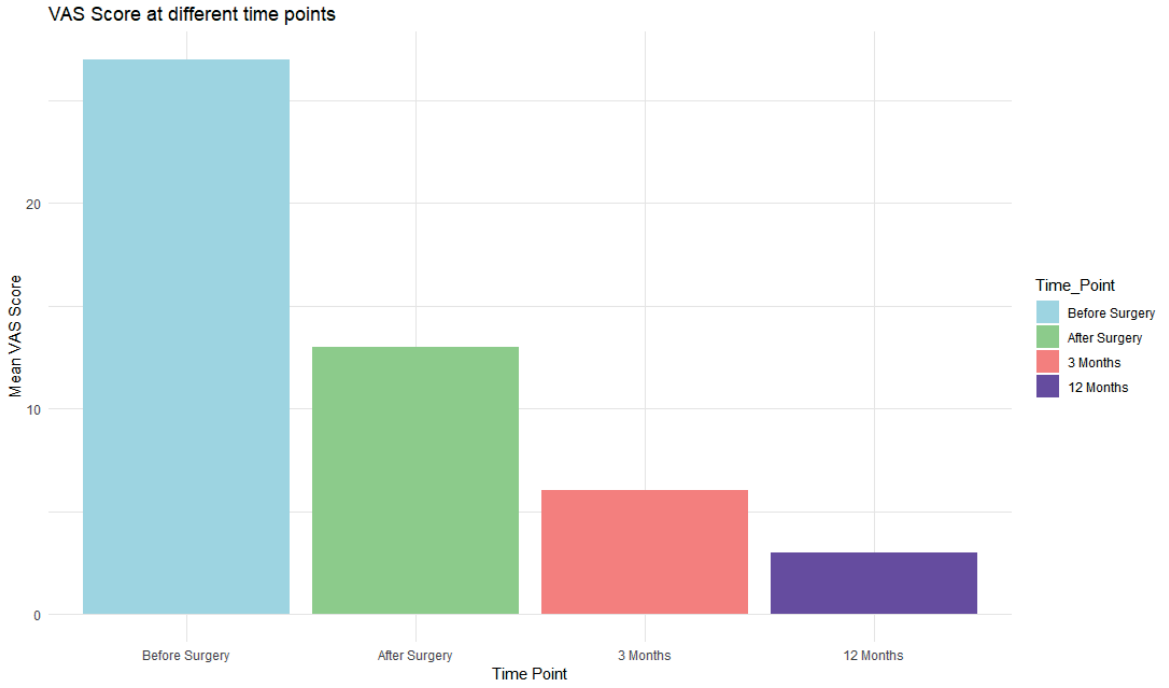

Figure 3 – Comparison VAS score

The outcomes observed in this study offer profound insights into the transformative potential of 3D-printed individual vertebral prostheses in the realm of spinal surgery. The notable improvements in both the Oswestry Disability Index (ODI) and Visual Analog Scale (VAS) scores underscore the efficacy of this innovative surgical approach in enhancing patient outcomes and pain management.

Patients' neurological function assessed using the Frankel scale at various time points. Before surgery, all patients had a consistent 'E' score on the Frankel scale, indicating intact motor and sensory function. After surgery, Patient 1 improved to a 'D' score, Patient 2 remained at 'E,' and Patient 3 retained a 'D' score.

A follow-up assessment three months after surgery revealed that both Patient 1 and Patient 2 returned to their initial 'E' scores, suggesting that their neurological function had largely recovered. Patient 3, however, continued to have a 'D' score, indicating limited improvement in neurological function during the three-month period. Histological analysis revealed hemangioma in 2 patients (50%) and giant cell was observed in 2 patients (50%). The mean observation period for the four patients in our study was approximately 28.75 months. This period represents the duration over which patients were monitored for changes in their medical condition and treatment outcomes (Table 1).

During meticulous examination of patients' CT images, no evidence of internal fixation failure or vertebral prosthesis dislocation was detected. Additionally, there were no instances of neurological deterioration across all patient complication.

Discussion:

3D printing has revolutionized complex spinal surgery by enabling the fabrication of personalized implants, leading to superior postoperative outcomes. This innovation streamlines surgical procedures through pre-planning using 3D printed patient models and digital imaging. Additionally, 3D printing offers the creation of tailored shapes, ensuring precise anatomical compatibility at the implant site. Notably, it has shown success in cranioplastic surgery, preserving skull anatomy and minimizing the risk of brain damage. Similar success stories include instances where titanium implants replaced spinal vertebrae, resulting in osteointegration and preserving anatomical integrity. Moreover, 3D printing empowers the modification of endplate porosity in implanted prostheses, enhancing osteointegration through surface modifications like roughening and topography, along with coating implant surfaces with materials such as hydroxyapatite or titanium plasma spray.

Despite these advantages, 3D printing in spinal neurosurgery presents challenges. Specialized software and 3D printers capable of working with titanium are required, and mathematical modeling is necessary to mitigate rejection risks, making the planning and production process time-consuming and resource-intensive. Surgeons must collaborate

closely with design engineers and possess CAD skills, posing a barrier to wider adoption of patient-specific 3D printing. Regulatory frameworks for 3D implants in spinal surgery are absent, necessitating the establishment of a registration and approval system.

However, despite these challenges, this method shows promise due to positive patient outcomes and minimal complications. This paves the way for future advancements in vertebral prosthetics, especially in complex cases. Larger studies with control groups are required to validate the benefits of 3D technologies in surgical preparation.

It is important to note that en-bloc resection with vertebral body replacement was found to be highly effective for spinal tumor cases. Prior to surgery, our patients exhibited a significant degree of disability, which was substantially alleviated post-surgery. This rapid and substantial improvement within the initial postoperative period highlights the profound impact of the surgical intervention on patients' functional abilities. Importantly, our long-term assessment revealed the enduring nature of these improvements, emphasizing the sustained and durable benefits of 3D-printed vertebral prostheses on patients' quality of life.

In parallel, the significant enhancements in VAS scores validate the effectiveness of the surgical intervention in providing pain relief and improving patients' overall well-being. The initial levels of pain and discomfort experienced by patients preoperatively were substantially reduced following surgery, affirming the procedure's effectiveness in alleviating pain. This rapid and significant relief emphasizes the surgical intervention's capacity to provide immediate benefits. Encouragingly, this positive trend persisted in our long-term assessment, conclusively demonstrating the enduring nature of the benefits conferred by the surgical intervention.

Our study underscores the substantial and persistent enhancements in functional outcomes and pain relief achieved through 3D-printed individual vertebral prostheses in spinal reconstruction following thoracolumbar Total En-bloc Spondylectomy (TES). These results highlight the transformative potential of personalized implants in spinal surgery, offering patients both immediate and long-lasting improvements in their quality of life. This research contributes to the growing body of evidence supporting the efficacy of 3D printing technology in spinal surgery, emphasizing its potential to revolutionize patient care and outcomes in the future.

Conclusions: The study recommends a modified total resection approach with 360-degree fixation and individual 3D implant replacement for tumor-affected spinal segments. This approach offers complete spinal cord decompression, leading to relatively low complication rates and improved patient quality of life. The integration of 3D printing in spinal surgery has immense potential for transforming patient outcomes and surgical practices, paving the way for a future of personalized and optimized procedures.

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«Ұлттық нейрохирургия орталығы» АҚ, Астана қ., Қазақстан

БЕС ЖЫЛДЫҚ БАҚЫЛАУ КЕЗЕҢІМЕН КЕУДЕ ОМЫРТҚАСЫНЫҢ ІСІГІН БЛОКТЫҚ РЕЗЕКЦИЯСЫНАН КЕЙІН ОМЫРТҚА ДЕНЕСІН АУЫСТЫРУҒА АРНАЛҒАН ДЕРБЕС 3D БАСЫП ШЫҒАРЫЛҒАН ИМПЛАНТ

Мақсаты: Бұл зерттеу омыртқаның қатерсіз ісіктері бар емделушілерде тораколюмбарлық толық En-bloc спондилектомиясынан (ТЕС) кейін омыртқаны қалпына келтіру үшін 3D басып шығарылған жеке омыртқалы протездерді қолдануды бағалауға бағытталған. Негізгі мақсат әртүрлі реконструкциялау оталарында 3D басып шығарылған протездердің орындылығын бағалау және олардың қысқа мерзімді перспективада омыртқаның тұрақтылығы мен неврологиялық қызметіне әсерін анықтау кіреді.

Әдістері: 2019 және 2020 жылдар аралығында ТЕС-тен өткен төрт пациентке ретроспективті талдау жүргізілді. Пациент деректері, соның ішінде демография, ісік сипаттамалары және хирургиялық мәліметт-

тер жиналды. Компьютерлік томография (КТ) және магнитті-резонанстық томография (МРТ) сканерлері негізінде арнайы 3D басып шығарылған омыртқалы протездер жасалды. Хирургиялық оталардан кейін клиникалық нәтижелерді зерттеу соның ішінде ауырсынудың деңгейін білу үшін Visual Analog Scale (VAS) және функционалдық күйін анықтау мақсатында Oswestry Disability Index (ODI) шкалаларын қолданылды. Имплантанттардың механикалық беріктігін сынау жүргізілді және статистикалық талдау ANOVA ($p<0,0001$) бағдарлама көмегімен жүргізілді.

Нәтижелер: Алдын ала нәтижелер 3D басып шығарылған жеке омыртқалы протездердің ТЕС-тен кейін алдыңғы бағананы қалпына келтіруге жарамды екенін көрсетеді. VAS және ODI көрсеткіштері ауырсынудың төмендеуін және жақсартылған функционалды нәтижелерді көрсететін операциядан кейінгі айтарлықтай жақсартуларды көрсетті. Механикалық тестілеу имплантардың беріктігін, тіпті максималды жүктемелерде деформация немесе бұзылу белгілері жоқ екеніне көз жеткізді.

Қорытынды: 3D басып шығару технологиясын омыртқа хирургиясына енгізу пациентке тән реконструкцияларды оңтайландыруға мүмкіндік береді. Жекелеген омыртқалы протездер хирургиялық жоспарлауды жақсарту, ота ұзақтығын қысқарту және отадан кейінгі қан жоғалтуды азайту сияқты артықшылықтарды ұсынады. Арнайы бағдарламалық қамтамасыз ету қажеттілігі және шектеулі ұзақ мерзімді деректерді қоса алғанда, қиындықтар болса да, бұл зерттеу пациенттердің нәтижелерін жақсартудағы 3D басып шығарылған имплантардың әлеуетін атап көрсетеді. Омыртқа хирургиясындағы жеке имплантардың тиімділігін анықтау үшін науқастардың үлкен тобымен және ұзақ мерзімді бақылау кезеңдерімен қосымша зерттеулер жүргізудің маңыздылығын көрсетеді.

Негізгі сөздер: 3D имплант, омыртқалар, ісік, блоктық спондиэктомия.

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ПРИМЕНЕНИЕ ПЕРСОНИФИЦИРОВАННОГО 3D ИМПЛАНТАТ ТЕЛА ПОЗВОНКА ПРИ РЕЗЕКЦИИ ОПУХОЛИ ГРУДНОГО ОТДЕЛА ПОЗВОНОЧНИКА ЕДИНЫМ БЛОКОМ С ПЯТИЛЕТНИМ ПЕРИОДОМ НАБЛЮДЕНИЯ

Цель. Целью данного исследования является оценка применения индивидуальных имплантов позвонков, напечатанных на 3D-принтере, для реконструкции позвоночника после тотальной спондилэктомии (TES) грудопоясничного отдела позвоночника у пациентов с доброкачественными опухолями позвоночника. Основные цели включают оценку возможности имплантов, напечатанных на 3D-принтере, в различных вариантах реконструкции и определение их влияния на стабильность позвоночника и неврологическую функцию в краткосрочной перспективе.

Методы. Был проведен ретроспективный анализ четырех пациентов, перенесших TES в период с 2019 по 2020 год. Были собраны данные пациентов, включая демографические данные, характеристики опухоли и хирургические особенности. Индивидуальные имплатны позвонков, напечатанные на 3D-принтере, были созданы на основе сканирования с помощью компьютерной томографии (КТ) и магнитно-резонансной томографии (МРТ). Были выполнены хирургические процедуры, а клинические результаты были оценены с использованием визуальной аналоговой шкалы (ВАШ) для боли и индекса нетрудоспособности Освестри (ODI) для функционального состояния. Было проведено механическое испытание прочности имплантатов, а статистический анализ был выполнен с использованием ANOVA ($p < 0,0001$).

Результаты. Предварительные результаты показывают, что 3D-печатные индивидуальные позвоночные импланты применинмы для реконструкции передней колонны после TES. Оценки ВАШ и ODI

показали значительные улучшения после операции, отражающие уменьшение боли и улучшение функциональных результатов. Механические испытания показали надежность имплантатов без признаков деформации или разрушения при максимальных нагрузках.

Выводы. Интеграция технологии 3D-печати в спинальную хирургию обещает оптимизацию реконструкций, специфичных для пациента. Индивидуально изготовленные позвоночные протезы предлагают такие преимущества, как улучшенное хирургическое планирование, сокращение продолжительности процедуры и минимизация кровопотери. Хотя существуют проблемы, включая необходимость в специализированном программном обеспечении и ограниченные долгосрочные данные, это исследование подчеркивает потенциал 3D-печатных имплантатов в улучшении результатов лечения пациентов. Дальнейшие исследования с более крупной группы пациентов и более длительными периодами наблюдения необходимы для подтверждения эффективности персонализированных имплантатов в спинальной хирургии.

Ключевые слова: 3D-имплантат, позвонки, опухоль, протез, тотальная спондилэктомия единым блоком.