ORIGINAL ARTICLE

Improved Planning of Endoscopic Sinonasal Surgery From 3-Dimensional Images With Osirix® and Stereolithography

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Abstract

Introduction and Objectives: The high variability of sinusal anatomy requires the best knowledge of its three-dimensional (3D) conformation to perform surgery more safely and efficiently. The aim of the study was to validate the utility of Osirix® and stereolithography in improving endoscopic sinonasal surgery planning.

Methods: Osirix® was used as a viewer and Digital Imaging and Communications in Medicine (DICOM) 3D imaging manager to improve planning for 114 sinonasal endoscopic operations with polyposis (86) and chronic rhinosinusitis (CRS) (28). Stereolithography rapid prototyping was used for 7 frontoethmoidal mucoceles.

Results: Using Osirix® and stereolithography, a greater number of anatomical structures were identified and this was done faster, with a statistically-significant clinical-radiological correlation (P<.01) compared with 2D CT plates. With a share of more than 75% of surgery performed by residents, surgical time was reduced by 38 ± 12.3 min in CRS and 42 ± 27.9 in sinonasal polyposis. The fourth-year residents reached 100% surgical competence in critical surgical milestones with 16 surgeries (CI 12–19).

Conclusions: The systematic use of Osirix® for visualisation and treatment of 3D sinonasal images from DICOM data files, along with the surgical team’s ability to manipulate them as virtual reality, allows surgeons to perform endoscopic sinonasal surgery with greater confidence and in less time than using 2D images. Residents also achieve surgical competence faster, more safely and with fewer complications. This beneficial impact is increased when the surgical team has stereolithography rapid prototyping in more complex cases.

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PALABRAS CLAVE
Realidad virtual; Imágenes en 3 dimensiones; Estereolitografía; Planificación quirúrgica

Mejora de la planificación de las cirugías endoscópicas nasosinunasales a partir de imágenes en 3 dimensiones con Osirix® y estereolitografía

Resumen

Introducción y objetivos: La elevada variabilidad anatómica de los senos paranasales requiere disponer del mejor conocimiento de su conformación tridimensional para afrontar la cirugía con mayor seguridad y eficiencia. El objetivo del estudio fue validar la utilidad de Osirix® y la estereolitografía en la mejora de la planificación de las cirugías endoscópicas nasosinunasales.

Métodos: Se utilizó Osirix® como visor y gestor de imágenes DICOM en 3 dimensiones (3D) en la planificación de 114 cirugías endoscópicas nasosinunasales por poliposis (86) y rinosinusitis crónica (28) junto con prototipos endoscópicos en 7 mucocellos frontoetmoidales.

Resultados: Se identificaron mayor número de estructuras anatómicas, más rápidamente y con una correlación clínico-radiológica estadísticamente significativa (p < 0,01) a favor de Osirix y estereolitografía, que con placas en 2D de la TAC. Con una participación de los residentes superior al 75% de la cirugía, se redujo el tiempo quirúrgico en 38 ± 12,3 min en sinusitis crónicas y en 42 ± 27,9 en poliposis nasosinunasales, alcanzando los residentes de cuarto año una competencia quirúrgica del 100% en los hitos quirúrgicos cruciales con 16 cirugías (IC: 12-19).

Conclusiones: La utilización sistemática de Osirix® para visualización y tratamiento autónomo de imágenes nasosinunasales en 3D desde archivos DICOM permite a los cirujanos efectuar las cirugías endoscópicas nasosinunasales con mayor confianza y seguridad y en menos tiempo que utilizando imágenes en 2D. Los residentes también alcanzan la competencia quirúrgica más rápidamente, con mayor seguridad y con menos complicaciones. La mejora en la planificación se incrementa cuando el equipo quirúrgico dispone de prototipos rápidos estereolítográficos en los casos de mayor complejidad.

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Introduction

Planning the execution of sinonasal endoscopic surgery requires knowing, before the intervention, the shape and placement of the sinonasal structures as precisely as possible. Its objective is treating the disease completely, avoiding complications and not causing failed surgeries. The elevated inter-individual variability of sinonasal anatomy has been the objective of many publications that attempt to make its own anatomy and its nomenclature more precise, as well as identifying the structures through X-ray images. The 3-dimensional (3D) configuration of the anatomical elements makes it necessary for surgeons to carry out a complex psychological and neurological process to interpret the 2-dimensional (2D) images from computed axial tomography (CAT) scans or nuclear magnetic resonance (NMR) studies. Surgeons have to prepare a speculative recreation of normal sinonasal anatomy and of the altered anatomy of the lesion to operate, as well as its relationship with the other anatomical structures and between them. Recent, widely disseminated texts attempt to help the surgeons in the task of planning sinonasal endoscopic surgery based on imaginative formulas that help them to interpret 2D X-ray images in 3D.

Imaging diagnostic services attempt to facilitate this mental process by proving 2D images in conventionally standardised space planes. Technological evolution is substituting the image selection of the radiologist in hospital reds that allow clinicians access, from specific visors or from computers located in surgeries or operating theatres, to the complete file of digital imaging and communication in medicine (DICOM) images with the “.dcm” extension. Nevertheless, information oriented towards surgery still remains insufficient. Intraoperative surgical navigators (computer assisted surgery) make 3D reconstructions of the DICOM images. They provide simultaneous multi-plane vision in 2D combined with the endoscopic image, but they require carrying out these tasks within the operating room.

In April 2004, Osirix® (Pixmeo, Switzerland) appeared. This is an open-code program developed by Rosset et al. that transforms an Apple Macintosh® computer into a DICOM workstation to process and visualise medical images from multiple source (NMR, CAT, PET, PET-CAT, SPECT-CAT, ultrasound, etc.). The program is distributed under a GNU-type license, and its code is available openly, without cost and freely. Osirix offers high reliability, admitting a maximum accuracy error of 0.3 mm. The surgeon can dynamically and simultaneously visualise all the cuts, displacing the cross point of the axes to any position desired. Surgeons can take linear, area and volumetric measurements and perform the 3D reconstructions considered the best. This all happens autonomously, even outside of the operating theatre, in surgeries or meeting rooms and classrooms, recording selections of the work in images or videos. Consequently, the loss of information generated in the process of radiological printing or vision through static cuts is eliminated.

An ideal method of obtaining 3D perception of the structures is based on the disposition of artificial models that simulate the real model to the maximum extent possible, fulfilling a function similar to that of the scale-size models
used in construction.11 Along this line, stereolithography has been used more and more over the past 20 years as a technological aid in training and surgical planning with the preparation of extremely precise, tangible 3D models through 3D printers from the DICOM images of CAT scans.12,13

The objective of this study was to validate the usefulness of the free software Osirix® and stereolithography (SLA) as technological tools to manage 3D images and rapid prototypes from DICOM files in 2 aspects: through the help provided to ear, nose and throat (ENT) specialists in planning sinonasal endoscopic surgery in a personalised fashion for each patient, and the improvement provided the residents in learning sinonasal anatomy and in their corresponding surgical competence.

Material and Methods

Material

The surgical planning process with Osirix® and SLA was assessed in 114 interventions of consecutive sinonasal endoscopic surgery interventions from February 2012 to May 2014 having the diagnoses of sinonasal polyposis (n=86) and chronic rhinosinusitis (CRS) (n=28) and a score of less than 16 points on the Lund–Mackay scale for CAT scans images, with involvement of the osteomeatal complex but in which obligatory navigator use was not indicated according to the recommendations of the American Academy of Otorhinolaryngology and Head and Neck Surgery.14 Seven additional cases were selected for designing SLA rapid prototypes; these cases presented frontal–ethmoidal mucocles and required the use of intraoperative navigator due to application of the previously mentioned recommendations because of there was uncertainty as to the limits of the lesions, whether or not healthy tissues and structures were involved, and the possible cleavage planes.

The participants were 4 ENT specialists from our own service, with specific dedication to rhinology, 2 medical specialists in training, 3rd year (MIR-3) and 5 MIR-4 in ENT.

Process of Surgical Planning

The surgical planning process was based on 2 activities: (1) preoperative navigation using virtual reality with Osirix® before the intervention; and (2) printing of a 3D SLA rapid prototype in the 7 complex sinonasal cases.

Virtual Preoperative Navigation With Osirix®

All of the cases were assessed by the ENT and MIR participants in a specific imaging session lasting 30 min before the surgery, filling in the list of verification of radiological images.15

Stereolithography

Our group used SLA models for training with cryopreserved human heads, and for surgical planning, since February 2012. The SLA rapid prototyping process consists of 4 phases:

Phase 1. DICOM images (.dcm) are selected in the patient’s CAT.

Phase 2. A 3D digital model is generated using Osirix®.

Phase 3. A digital model is obtained of 1 or more independent solids with all its faces closed correctly. This is something that cannot be done using Osirix®, so a computer program to do so is needed. We used Rhinoceros®, a non-uniform rational b-splines (NURBS) modeller that uses a mathematical model to generate and represent curves and superfluities to prepare them for printing. A file is obtained with the ‘‘.stl’’ (from SLA) format that creates a triangular matrix grid whose objective is to explicitly artificial to differentiate clearly between the different levels of representation of the real model and its limitation for clinical and technical motives. The program transfers the complex algorithms to Cartesian point matrices that can be interpreted by 3D printers that work with a single model based on 1 or more independent solids, and allows this to be done with various layers. The model constructed digitally with Rhinoceros® goes through the following steps: (1) evaluation of the model; (2) elimination of unnecessary areas; (3) generation of upper and lower horizontal auxiliary grids; (4) generation of dorsal auxiliary grids; (5) union of auxiliary grids to the main model; (6) analysis of the resulting grid; (7) search for and repair of open borders and axes; and (8) exportation of the model to print.

Phase 4. The 3D image is printed from the .stl files generated with Rhinoceros®. We used 2 3D printers: (1) ProJet SD 3000® (3D Systems, Rock Hill, SC, USA) printer for industrial design that uses photosensitive liquid resin; and (2) MakerBot Replicator®, a home-use printer that uses melted ABS plastic filament. The high printer price is in consonance with the high quality prototypes that it produces, as it photo-polymerizes a liquid monomer of epoxy resin (Accura 60 SLA®, 3D Systems, Rock Hill, SC, USA) by the action of ultraviolet radiation emitted by a mobile laser (“setting”) to which photo inhibitors are added. The depth of the setting depends on the depth of optical resin penetration and on the speed and power of the mobile laser, which establish the thickness of each sheet. The resolution of each plane is mainly determined by the limited size of the laser ray and by the precision of the laser displacement mechanics. After that, the surface is covered with a new layer of liquid monomer over which the laser ray inscribes a pattern once again. When the prototype is finished designing, sheet by sheet the excess resin is eliminated by rinsing it with a dissolvent such as tripropylene glycol monomethyl ether, followed by another rinsing with alcohol or water. The rapid prototypes obtained with ABS plastic are of lesser quality with respect to texture and consistency and to their resemblance with the real models.

The SLA rapid prototypes were studied before the surgery in the corresponding imaging sessions. After that, they were sterilised and taken to the operating theatre to complement the imaging arsenal during the intervention.

Procedure for Surgical Planning Validation

The assessment of the possible improvements that surgical planning based on 3D images with Osirix® and SLA provided
were measured through the clinical–radiological correlation, reduction of surgery time, surgeon confidence and security during surgery and resident competence in carrying out the procedures.

Clinical–radiological correlation was assessed by comparing the identification made based on the list of radiological verification in the conventional 2D plates with the preoperative identifications made with Osirix® and the endoscopic findings and images with the navigator (DiPiPointeur®, CollinMedical) intraoperatively. The Mann–Whitney U test was used to do so, setting statistical significance to $P<.05$.

The reduction in surgery time was measured by comparing with surgeries similar in type and complexity before the period of study using the hospital surgical database (MEDIX 3) performed by the same surgeons and with a performance ratio for the residents that was also similar: higher than 75% of the intervention.

To assess confidence and security during surgery, each surgeon randomly assessed a sample of 9 cases from each group (CRS and polyposis). The surgeons had to identify the crucial anatomical structures for clinical–surgical orientation: agger nasi cells, frontal–ethmoidal cells, frontal recess, unciniform apophysis, middle turbinate, anterior and posterior ethmoidal arteries, Keros grade, ethmoid bulla, peribullar cells and recesses, posterior ethmoidal cells, sphenoid sinus, optic nerve, Vidian nerve, second branch of the trigeminal nerve, pterygopalatine fossa, greater palatine conduit, and internal carotid artery. They initially saw the original 2D images printed on radiological plates (standard visualisation). After that, they visualised the images and manipulated them freely with Osirix® (virtual visualisation + image treatment). The time used and the percentage of structures correctly identified in each of the 2 options were measured. Finally, the surgeons filled in the National Aeronautics and Space Administration Task Load Index (NASA-TLX) to measure the workload that each case had required. The standard questionnaire includes 6 subscales for effort, frustration, mental, physical and time demands, and performance, in a visual analogue scale from 0 to 20. In our study, physical demand was excluded because there was no physical task to complete. The assessments of the 7 sinonasal cases on which SLA rapid prototypes were obtained were broken down. The scores were analysed by the Wilcoxon test, after confirming the assumption of normality for the data using a quintile chart, with a statistical significant of $P<.05$.

The residents’ competence in sinonasal endoscopic surgery was verified using the tool proposed by Lin17 (Table 1). This consists of a verification list that assesses the resident’s achievement on a scale from 1 to 5, grouping them into 3 critical elements (milestone 1: uncinctomy, maxillary antrostomy and anterior ethmoidectomy; milestone 2: posterior ethmoidectomy and sphenoidotomy; and milestone 3: frontal sinusectomy), plus a global section that assessed performance in more generic tasks. With a score of 3 out of 5 on each item, the resident was considered competent in the performance of sinonasal endoscopic surgery (60%), applying the competence levels proposed by Laeke18 and remembering that the resident had performed over 75% of the procedure with supervision. Progress validation was carried out by the tutors of the 7 residents assessed during 2012, 2013 and 2014 through the FORMIR application of the Spanish Society for Otorhinolaryngology and Cervical-Facial Pathology.

Results

The clinical–radiological correlation obtained through intraoperative endoscopy and the navigator was statistically significant in favour of Osirix® ($P<.01$) in all the structures assessed (95%; CI: 95–98) in comparison with the use of 2D images printed on plates. The latter achieved a correlation of 57% in precise identification of the frontal–ethmoidal cells (CI: 46–72), of 62% in agger nasi cells (CI: 47–65), 67% in upper insertion(s) of unciniform apophysis (CI: 52–77), 68% in peribulla cells and recesses (CI: 56–78), 73% in superior/lateral insertion of the middle turbinate (CI: 64–81) and of more than 90% in the other structures.

Using Osirix® reduced surgery length by a mean of 38 min (standard deviation [SD]: 12.3) in CRS and by 42 min (SD: 27.9) in sinonasal polyposis.

The Wilcoxon test for paired samples showed statistically significant results for all the subscales in the NASA-TLX, with a value of $P<.007$ in all the comparisons of 3D images with which Osirix® faced and the SLA rapid prototypes with the 2D images of the plates printed by the Radiodiagnostic Service (Fig. 1).

Fig. 2 shows the sequence for the surgical planning process. Table 2 collects all the scores that the residents reached in each of the Lin17 milestones. Likewise, it shows the development of their learning curve to reach each of the levels of competence.

Discussion

With Osirix®, DICOM image visualisation and treatment acquire an especially relevant dimension for surgical planning and for learning in the ENT specialists in training. It is currently available only for Apple Macintosh® platforms. However, it goes beyond the services of other visors designed for Windows® environments due to how simple it is to visualise and manipulate images in a multimodal and multidimensional form (2D, 3D, 3D series with temporal dimension, multiplane reconstruction, surface simulation, volume simulation of and endoscopic simulation), especially in the “region of interest” (ROI)19 function. Transforming and manipulating images with Osirix® with virtual reality criteria at the surgeon’s demand can be carried out in environments outside of the Radiodiagnostic Service and of the operating theatres. The surgical teams’ autonomy is thus raised, along with strengthening their sense of security during the surgery. Consequently, Osirix® can become a tool of inestimable help for the surgeon in centres not having a surgical navigator or radiological stations with multiplane visors available.

Various factors affect the length of a sinonasal endoscopic operation. However, surgeon memorising and the possibility of consulting intraoperatively the images treated with Osirix® can reduce surgery length by their precision and elevated clinical–radiological correlation and by the visualisation of the entire conformation of the anatomical structures. The tentative manoeuvres during surgery are avoided and the surgeon gains in security. These last
## Table 1 Verification List of the Specific Sinonasal Endoscopic Surgery Tasks (Lin10).

<table>
<thead>
<tr>
<th>Residency's name:</th>
<th>Evaluator:</th>
<th>Incapable of performing the task</th>
<th>Capable of performing the majority of the tasks</th>
<th>Performs it with ease and facility</th>
<th>Not available</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(1) Endoscopy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Lower step</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b. Intermediate step</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c. Upper step</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>(2) Intranasal preparation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placement of lenses with vasoconstrictor</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Infiltration of the lateral nasal wall</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Sphenopalatine infiltration through the greater palatine hole, when indicated</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>(3) Uncinectomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of the unciform apophysis and its limits</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Retrograde incision or with falciform scalpel</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Extirpation with forceps or debridement tool</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>(4) Maxillary antrostomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of the natural ostium of the maxillary sinus</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Extension of the ostium at the expense of the posterior fontanel, when indicated</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>(5) Anterior ethmoidectomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of the bulla</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Extirpation of the bulla with forceps or debridement tool, preserving the mucosa</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Extirpation of the anterior ethmoidal cells with identification of the limits (middle turbinate, basal lamella, superior turbinate)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>(6) Posterior ethmoidectomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inferior penetration through the basal lamella, preserving its horizontal part</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Extirpation of posterior ethmoidal cells, identifying the skull base and the superior turbinate</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>(7) Sphenoidotomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to the sphenoid sinus through the posterior ethmoids in the inferior-medial triangle or through its natural ostium</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Extension of the sphenoid ostium</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Identification of the location of the internal carotid and the optic nerve</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>(8) Frontal sinusotomy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-traumatic extirpation of bone walls in the frontal recess</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Identification of the skull base and orbital wall</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

MIR: medical specialist in training, Spanish system.
aspects are relevant when the surgery is handled in more than 75% of its performance by specialists in training with different levels of competence, which prolong how long the intervention lasts. The variability in the degree of resident competence and the high percentage of the surgeries assessed (just as what happened with those compared in the previous period) permit thinking that the reduction in surgery length took place mainly through the improvement in operation planning provided by Osirix® and SLA. The time and effort invested in the preoperative assessment of DICOM images with Osirix® are less than those used in analysing plates or 2D images, and better results are obtained. It has been shown how even ENT specialists expert in preparing 3D mental reconstructions from 2D plates benefit significantly from the use of technological tools such as Osirix® that facilitate this process. This is especially true in the disposition of tangible models such as SLA rapid prototypes, as can be confirmed with the NASA-TLX results (Fig. 1). Nevertheless, because SLA has been reserved for especially complex cases, it is possible that the benefits perceived in those occasions cannot be extrapolated to less complex cases.

Since its promising inclusion in the medical-surgical arsenal, SLA use has not spread in ENT with the intensity and promptness forecast in its beginnings. Very few experiences in the use of SLA models in our speciality have been published. It is possible that several factors are responsible for this situation in the ENT environment: the high costs of the procedure, the slowness of model fabrication and the low quality of the resolution of the printed structures. This has not occurred in other specialities such as cranial-maxillary-facial surgery and dentistry, where SLA application has been aimed at planning and execution of bone reconstructions and modelling with synthetic and autologous materials that are identical to the defects to be repaired, or aimed at exact repositioning of self-transplant materials. New 3D printing devices are continually appearing, but those that offer higher print quality still reach high cost levels and require long printing times (printing a complete, 3-cm high real scale axial cut of the head can even take up to 8 h). The best printers have to amortise a purchase price of more than €50,000, while those that offer lower levels of quality (such as ours) can be bought for about €2500. The price for resin and plastic ranges between €45 and €125 for each printing kit. However, the greatest cost falls on the personnel that have to handle the DICOM images to transform them into .stl files. This has caused 3D printing of rapid prototypes to be limited, in our case, to the patients presenting the most anatomical complexity. The 3D rapid prototypes that our group prints achieve finishes of appearance and bone texture that are much more acceptable and realistic than those obtained by the pioneers of this technique in ENT. We have also been

Table 2 Obtaining Surgical Competency by ENT Residents Using Osirix® and Stereolithography.

<table>
<thead>
<tr>
<th>Scores with which 60% competence is reached in each milestone</th>
<th>No. of patients with which competence is reached in each level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of MIR</td>
<td>Milestone 1 (max. 40)</td>
</tr>
<tr>
<td>R3</td>
<td>35</td>
</tr>
<tr>
<td>R3</td>
<td>36</td>
</tr>
<tr>
<td>R4</td>
<td>40</td>
</tr>
<tr>
<td>R4</td>
<td>40</td>
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<td>R4</td>
<td>40</td>
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<tr>
<td>R4</td>
<td>40</td>
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<tr>
<td>R4</td>
<td>40</td>
</tr>
</tbody>
</table>

MIR: medical specialist in training, Spanish system.
Improved Planning of Endoscopic Sinonasal Surgery

Figure 2  Case of posttraumatic left frontal mucocele from obliteration of the frontal recess with a bone fragment and disappearance of bone elements from the left external frontal table and orbit roof. a–c) Identification of the point of interest by the axis cross, which can be seen simultaneously in the sagittal, axial and coronal Osirix planes and can be moved at will; d) surface reconstruction with Osirix®; e) volume reconstruction with Osirix® and treatment of the 3D images based on the interest of the areas to visualise; f) stereolithographic [SLA] rapid prototype of volumes selected based on DICOM images from a lower viewpoint; g) [SLA] rapid prototype of volumes selected based on DICOM images from a higher viewpoint; and h) operating theatre use of sterilised SLA rapid prototypes to complete an image arsenal. Thick arrow: frontal–ethmoidal bone fragment; thin arrow: orbital bone fragment.

able to profit from one of the advantages of SLA, which is the possibility of modifying the printing scales.

Experts from the U.S. model of specialised ENT training indicate that residents should have experience with 30 cadaver head dissections before performing sinonasal endoscopic surgery in an operating theatre on live patients. The reality in the majority of the countries is incompatible with this opinion. For this reason, the transfer of abilities from virtual reality simulators and from a small number of cadaver dissections in courses posits the development of a learning curve on real patients. This method leads to the registry of an incidence of 15.9% of lesser complications among the residents that perform sinonasal endoscopic surgery on patients; this is a significantly higher incidence than that of graduated specialists (8%). Laeeq demonstrated, using the assessment method of Lin in residents from the 2nd to the 5th year of MIR, that milestone 1 competence is reached after operating on 23 patients (1–49), for milestone 2 on 22 patients (1–49) and for milestone 3 on 33 patients (15–44); overall competence of 60% was reached with the performance of 42 cases (competence of 80% with 51 cases and of 100% with 55 cases). The wide range of cases that divide each result stems from the lack of differentiation in the progress reached based on the year of MIR participation. However, our experience with systematic Osirix® use in surgical planning and with obtaining SLA rapid 3D prototypes improves these results. The surgical milestone competence of the residents is reached with a lower number of patients,
much more rapidly, independently of the resident’s natural ability for surgery and in the compressed training time of 4 years that exists by regulation in Spain. The number of residents that have participated in the validation of our process is small, as it was limited to only our centre. However, it is foreseeable that this model may be extended to more centres, making a greater number of residents available to validate including this methodology in their teaching itineraries systematically.

Conclusions

Systematic use of Osirix® for autonomous visualisation and treatment of sinonasal images in 3D from DICOM files makes it possible for surgeons to perform sinonasal endoscopic surgery with greater confidence and security, and in a shorter time, than using 2D images. Residents also reach surgical competence faster, with greater security and with fewer complications. The improvement in planning is increased when the surgical team has SLA rapid prototyping available for the cases of greater complexity.

Conflict of Interests

The authors have no conflicts of interest to declare.

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References