Resection of Spinal Osteoid Osteoma Assisted by 3D Planning. Case Report

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ABSTRACT
The vertebral location of a lesion compatible with an osteoid osteoma often requires a marginal en bloc resection. Our objective is to present the use of 3D printing technology for the development of specific cutting guides that achieve a safe and complete resection of an L1 osteoid osteoma. We present the case of a 13-year-old male who underwent surgery for an L1 osteoid osteoma, detailing the preoperative planning assisted by 3D technology, the surgical technique using 3D printed cutting guides, a real model of the lumbar spine, and the postoperative control. **Conclusion:** Before the surgical indication of a lesion compatible with an osteoid osteoma in the spine, we must decide between the possibility of an open intralesional resection or percutaneous and marginal en bloc resection. Different methods can be used for the intraoperative location of the lesion. In our department, we use 3D technology for preoperative planning of multiple acute and post-traumatic pathologies. This allows us to be precise and safe in the identification of intraoperative resection margins, minimizing the removal of healthy tissues and avoiding postoperative instability.
Keywords: Osteoid osteoma; en bloc resection; 3D printing technology.
Level of Evidence: IV

Resección de osteoma osteoide vertebral asistida por planificación 3D. Presentación de un caso

RESUMEN
La localización vertebral de una lesión compatible con un osteoma osteoide requiere, muchas veces, su resección en bloque marginal mediante cirugía. El objetivo de este artículo es informar sobre el uso de la tecnología en impresión 3D para desarrollar guías de corte y así lograr una resección segura y completa de un osteoma osteoide de L1. Presentamos a un varón de 13 años, operado de un osteoma osteoide de L1 y detallamos la planificación preoperatoria con asistencia de la tecnología 3D, la técnica quirúrgica mediante guías de corte impresas y un modelo real de la columna lumbar y el control posoperatorio. **Conclusión:** Ante la indicación de cirugía para una lesión compatible con osteoma osteoide en la columna debe decidirse entre la posibilidad de resección intralesional abierta o percutánea y la resección marginal en bloque. Para localizar la lesión durante la cirugía, se utilizan diferentes métodos. En nuestro Servicio, estamos utilizando la tecnología 3D para la planificación preoperatoria de múltiples patologías traumatológicas agudas y las secuelas. Esto nos permite una mayor precisión y seguridad en la identificación de los márgenes de resección intraoperatoria, reduciendo, al mínimo, la extracción de tejidos sanos y evitando la inestabilidad posoperatoria.
Palabras clave: Osteoma osteoide; resección en bloque; impresión 3D.
Nivel de Evidencia: IV

INTRODUCTION

Osteoid osteoma is a benign bone tumor described by Jaffe in 1935.[1] It represents 3% of all bone tumors and 10-12% of benign tumors. It appears in the second decade of life and mainly affects long bones (particularly lower limbs). 10-25% of cases involve the spine and, in 70-100%, it affects the posterior elements. It is characterized by a nest (nidus) of osteoid tissue, osteoblasts, and fibrovascular stroma surrounded by sclerotic bone; typically <1.5 cm in diameter.[2]

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In the spine, the characteristic presentation includes local pain (related to the increase in prostaglandin E2), predominantly at night, which can be accompanied by segmental rigidity (89%), antalgic scoliosis (60-70%) and, in exceptional cases, neurological deficit. The pain usually responds to treatment with nonsteroidal anti-inflammatory agents (NSAIDs) and aspirin.[3,4]

The diagnosis is confirmed with a computed tomography (CT) scan that typically shows a hypodense area surrounded by sclerotic bone. MRI in T2-weighted sequences shows a hypointense image surrounded by variable edema and the administration of gadolinium generates an enhancement around the nidus. The scintigram is invariably positive and allows localization of the hyperenhancing lesion in patients with a presumed lesion.[5]

Extirpation of the lesion is indicated if conservative treatment fails or in the event of the possibility of structuring antalgic scoliosis.[6]

Surgical resection of the lesion is recommended if there is a clinical or imaging suspicion of a spinal osteoid osteoma with a nidus in close proximity to neurological structures (<6 mm) or the absence of a cortical layer protecting the spinal canal. Undoubtedly, the most important difficulty is the intraoperative localization of the lesion.

In our Service, we have gained experience with 3D planning and printing. This technology allows us to precisely locate and visualize the lesion and, in this way, print specific cutting guides that closely adapt to the anatomy of the bone to be resected. It is an economical and safe way to delimit bone resection, minimizing the damage to adjacent structures.

The objective of this article is to report on the use of 3D printing technology to develop cutting guides in a case of osteoid osteoma of L1 to achieve a safe and complete resection of the lesion, minimizing bone resection to reduce the risk of postoperative instability.

CLINICAL CASE

A 13-year-old male consulted for left-sided, paravertebral, high lumbar pain of three months' duration, predominantly at night, constant, which improved with NSAIDs and reappeared when they were discontinued. The radiographs showed scoliosis at the level of T11-L3 and sclerosis of the left L1 pedicle (Figure 1).

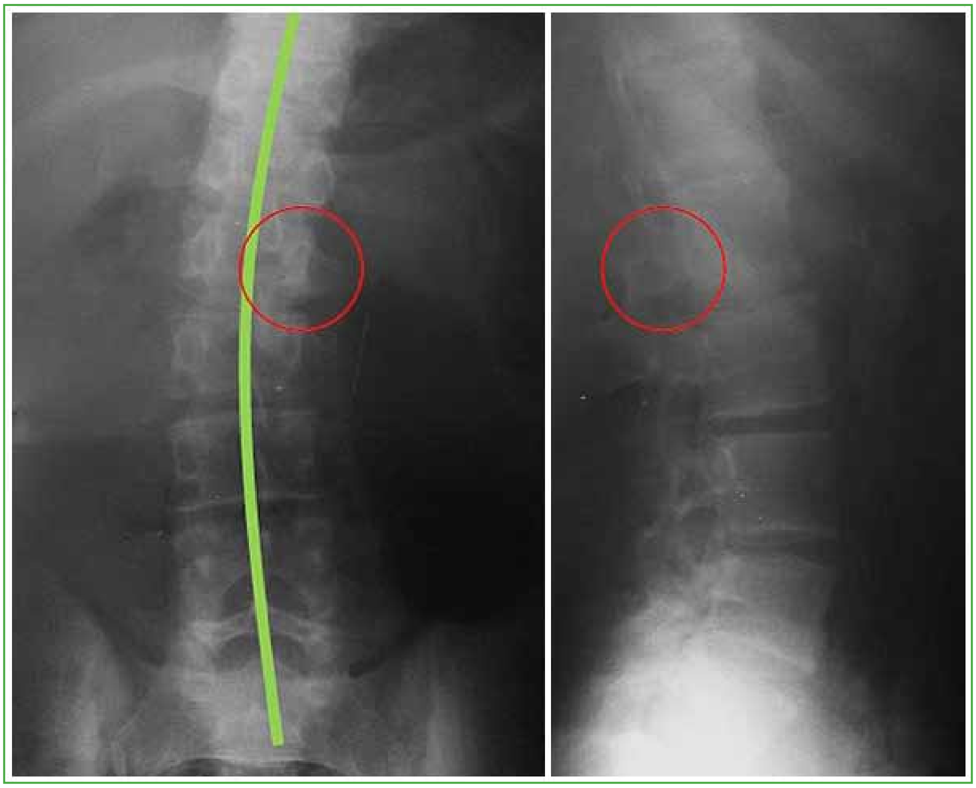

Figure 1. Anteroposterior and lateral radiographs of the lumbar spine. Note the antalgic scoliosis in the coronal plane and the focal sclerosis in the left pedicle of L1.

The patient presented an MRI that showed edema of the left pedicle, of the posterior region of the body of L1 and the posterior elements, and a hypointense lesion that suggested a bone tumor (Figure 2).

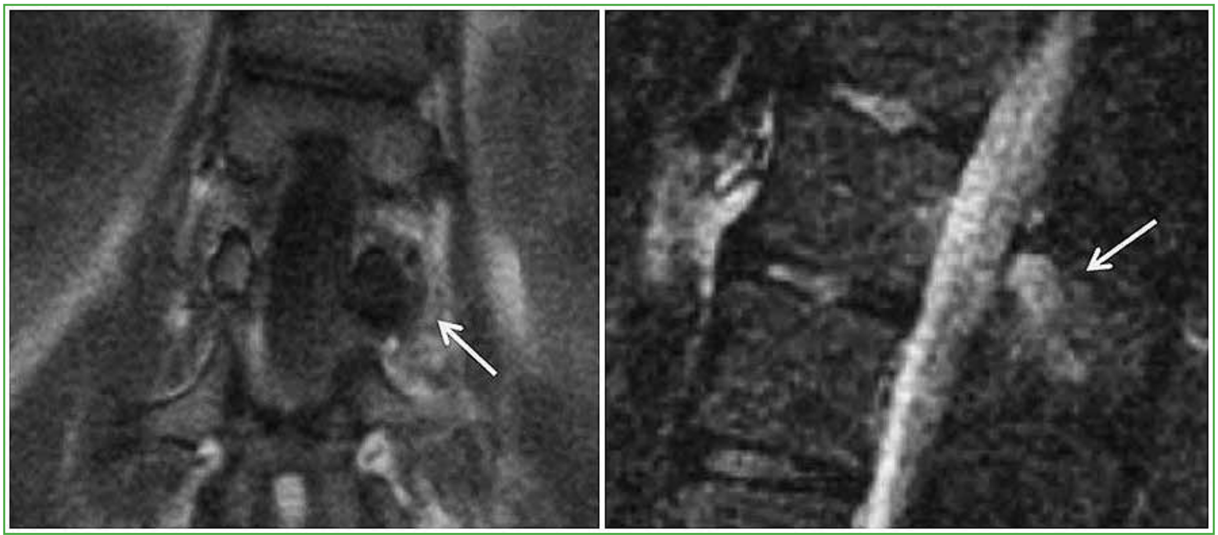

Figure 2. MRI, coronal and sagittal sections. A hypointense lesion and localized edema of the left pedicle, the posterior region of the body of L1 and the posterior elements are visualized.

A CT scan was requested which revealed the typical hypodense nidus with sclerosis around the anterior border of the L1 pars, with thinning of the anterior cortical bone near the spinal canal, a diameter of 1.1 cm and a margin of <6 mm in relation to the dura mater (Figure 3).

Physicians from the Neuroradiology Department recommended en bloc resection of the lesion, since the proximity of the neural elements contraindicated radiofrequency or laser ablation.

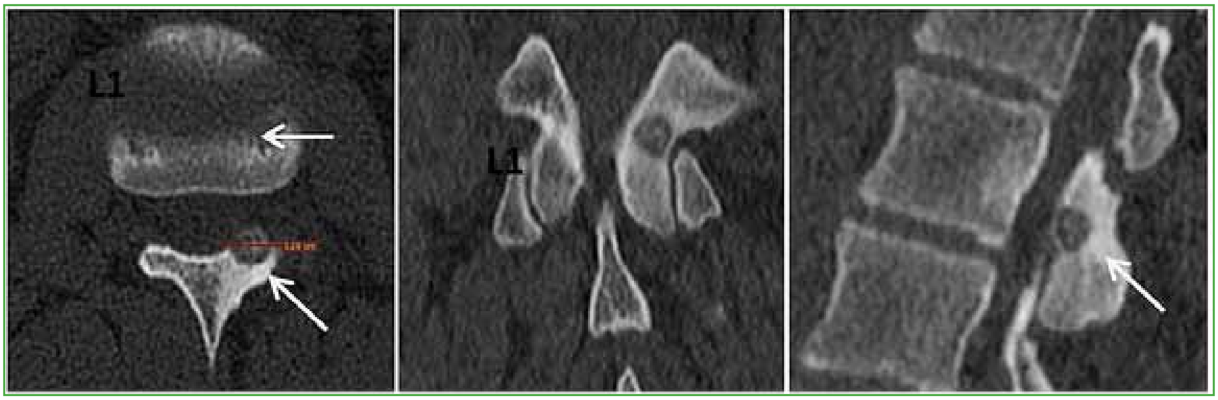

Figure 3. Multislice computed tomography of the lumbar spine, axial, coronal and sagittal slices. Hypointense image of a rounded osteolytic lesion in the anterior border of the L1 pars, of 12 mm in diameter with peripheral sclerosis of 30 mm and with thinning of the anterior cortical bone near the spinal canal.

Preoperative planning

In order to accurately locate the lesion, remove it with safety margins, and minimize damage to adjacent structures, we resorted to 3D planning and printing.

A multislice CT was performed, with fine slices (<1 mm) of the upper lumbar spine, focused on L1. The CT data was saved in a standard format (DICOM) and downloaded into a specific program, and a three-dimensional image of the area of interest was obtained. By manipulating these images, it was possible to locate and delimit the lesion (Figure 4).

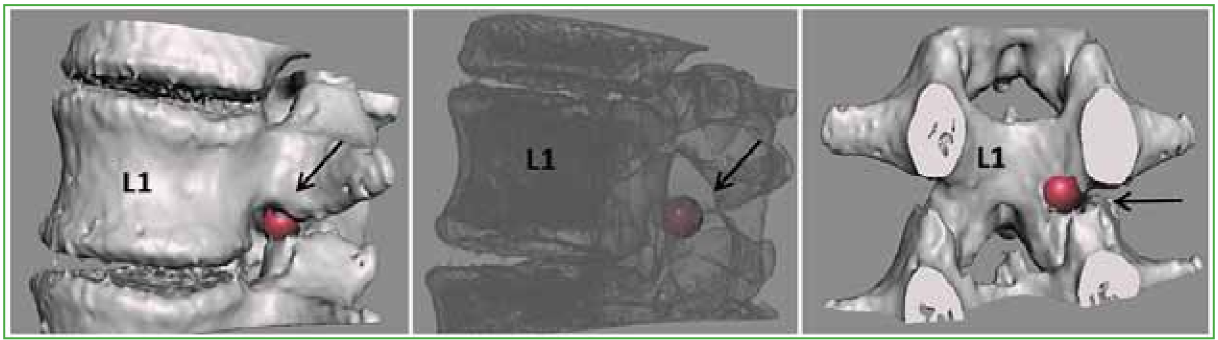

Figure 4. 3D manipulation of the area of interest allows the lesion to be marked and delimited.

To delimit tumor resection and avoid injury to adjacent healthy structures, three osteotomies marginal to the injury were planned. An osteotomy plane passing caudally to the tumor, proximally to the L1-L2 joint; another superior, oblique plane, distal to the D12-L1 joint, immediately inferior to the L1 pedicle; and a third osteotomy plane tangential to the other two planes (Figure 5). In this way, the aim was to limit bone resection and thus avoid postoperative instability.

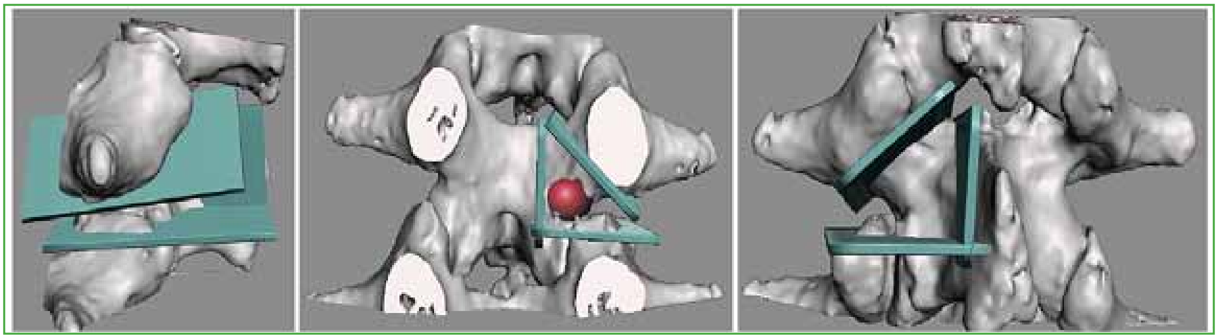

Figure 5. Determination and marking of the osteotomy planes marginal to the lesion. *Caudal plane*: above the L1-L2 joint. *Medial plane*: parallel to the spinous process. *Cephalic plane*: tangential to the anterior ones below the D12-L1 joint.

Once the osteotomy planes were determined, a plastic guide with the three well-defined cutting planes was designed and 3D printed. This guide closely matched the anatomy of the patient's L1 spinous process (Figure 6).

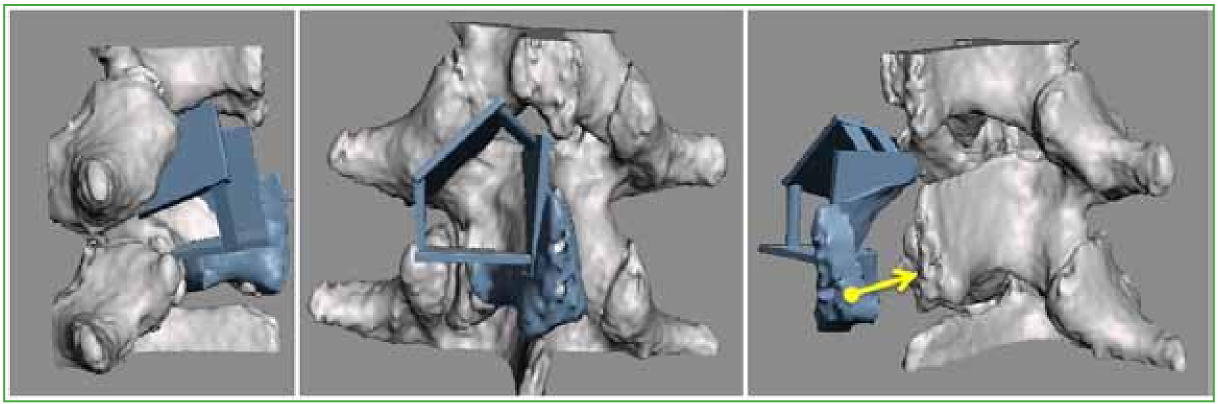

Figure 6. Design of the guide specifically adapted to the spinous process of L1 of the patient, with the osteotomy planes marked.

In this way, we can obtain an anatomical reference for the placement of the cutting guide and thus the correct direction of the osteotomy planes is ensured.

A real model of the patient's spine was also printed to be able to define the lesion in a tangible way and, in turn, to optimize the spatial orientation of the surgical area (Figure 7).

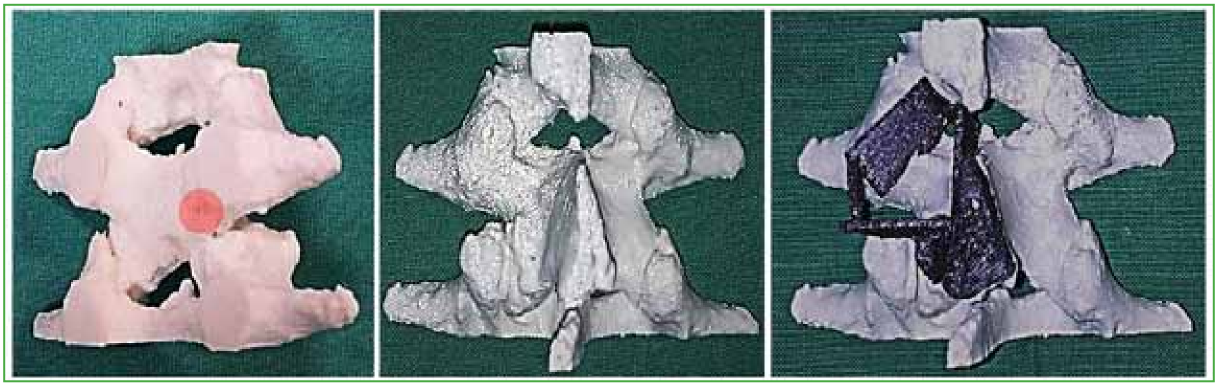

Figure 7. Design of the guide specifically adapted to the spinous process of L1 of the patient, with the osteotomy planes marked.

Surgical procedure

With the patient under general anesthesia, in the prone position, a median posterior approach was performed on the left paravertebral muscular gutter until reaching the bone plane. The level was identified with an image intensifier marking the spinous process of L1, which was the point on which the guide, made in the preoperative planning, was supported, delimiting the places of safe osteotomy for tumor resection (Figure 8).

First, a flavectomy was performed identifying the neural elements; then, the osteotomies were performed with a chisel. In this way, an en bloc resection of the lesion with marginal borders was achieved, minimizing bone resection and leaving the infra and supra-adjacent joints, the medial osteoligamentary elements, and all the stabilizing structures on the right side intact.

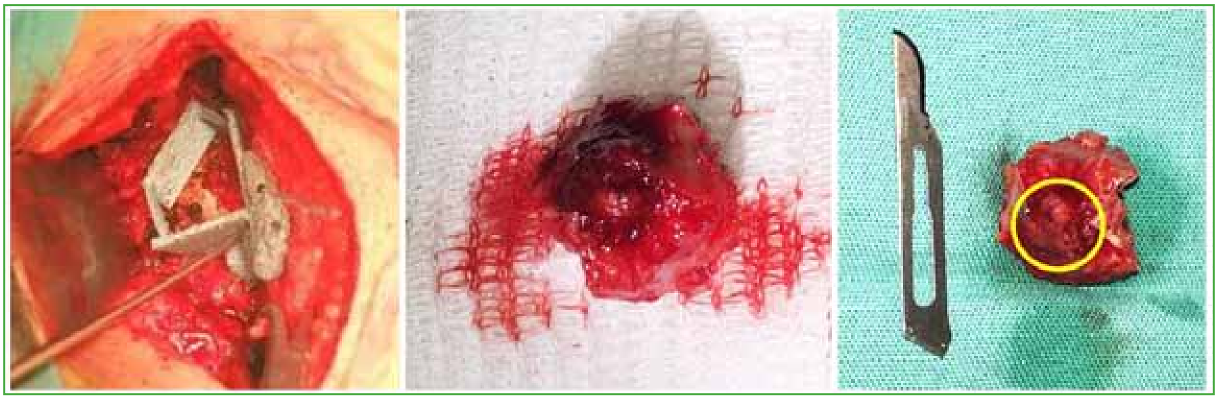

Figure 8. Intraoperative image. The adapted osteotomy guide on the spinous process of L1 is shown. Resected piece with tumor lesion in the center.

Computed tomography of the piece

Once the piece was resected, the lesion was confirmed macroscopically on its anterior edge and a CT scan of the resected piece was performed to ensure complete resection.

Postoperative control

The patient was discharged the following day, did not require postoperative immobilization, and preoperative symptoms completely resolved.

DISCUSSION

Given the clinical and imaging suspicion of a spinal osteoid osteoma, multiple therapeutic options can be considered. Spontaneous remission of these lesions[7] and pharmacological treatments have been described,[8] especially for lesions that are difficult to approach surgically. When symptoms persist despite conservative treatment or in an adolescent at risk from antalgic scoliosis, surgery is indicated.

Multiple techniques have been described from less to more invasive for tumor resection: intralesional (with endoscopic or navigation assistance) and marginal or en bloc.[9-15] In the literature, it has been published that en bloc surgical resection is a method of safe treatment for spinal localization. This technique has a lower recurrence rate, but carries the risk of postoperative instability.

At present, intralesional (7% recurrence rate) and radiointerventional methods have gained great importance, consisting of ablation of the nidus with radiofrequency or CT-guided laser, taking neuroprotective measures when the nidus is very close to the neurological structures; today it has become the most recommended treatment when it can be performed safely.[16-18]

The decision of the type of treatment to resect the tumor depends on the location of the lesion, the distance from the nidus to the neural elements, and the presence of cortical bone protecting the spinal canal.

In lesions that are within 10 mm of the neural elements, with visible cortical bone on imaging studies protecting the spinal canal, and accessible percutaneously under CT guidance, the first indication is radiofrequency or laser thermoablation of the lesion. Neuroprotective measures have been described to reduce the risk of neurological injury, which has increased the indications for these methods.[13,16,17]

But when the lesion is very close to the neural elements or there is a break in continuity with the cortical bone that separates it from the spinal canal, surgical resection of the lesion should be indicated.

Undoubtedly, the most important difficulty is the intraoperative localization of the lesion. Thus, there have been descriptions of navigation-guided intralesional resections, tetracycline labeling,[19] and en bloc resections.

Navigation allows tomographic vision in three planes of the lesion, but it is a method that is not available in all environments.[20,21]

3D planning and printing are tools that are being used for preoperative planning and the preparation of guides for placing cages or screws at the vertebral level.[22-24]

In recent decades, surgical guides or anatomical templates have been used as high-precision technological tools. This technology is being applied for various types of surgery, such as oral implantology, oncology, pedicle screw placement for spinal fixation, shoulder, knee and hip arthroplasty, treatment of joint fractures, and maxillofacial surgery.

The surgical template is a guide intended to direct the placement of an implant, a tumor resection, an osteotomy, or the alignment of a bone. Using a specific surgical template, preoperative planning can be transferred to the actual surgical site, thus improving the accuracy, safety, and reliability of the final outcome.

The general workflow of template design and fabrication is described as follows: based on data from complementary studies (CT, MRI), images are processed and 3D reconstruction is performed through the preoperative planning program. Based on these 3D images, preoperative planning is carried out to optimize the surgical outcome.

The guide can be designed using reverse engineering and surface reconstruction technologies. Then, through an additive manufacturing process (3D printing), the designed guide can be manufactured and, finally, the clinical application can be carried out.

When compared to the surgical navigation system, the advantages of anatomically specific guide applications are comfort and ease of use. In addition, by using a specific surgical guide, surgery can be minimally invasive and surgical procedures can be performed in a shorter time, with less stay in the operating room, which allows significant savings in health costs and lower risks for the patient.

The most widely used and economical manufacturing is fused deposition modeling. In this case, a polymer filament (usually plastic) is used, which, heated in the printer head, is extruded and deposited in a semi-liquid state. Once the polymer is deposited, it hardens rapidly at room temperature and thus allows layer-by-layer deposition of the polymer. The final 3D model is generated by superimposing 2D layers one on top of the other.

Some issues and inaccuracies may arise in specific template-guided surgeries, so surgeons should also check the images of planning, fabrication progress, correct positioning, and fixation of the template.

In the field of spinal surgery, Hu et al.[25] evaluated the precision of specific guides for pedicle screw placement based on tomographic images of the patient and the results proved that this technology improves the safety of the fixation technique.

CONCLUSIONS

3D technology allows us to carry out precise preoperative planning of tumor resection in a safe, simple, and inexpensive way. The preparation and printing of osteotomy guides with a specific anchor point ensures the intraoperative identification of the lesion, which continues to be the most important difficulty. Printing a real model of the spine with the lesion present in the operative field offers the possibility to be very precise with the osteotomies and careful with the neighboring neurological structures.

Conflict of interest: The authors declare no conflicts of interest.

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