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Orthognathic Surgery

Learning condyle repositioning during orthognathic surgery with a surgical navigation system

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Abstract. Condyle repositioning during bilateral sagittal splint osteotomy (BSSO) is a challenging step for the inexperienced surgeon. We aimed to demonstrate the benefit of navigation for learning the condyle repositioning. We treated 100 patients who underwent a BSSO. A trainee performed the condyle repositioning of one side in two phases. In the first one, the trainee positioned without watching the screen of the Orthopilot Navigation system (ONS). In the second one, the trainee could use the ONS to replace the condyle. Heuristic, anatomical and functional scores of each phase were recorded. Heuristic (17% vs. 75%; $p < 0.0001$), anatomical (35% vs. 86%; $p < 0.0001$) and functional (14% vs. 56%; $p < 0.0001$) scores were significantly greater with the ONS. The ONS is a promising and original intraoperative learning tool for the repositioning of the condyle during BSSO.

Key words: orthognathic surgery; computer-assisted surgery; condyle repositioning; surgical education; medical education.

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The final result of bilateral sagittal split osteotomies (BSSOs) mainly depends on the correct repositioning of the condyle intraoperatively¹. For the inexperienced surgeon, condyle repositioning is a challenging step. Many techniques and devices have been described to improve this skill^{2–7} but manual seating remains the method used by the majority of surgeons. The accuracy and reproducibility of this empirical repositioning requires extensive experience and its learning is very complex.

We routinely use in our unit the OrthopilotTM navigation system (ONS) for orthognathic surgery and particularly for condyle repositioning^{2,3}. While this device improved our postoperative occlusal and functional results, its pedagogical interest has not been studied to date.

In this work, our aim was to evaluate the benefit of navigation for learning condyle repositioning during BSSO and to see how resident and inexperienced surgeons acquired this surgical skill.

Materials and methods

This monocentric, observational and retrospective study had included 100 patients needing a BSSO (isolated or associated to a Le Fort I osteotomy), between October 2012 and December 2014. Study ethics approval was obtained on 6 July 2018 (CECIC Rhône-Alpes-Auvergne, Clermont-Ferrand, IRB 5891).

The surgical indication was confirmed after clinical examination, sagittal and



Fig. 1. Navigation system software interface.

frontal cephalometry, and a plaster cast study. The condyle centric relation was recorded preoperatively and documented with a dental splint. The BSSO itself was made by the same experienced surgeon on both sides; on the left side the condyle was repositioned and the bicortical screw osteosynthesis was performed by the trainee under supervision of the senior surgeon who positioned and fixed the contralateral condyle. Only the data from the trainee side were considered in this study.

Nineteen trainees were involved in 100 BSSOs. They performed between one and 14 surgical procedures.

Surgical procedure

The navigation procedure has been described elsewhere². Infrared reflectors (rigid bodies) were anchored via a small vice on each coronoid process. An intermediary fixation between the rigid body and the osseous anchorage allowed the removal and replacement of the rigid body without losing the landmark. Condyle centric relation position was recorded by the system using the specific splint prepared preoperatively and sterilized. BSSOs were performed according to the Obwegeser-Dal Pont technique.

Final occlusion was stabilized by a maxillomandibular fixation. The rigid body was fixed on its vice for condyle navigation. Condyle position was con-

trolled on the computer screen, the surgeon trying to minimize the three translations and the three rotations superimposing the current virtual image of the condyle on the planned one (Fig. 1). The goal was to be as close as possible to zero. The condyle repositioning procedure was conducted in two phases. During the first phase, the trainee manually repositioned the condyle; the screen of the computer was occluded so that he had no access to the navigation data. Once the surgeon believed that the condyle was correctly positioned, the condyle the data were collected by the navigation system and the screen was freed. These data were stocked in a file entitled "without ONS".

During the second phase, the trainee tracked the position on the computer screen and replaced the condyle minimizing the values of rotation and translation. When values of discrepancies were as closed to 0 as possible, the osteosynthesis was performed with three bicortical screws. This second set of data was recorded in a second file entitled "with ONS".

Statistical analysis

The collected data included: (1) seniority and number of intervention for each surgeons; (2) type of surgical procedure (BSSO isolated or associated to a Le Fort

I osteotomy, asymmetry, vertical movement); (3) discrepancies from the reference position of the condyle without and with the ONS (translation top/bottom (Ttb), translation back/front (Tbf), translation left/right (Tlr), frontal rotation (Rf), axial rotation (Ra) and sagittal rotation (Rs)).

The primary outcome was the heuristic score, calculated as follows:

$$SH = \sqrt{Ttb^2 + Tlr^2 + Tbf^2 + Rs^2 + Ra^2 + Rf^2}$$

Heuristic score was considered good when ≤ 5 . The secondary outcomes were the anatomical score and the functional score. Anatomical score was defined by Ttb, Tbf and Rs. Functional score was defined by Ra, Rf and Tlr. Anatomical and functional scores were considered good when each value was ≤ 2 .

Scores could be both qualitative (good/not good) and quantitative variables (values). Each score was calculated with and without the ONS (paired series). SA, SH and SF with and without the ONS were analysed by a McNemar test for paired series⁸, in order to know whether the condyle repositioning was significantly better with ONS.

Results

Fifty-seven patients were operated by isolated BSSO and 43 also had a Le Fort I

Table 1. Number of interventions by surgeon.

Number of interventions	Number of surgeons	Percentage	Cumulated number of surgeons	Cumulated percentage
1	4	21.05	4	21.05
2	3	15.79	7	36.84
3	1	5.26	8	42.11
4	2	10.53	10	52.63
5	2	10.53	12	63.16
6	1	5.26	13	68.42
8	2	10.53	15	78.95
9	1	5.26	16	84.21
11	1	5.26	17	89.47
13	1	5.26	18	94.74
14	1	5.26	19	100.00

osteotomy. Seventy-four patients had an asymmetry. A maxillary impaction was carried out on 31 patients.

The number of interventions performed by each surgeon is listed in [Table 1](#).

The heuristic score was ≤ 5 and considered as good in 17% of the procedures without the ONS and in 75% with the ONS. The anatomical score was ≤ 2 in 35% of the procedures without the ONS and in 86% with the ONS. The functional score was ≤ 2 in 14% of the procedures without the ONS and in 56% with the ONS. The use of the ONS significantly improved the three scores of condyle repositioning ($p < 0.0001$). [Table 2](#) (upper) shows the heuristic scores with and without the ONS: 38 patients had a bad score without the ONS and remained bad with the ONS, 55 patients were bad without the ONS and achieved a good score with the ONS, one patient had a good score without the ONS and became bad with the ONS, and six patients had a good score without

Table 2. Agreement of each score with and without Orthopilot Navigation system (ONS).

Heuristic score (HS)			
HS without ONS	HS with ONS		
%	Bad	Good	Total
Bad	38	55	93
Good	1	6	7
Total	39	61	100
Anatomical score (AS)			
AS without ONS	AS with ONS		
%	Bad	Good	Total
Bad	12	53	65
Good	2	33	35
Total	14	86	100
Functional score (FS)			
FS without ONS	FS with ONS		
%	Bad	Good	Total
Bad	41	44	85
Good	4	11	15
Total	45	55	100

the ONS and remained good with the navigation system. The remainder of [Table 2](#) shows the same type of information for anatomical and functional scores.

The distribution of the discrepancy of each variable (Ra, Rf, Rs, Tbf, Trl and Ttb) with and without the ONS is listed in [Fig. 2](#). Graphically, mean and the dispersion of the values were greater without the ONS, especially for the Ra and the Rs.

[Figure 3](#) shows the linear relation between the heuristic score with and without the ONS and the number of interventions performed by the surgeon. The ONS seemed to allow a better repositioning, but with increasing numbers of interventions (and experience) the regression lines tended to join. The intersection was around 15 interventions.

Discussion

The surgical education environment has changed in the past few decades with the tightening of the medical legislation (leading to a decreased autonomy of the practice of trainees), demands for patient safety, the development of new technologies and the limitation of working hours^{9,10}. This change imposed the development of new surgical educational tools: cadaveric dissection, simulations¹⁰, videos¹¹ and now virtual reality¹².

Our study demonstrated the educational value of the ONS for condyle repositioning during BSSO. The trainees obtained heuristic (17% vs. 75%; $p < 0.0001$), anatomical (35% vs. 86%; $p < 0.0001$) and functional (14% vs. 56%; $p < 0.0001$) scores significantly greater with the ONS. The ONS gave a virtual image of the condyle and of the target (the final position), so for the trainee the good position is better understood, easier to reach and more accurate than with the empirical (blind) positioning.

The heuristic score was chosen to evaluate the improvement of the condyle repositioning

because it took into account all of the parameters and considered the control of the three dimensions. The anatomical score represented the condyle position in the sagittal plane. We indicated in a previous study that it was the principal factor in the quality of postoperative occlusion and skeletal stability². The functional score reflected the axial and frontal control of the condyle position and was correlated in the same study with better functional results, especially considering postoperative mandibular motion.

In the present study, the functional score was the less improved by the ONS. It proved that perfect repositioning even with tool control is not always possible. Sometimes compromises are needed. The discrepancies are generally due to anatomical conflicts between the proximal and the distal bone segment¹³, especially in asymmetric cases. Rigid osteosynthesis may increase this problem. The improvement of the functional score required a remodelling of the osseous valves¹⁴, but this not always possible without damaging the infra-alveolar nerve.

The analysis of the distribution of the values of each direction with and without the ONS showed that the dispersion of the variables was smaller with the ONS with fewer outliers. The use of the ONS could avoid large discrepancies in the repositioning of the condyle. Berger et al. reached the same conclusion on this point⁴. Without the ONS the dispersions were greater, especially for Rs and Ra. These two dimensions were the most difficult to control without the ONS. This could be explained by the lack of landmarks in the exiguous exposition of the bone intra-orally.

The benefit of a condyle positional tool is the subject of a controversial and long-lasting debate among experts. It is not the subject of this work. We only wanted to emphasize the relevance of navigation in learning this difficult task.

Surgical practice is an essential step for the learning of trainees^{15,16} and the use of the ONS can be beneficial for their educational in orthognathic surgery. Indeed, it allows an inexperienced surgeon to perform a critical step of the surgical procedure without compromising patient safety and postoperative results, his actions being watched continuously. Thus, the ONS allowed to inexperienced surgeons to directly acquire and improve skills to replace the condyle to its reference position (whatever the position chosen preoperatively). This point was demonstrated by the representation of the linear relation between the heuristic score and the num-

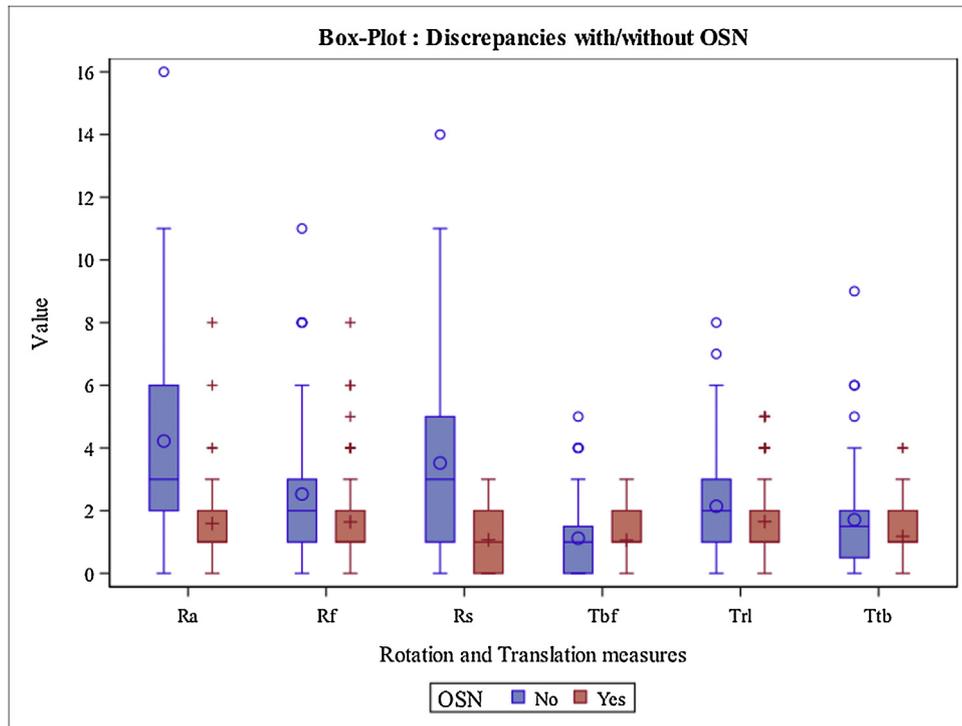


Fig. 2. Distribution of the discrepancies of each dimension with and without Orthopilot Navigation system (ONS).

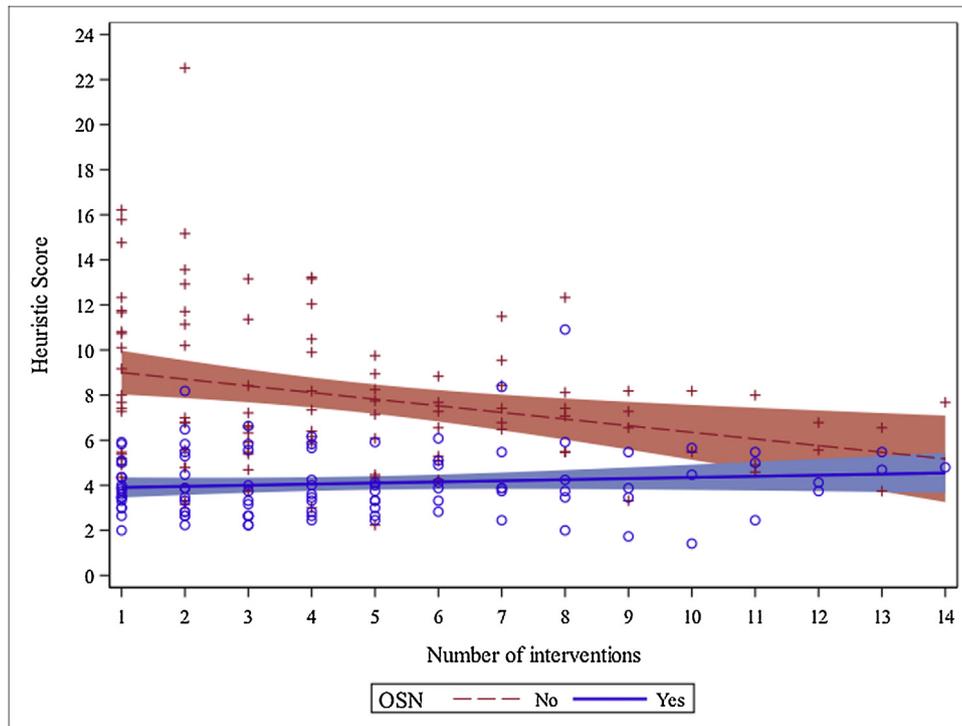


Fig. 3. Linear representation between the heuristic score and the number of interventions with and without Orthopilot Navigation system (ONS).

ber of interventions with and without the ONS: with an increasing number of procedures, the trainee improved his heuristic score without the use of the ONS. The lines seemed to cross at around 15 proce-

dures. In other words, a trainee would be able to place the condyle in the right position without using the ONS after 15 procedures with the ONS. Of course, learning can not be summarized by a linear

relation but it would be interesting to compare this number with those obtained from other learning tools.

Training is more efficient if it is multi-modal¹⁷. The ONS is a new way to teach

condylar repositioning and is complementary to other existing tools. To our knowledge, it is the only tool that can be used in the operating room.

Furthermore, evaluating technical skills and competence of a trainee in the operating room is difficult¹⁸, especially because the methods are subjective and unreliable. The ONS could be a good way of objectively following the heuristic scores of trainees and thus their progression.

Our study presented several limitations. It was a monocentric study and the number of procedures performed by each trainee was not variable. Our results were mainly dependent on the scores obtained by the trainee who performed 14 procedures. A multicentric study with a mixed model (taking into account the correlation of the data) is necessary to confirm our results. The side performed by the trainee was not randomized. This would have introduced a bias. The side should be randomized in future explorations.

Another bias was the failure to take into account the trainees' dominant hand. Indeed, a right-handed surgeon would find it more difficult to operate on the left side, for example. This bias had little consequence because the trainee only performed the condyle repositioning and the osteosynthesis (and not the entire intervention) so he could use his dominant hand whatever the operated side. Consequently, a learning effect was observed regardless of the operated side or the dominant hand. However, we should take this point into account in the future.

In conclusion, the ONS is a promising and original intraoperative learning tool for the repositioning of the condyle during BSSO. Its use allowed trainees to improve their accuracy and their surgical skills during this challenging step. However, further explorations are needed to confirm these preliminary results.

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Competing interests

None.

Ethical approval

Study ethics approval was obtained on 06 July 2018 (CECIC Rhône-Alpes-Auvergne, Clermont-Ferrand, IRB 5891).

Patient consent

Not required.

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