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Original article

IMPLEMENTING A 3D ROBOTIC DIGITAL MICROSCOPE IN THE NEUROSURGICAL PRACTICE: FINDINGS FROM A SINGLE-CENTRE STUDY

Milan Mladenovski
Department of Neurosurgery, Faculty of Medicine, Medical University Pleven, Bulgaria.

ABSTRACT:

The current era of modern devices and techniques requires improved visualization. The microscope and endoscope significantly influenced the historical advancement of neurosurgical practice, and the introduction of the exoscope has further transformed the field. This study aims to investigate the clinical implementation of the Aesculap 3D digital surgical microscope (AEOS) among neurosurgeons and their transition from (conventional optical microscope) OPMI to AEOS. Cases were documented within five months in 2022 and 2023. In this prospective study, we assessed the implementation of AEOS in correlation with the neurosurgeons' age and their transition over time We used the chi-square test and chi-square trend test for statistical significance. Additionally, we used multilinear and control chart graph statistics. The transition from OPMI to AEOS marks a period when AEOS-assisted procedures are more common than OPMI-assisted procedures performed in the clinic. The transition means that every neurosurgeon considers the primary use of AEOS in neurosurgical procedures, whether cranial, spinal, or peripheral nerve procedures. Our research indicates that the transition could be accomplished within 3 months (chi square trend test p<0,05) of use or after 19-35 (average 27) neurosurgical procedures. The age of the neurosurgeons was a significant factor in the initial transition.

Keywords: 3D robotic microscope, digital exoscope, transition, clinical implementation,

INTRODUCTION

The current era of modern devices and techniques requires improved visualization. The microscope and endoscope significantly influenced the historical advancement of neurosurgical practice, and the introduction of the exoscope has further transformed the field. Over the past decade, the robotic 3D digital surgical microscope (exoscope) has been developed to eliminate the limitations of microscopes and endoscopes, such as a small working distance, a small field of view, limited application to any procedure, and a long learning curve. The exoscope provides ergonomic and educational benefits alongside high-quality imaging and fluorescence in combination with digital and robotic functionalities. The main specifications of the operative scopes used in our clinic are listed in the next table (Table 1).

Aim:

To investigate the clinical implementation of the Aesculap 3D digital surgical microscope (AEOS) among neurosurgeons and their transition from (conventional optical microscope) OPMI to AEOS.

MATERIALS AND METHODS:

To perform outstanding tasks with high precision, neurosurgeons should see more and be supported by advanced imaging equipment. In September 2022, the Medical University of Pleven purchased an AESCULAP® robotic digital surgical microscope for neurosurgeons at the University Clinic of Neurosurgery (UMHAT "D-r Georgi Stranski Pleven). All six participating neurosurgeons were trained on the device, and they could switch to a conventional microscope at any point during the procedures. Inclusion criteria: Patients older than 18 years who needed cranial, spinal, or peripheral nerve procedures. Emergency and high-complexity neurosurgical interventions, such as intraventricular hematoma and cerebrovascular surgeries, were not included in the criteria. Cases were documented within five months in 2022 and 2023. In this prospectively designed research, we assessed the implementation of AEOS in correlation with the neurosurgeons' age and their transition over time. We used the chi-square test and chi-square trend test for statistical significance. Additionally, we used multilinear and control chart graph statistics.

Table 1. Main specifications of the surgical scopes used in our clinic.

	Conventional microscope (Zeiss Opmi Pico)	Endoscope (Storz)	Exoscope (AEOS 3D Robotic Surgical microscope)
Working distance (mm)	200-400	3-20	250-750
Field of view (mm)	<20	Small 25	Large 600
Depth of the field (mm)	<20	<20	35 – 100
Image	2D	2D	3D
Other (disadvantages):	Bad neck position of the surgeon	Limited to some procedures. Frequently blood obstructs the vision.	Not available everywhere. Expensive.

RESULTS:

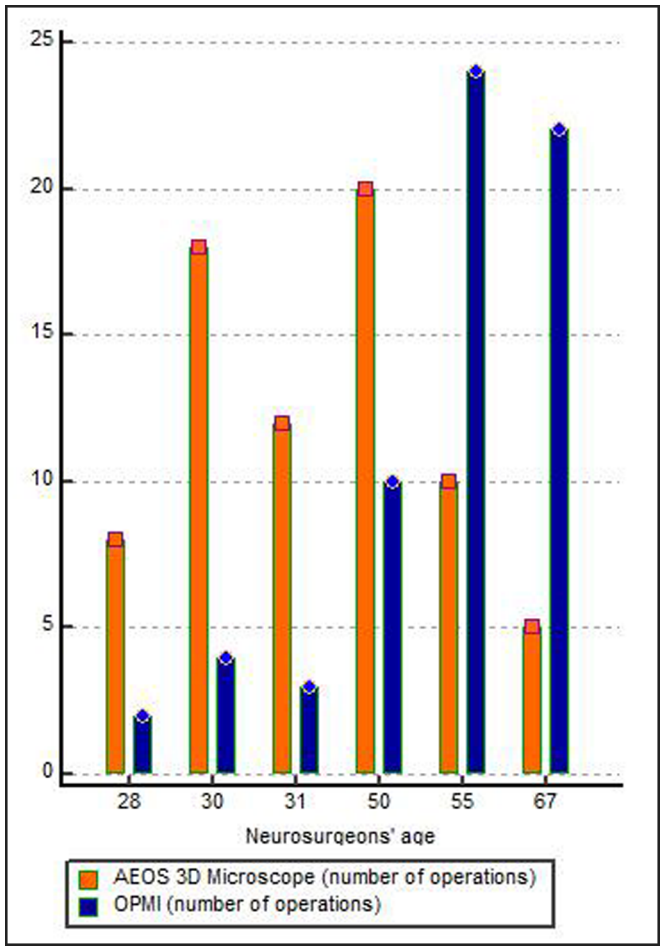
A total of 138 neurosurgical operations were performed and 73 patients underwent neurosurgical procedures using an AEOS 3D surgical microscope. The cohort included 54,8% men (n=40) and 45,2% women (n=33). The cohort's median age was 56 years (range 19-84). Thirty neurosurgical interventions were cranial surgeries, 38 were spinal surgeries, and five were peripheral nerve decompressions. The surgeries had a median duration of 122 minutes, with a range from 35 to 335 minutes. All surgeries were performed by six neurosurgeons with 5 to 40 years of experience (Table 2, Figure 1.). All procedures in which the operator converted to a conventional microscope were not calculated for the AEOS 3D operations (10 neurosurgical procedures). Our statistics showed that the clinical implementation of AEOS among neurosurgeons at the University Neurosurgery Clinic in Pleven was statistically significant (p< 0,05) with the operators' age in the initial five months of usage.

Table 2. Clinical implementation of AEOS among neurosurgeons at the University Neurosurgery Clinic in Pleven.

No.	Name	Age	OPMI (number of operations)	AEOS (number of operations)	Total
1	**V.I**	67	22	5	27
2	**O.M**	55	24	10	34
3	**M.E**	50	10	20	30
4	**V.N**	31	3	12	15
5	**M.M**	30	4	18	22
6	**D.I**	28	2	8	10
	Total		65	73	**138**

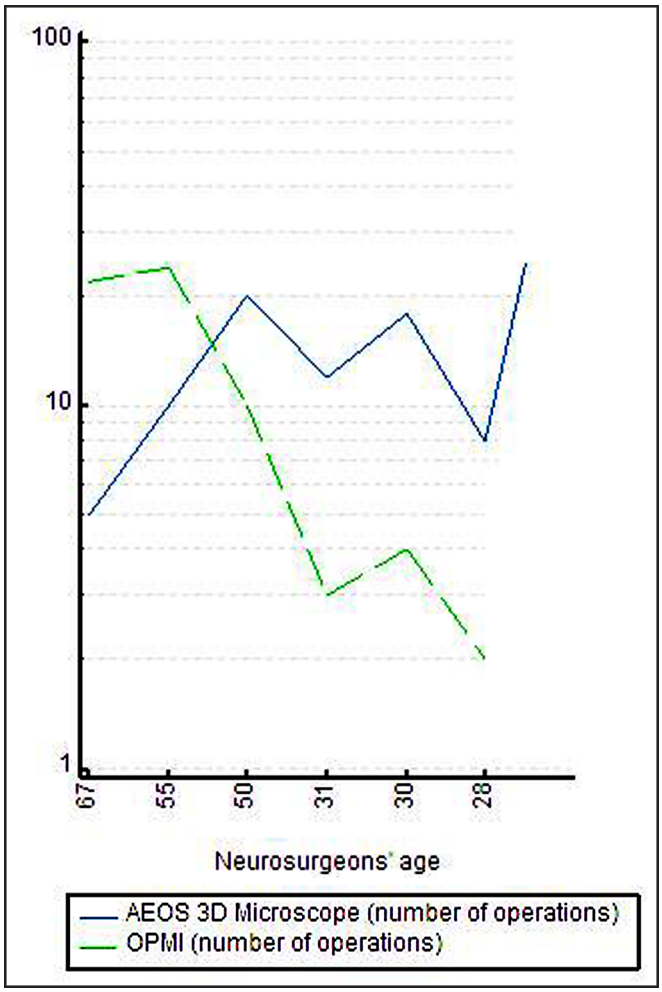
Chi-squared	**33.89**
DF	5
Significance	**P < 0.0001**
Contingency	0.444

Fig. 1. Clustered multiple variable graphic presentation of the clinical implementation of AEOS among neurosurgeons.



The surgeons' age is inversely proportional to the use of AEOS in the initial five months. This may be explained by the technological era during the growth of young neurosurgeons. The correlations were presented using multiple-line graphic statistics (Figure 2).

Fig. 2. Multiple-line graphic presentation of the clinical implementation of AEOS among neurosurgeons in correlation with the age of neurosurgeons



The transition from OPMI to AEOS marks a period when AEOS-assisted neurosurgical procedures are more common than OPMI-assisted procedures performed in the clinic. The transition means that every neurosurgeon considers the primary use of AEOS in neurosurgical procedures, whether cranial, spinal, or peripheral nerve procedures. In our clinic, we achieved the transition during December (2022) or 3 months of AEOS usage (chi square trend test p<0,05) (Table 3).

Table 3. Transition from OPMI to AEOS in correlation with time at the University Neurosurgery Clinic in Pleven.

Months	OPMI (number of operations)	AEOS (number of operations)	TOTAL
October (2022)	25	8	33
November (2022)	14	11	25
December (2022)	10	16	26
January (2023)	9	18	27
February (2023)	7	20	27
TOTAL	65	73	**138**

Chi-squared (trend)	**20.317**
DF	1
Significance level	**P < 0.0001**

The period of AEOS use was directly proportional to the clinical transition. This could be interpreted based on the numerous advantages of the AEOS 3D surgical microscope and its timely approval. The correlation is illustrated with control chart graphic statistics. (Figure 3, 4)

Fig. 3. Control-chart of the clinical implementation of AEOS among neurosurgeons in correlation with time. Note: Ascendant use of AEOS.

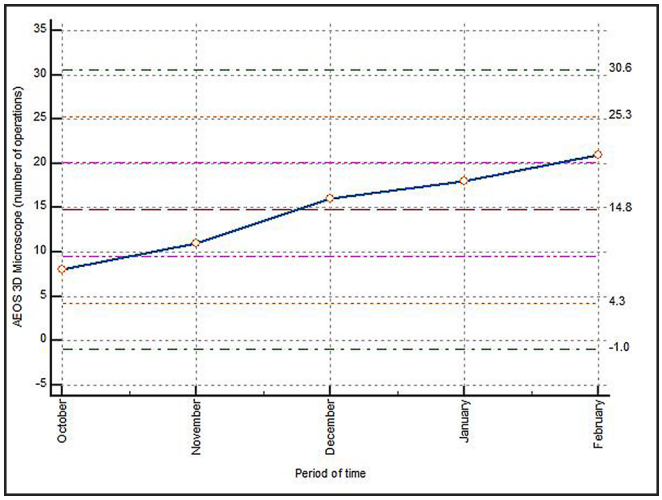
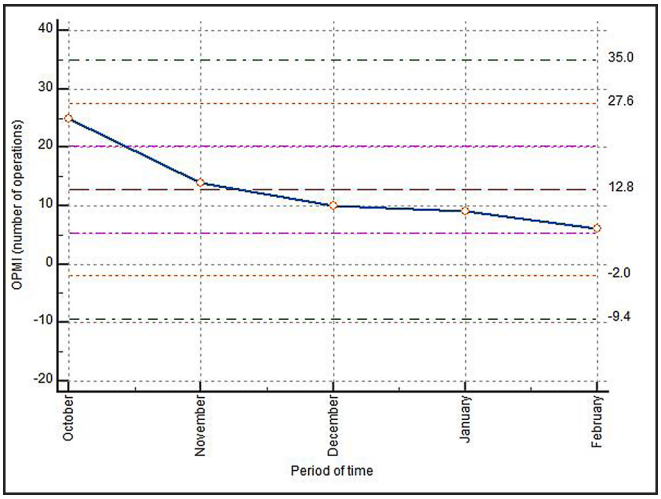
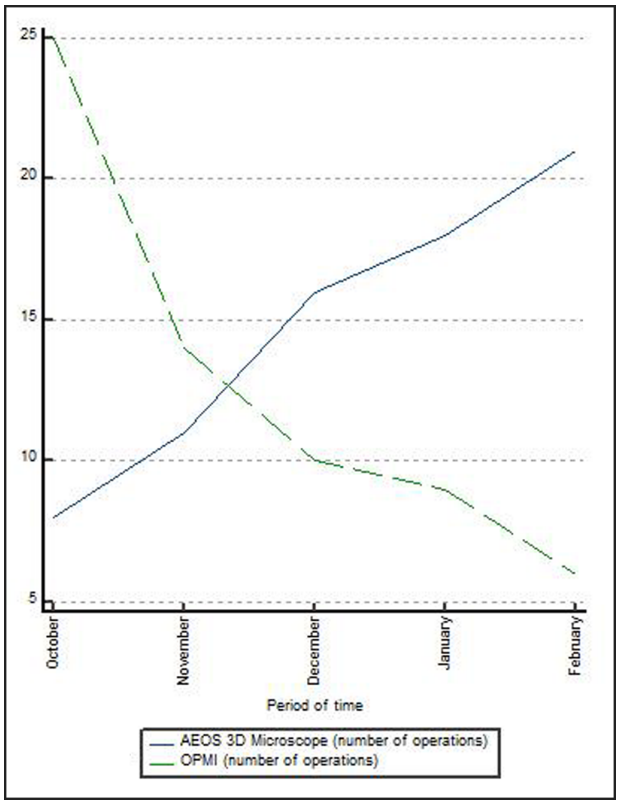


Fig. 4. Control-chart of the clinical implementation of OPMI among neurosurgeons in correlation with time. Note: Descending usage of the OPMI.



At the end of December 2022, at the University Neurosurgery Clinic in Pleven, there will be more AEOS-assisted neurosurgical procedures than OPMI-assisted procedures (16 versus 10). After 3 months of using AEOS, more neurosurgeons are considering using it as their primary tool for neurosurgical procedures. We have successfully implemented a 3D digital microscope/exoscope in 27 neurosurgical procedures, as indicated by our data (19 AEOS procedures at the end of November and 35 AEOS assisted procedures at the end of December) (Figure 5).

Fig. 5. Control-chart graphic presentation of the transition from OPMI to AEOS in correlation with time.



DISCUSSION

The exoscopic systems available for neurosurgical use, including VITOM®, ORBEYE™, Modus V™, Kinevo 900, BrainPath®, and Aeos®, provide comfortable, high-resolution visualization. They come with integrated features such as lock-on-target and waypoints, offer hands-free camera placement, making them more convenient and ergonomic compared to OPMI, even when extreme angles are required for visualization [1, 2, 3, 4, 5, 6].

Exoscopic surgery provides excellent imaging with high magnification, zoom, and brightness, making it suitable for a variety of procedures. However, transitioning to exoscopic surgery may require an adjustment period, especially in the beginning. It is crucial to accurately plan the intraoperative setup and optimize image settings for each case to ensure the surgical team's full compliance [7].

According to Montemurro, the overall rate of switching from exoscope to OPMI during surgery was 5.8%. In our study, the switches were carried out in 10 operations (7.2%). Exoscopes, like other modern devices, require specific training, but the learning curve is short compared to other devices such as operative microscopes (OPMI) and endoscopes [8]. The 4K-3D exoscope enables a three-surgeon-six-handed collaborative surgical approach, leading to simultaneous maneuvers by multiple hands, reduced operative time, intermittent brain retraction by two assistants, and educational benefits through visual sharing of the surgical procedure [9]. Exoscopes enable surgeons to easily transition between micro and macro vision as needed, providing comprehensive visibility of the surgical area and allowing them to monitor any potential bleeding [10].

Although our study did not involve neurovascular surgeries, other research has shown that exoscopic surgery is feasible for these procedures too [11]. One limitation of our study was the high number of different surgeons over a short observation period, resulting in a relatively low number of cases per surgeon. However, providing surgical education to young neurosurgeons and residents by allowing them to observe high-resolution surgeries from the first surgeon's perspective can be incredibly valuable, especially when learning not common procedures. Hànds-on tràining is ànother àddition for students ànd residents. Different hànds-on tràining opportunities àre àvàilàble, such às suturing, evàcuàtion of ICH in the 3D printed model, ànd càdàver dissection for crànià̀l ànd spinàl àpproàches [12].

According to Murai and colleagues, observing the exoscope's outcomes on display is similar to playing video games. Users who preferred the microscope reported that they do not play video games [13]. Motov and colleagues demonstrated that 76.5% of the surgeons found the ÀEOS exoscopic microscope easy to use. All of them reported a crucial improvement in the neurosurgical approach for

minimally invasive spinal procedures [14]. Maurer and colleagues reported a 78.95% satisfaction rate for cranial surgery, with 84.21% of surgeons finding the surgical ergonomics satisfactory, and 78.95% preferring frequent use of this system [15].

Gabrovsky and colleagues determined that the transition to AEOS was considered complete when achieving a performance above 80% and reducing frustration and effort below 20%. They accomplished this transition around the 20th operation, with earlier success seen in spinal operations [16].

A study by Gadjradj PS, et al. found that 73.6% of 417 neurosurgeons experienced work-related musculoskeletal disorders (WMSDs). Some of them even considered changing specialties or careers [17]. Màrovounis and colleagues found even more alarming results after surveying 409 members of different neurosurgical associations. Among the 409 members, 87.9% reported experiencing work-related musculoskeletal disorders, particularly neck and shoulder pain [18]. Modern exoscopes currently provide crucial ergonomic postures and decrease WMSDs for neurosurgeons.

CONCLUSION/S/:

Our research indicates that the transition could be accomplished within 3 months of use or after 19-35 (average 27) neurosurgical procedures. The age of the neurosurgeons was a significant factor in the initial transition. The exoscope eliminates the disadvantages of a microscope and an endoscope. Along with a 3D digital surgical microscope, the neurosurgical equipment setup should include conventional microscopes and endoscopes that are irreplaceable devices in a university neurosurgical department. AEOS offers an opportunity for our clinic and department to organize hands-on courses. Future studies should compare the results between different brands of exoscope devices and the results of exoscopic versus microscopic surgery for various neurosurgical conditions.

Abbreviations:

AEOS - Aesculap 3D digital surgical microscope
OPMI - Conventional optical microscope

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Address for correspondence:
Dr Milan Mladenovski
Department of Neurosurgery, Faculty of Medicine, Medical University Pleven, 8a, Georgi Kochev Str., Pleven, Bulgaria.
E-mail: mladenovskinhk@gmail.com,