

COMPARATIVE STUDY ON THE GUIDANCE OF ORTHODONTIC TREATMENTS THROUGH ARTIFICIAL INTELLIGENCE-BASED SOFTWARE AND CLASSIC SOFTWARE

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Abstract

When it comes to guiding orthodontic treatments, our study aims to evaluate the effectiveness and benefits of software powered by artificial intelligence (AI) compared to traditional software.

The software underwent a thorough evaluation to assess its performance, adaptability, and verbal communication. According to the findings, the software showed a remarkable ability to process and analyze information, resulting in more accurate planning of orthodontic treatments. Its adaptability has been found to be noteworthy, enabling it to identify and address individual patient conditions and problems with greater precision. With the help of this software, orthodontic treatments can be modified and improved in real time, considering the progress and alterations of the case throughout the treatment. Verbal communication through "speech recognize" AI algorithms contributes significantly to their long-term use and user satisfaction.

Creating a comfortable and pleasant environment, this software improves the user experience and strengthens their relationship with technology.

Comparatively, the classic software presented a lower level of performance and adaptability, and it was impossible to communicate verbally with the software interface. It is based on fixed rule settings and cannot individualize the orthodontic treatment. On the other hand, it uses standardized planning that can lead to unsatisfactory results or further adjustments. According to the comparative study, the artificial intelligence-based software improved the performance and adaptability of orthodontic treatments. Additionally, it enabled direct verbal communication, eliminating the need for a keyboard and a mouse. They can provide more precise guidance by collecting data and machine learning capabilities. However, it is crucial to consider the cost and security aspects of implementing and using this software in the orthodontic practice.

Keywords: Artificial intelligence, performance, adaptability, interface, OpenCV Haar Cascades, orthodontics

Introduction

Orthodontic treatments are sometimes necessary for getting a beautiful and healthy

smile. Proper planning and execution of these treatments are essential to achieve optimal results and avoid complications [1]. In recent years, the technological evolution and the

development of machine learning capabilities have opened up new perspectives in guiding orthodontic treatments through artificial intelligence-based software. These software were designed to provide a personalized approach and precise guidance of orthodontic treatments by optimizing their effectiveness and efficiency. As per recent studies, artificial intelligence software has shown tremendous potential in identifying and adapting to individual patient conditions and problems [2-5].

In the digital age we are living in, the use of artificial intelligence (AI) brings multiple advantages and benefits in various domains. These include improved performance, increased adaptability, and the ability to communicate through human voice recognition technology [2,3].

The software's ability to process and interpret relevant information quickly and accurately represents its performance. AI-based software is being developed to have a superior ability to analyze and interpret data, which can lead to more accurate and faster treatment planning. This software can also identify and adapt treatments to individual patients' conditions and problems, thus providing personalized solutions [2-4].

Adaptability refers to the software's ability to learn and adapt to patient changes and developments during treatment. AI-based software can learn from the collected data and adjust treatment in real time as the patient's status changes. Thus, this software can offer a personalized and dynamic approach to orthodontic treatment [2-4].

This ability facilitates two-way interactions and creates a more natural and fluent

experience, the rapid exchange of information between the app and the dentist without the need to use a keyboard or other additional devices [5,6].

In contrast to classical software, which relied on fixed rules and standardized planning, modern software offers greater customization and adaptability for orthodontic treatments. These can lead to more accurate planning and results that require fewer additional adjustments [2-6]. Our research objective was to assess the advantages of AI technology in guiding orthodontic treatments compared to traditional software. We aimed to highlight three key benefits: enhanced performance, greater adaptability, and verbal communication facilitated by voice recognition technology.

Through the study, two versions of ORTHO AI software were developed - one using classic algorithms and the other using specific Artificial Intelligence algorithms. Both versions aimed to guide the alignment of teeth during orthodontic treatment based on facial information. The designed and developed AI version of the software has the potential to revolutionize the dental field, offering dentists a friendly and attractive but also innovative and effective tool for directing teeth to obtain dental aesthetics correctly related to the patient's facial aesthetics. The use of advanced detection technology and an intuitive voice interface facilitates communication and efficiency of the treatment process, bringing significant benefits to patients and dental professionals.

Materials and methods

The development of this software application involved cutting-edge technologies for image analysis and facial point detection, as well as the use of OpenCV Haar Cascades and synchronization projection in video images.

Machine learning algorithms and advanced image processing techniques were employed to precisely identify and locate the defining points of the patient's facial aesthetics, thereby detecting the anatomical shapes of the face with great accuracy.

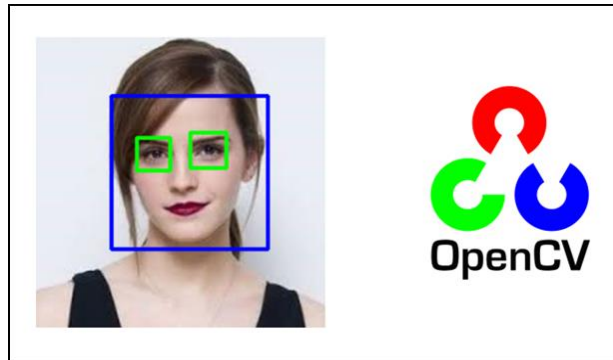


Fig.1 Facial recognition, OpenCV Haar Cascades [7]

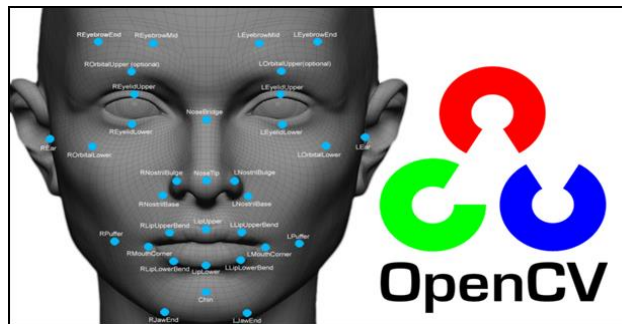


Fig.2 Facial point detection, OpenCV Haar Cascades [8]

This step is crucial in making an accurate assessment of facial symmetry and determining optimal facial axes. Thus, correct and efficient targeting for precise alignment among tooth structures without compromising overall facial aesthetics can be achieved.

We also created an Artificial Neural Network containing a database of anatomical forms of the oral cavity in normal and pathological variants, which helps the application recognize anatomical shapes, can be

processed, and elaborates accurate medical information that is impossible to find out directly by clinical examination.

Also, the application includes a verbal communication interface, which allows voice recognition (figure 3), speech recognition, and bidirectional communication between the dentist and the application. Through voice commands, the doctor can quickly access the necessary information and receive the proper guidance to target each tooth accurately and efficiently. This voice interaction facilitates

the rapid exchange of information and allows the dentist to focus more on the patient

without being distracted by the use of the keyboard or other additional device

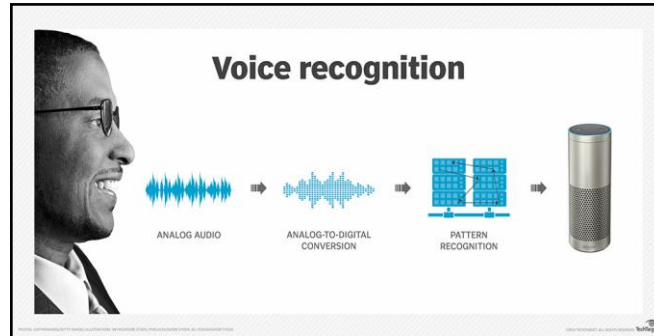


Fig.3 Voice recognition

The study group consisted of 48 patients, and the criteria was signing an informed consent. They were randomly divided into four subgroups of 12 patients treated by four doctors: group A - Dr. Marius Hack, group B - Dr. Ludmila Hack, group C - Dr. Daniela Stan. and group D - Dr. Eduard Nedelcu. The study was carried out in the clinic HACK DENTAL Srl, Romania. Both software versions were used for each patient to compare the advantages and disadvantages of the two versions as concretely as possible. Each doctor had a dedicated video camera installed at the dental unit, with optical zoom

suitable for dental treatments (optical zoom 30x), mounted at the level of the dental unit's light lamps and connected to a computer on which the ORTHO AI software application with both versions was installed. The automatic version based on AI detected facial information through the FaceMech function (figure 4) for processing facial axes and other elements necessary to guide dental aesthetics. The second version of the application gets classic algorithms, in which each step was done manually, respecting the technical specifications.

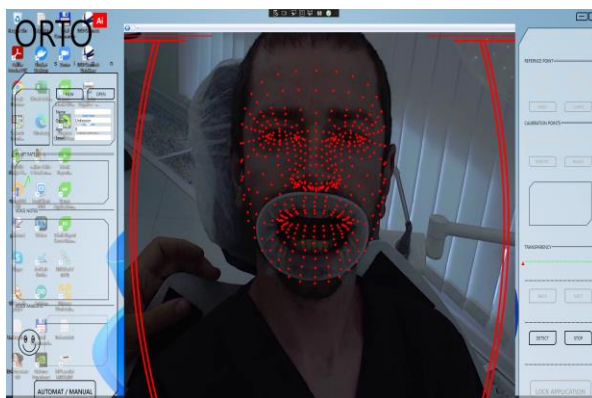


Fig 3 Face mech detection

The video images during the treatments, analyzed by the ORTHO AI application, were visualized

on the monitor/television in front of the patient, mounted on the light arm from the ceiling or on the arm of the dental unit. Initially, the classic application without AI was used, after which the same procedure was repeated with the AI version.

Thus, after applying the lip spacer and fixing the video camera on the patient's face, we opened the classic application using the image filmed in real-time. The doctor used

the keyboard for writing the patient's data and the mouse at every stage of the procedure; the symmetrical points of the face were manually selected. Based on these points, the application displayed the axes of the face which were synchronized with the oral cavity based on the oral points selected by the doctor using the mouse. After selecting the synchronization oral points, the facial axes remained synchronized with the oral cavity throughout filming and helped the doctor to observe and decide how the front teeth should be moved to get appropriate dental aesthetics.

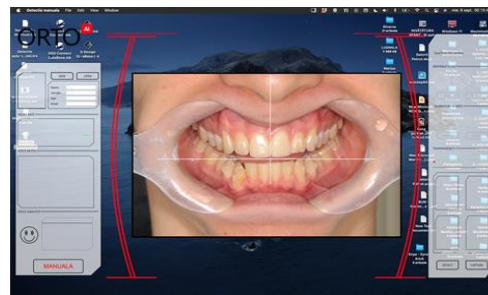


Fig.4 ORTHO AI - automated version [10]

In the second version, after applying the lip spacer for exposure to the oral cavity, the AI-based application was opened. The keyboard and the mouse were no longer used, as communication with the application was done verbally. The patient's data were dictated (by verbal feedback), and the

detection of facial information was ordered verbally. The application automatically detected the facial information from the video images. After analyzing them, it designed and automatically synchronized the facial axes directly on the oral cavity.

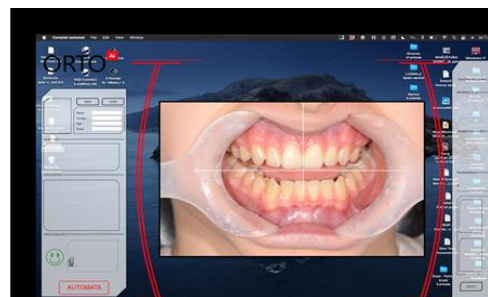
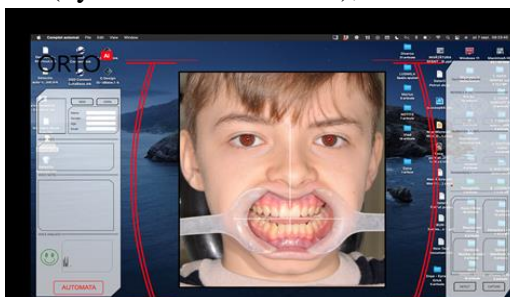


Fig.5 ORTHO AI - manual version [11]

ORTHO AI automatically zooms in to provide an easy visualization of the position of each tooth in relation to the facial axes, allowing for an adequate framing and visualization of just the oral cavity. This helps orthodontists obtain dental aesthetics that align with facial aesthetics [12]. The AI application provides necessary information about where and how much each tooth should be moved to achieve these results. The best part is that everything is done automatically through direct verbal communication with the AI application, reducing working time and eliminating the need to touch the keyboard or mouse.

The accuracy of the design of the facial axes and their synchronization on the oral cavity in the AI application was also distinguished, compared to the classic version, where the manual selection of symmetry and synchronization points was uncertain [13]. The patients were asked to rate each software

version on a scale of 1-10, based on its ease of use, performance, and adaptability.

By using this method, we were able to quickly and accurately compare the benefits and effectiveness of using software guided by AI in orthodontic treatments versus traditional software. We focused on three important aspects: performance, adaptability, and communication with the software interface.

Results and discussions

It was interesting to see how their opinions varied from one version to the next. Some found a certain version easy to use, but lacking in performance, while others felt that the adaptability of a certain version was superior to others. Overall, it was clear that each patient had their unique preferences when it came to software versions. The results were quite illuminating and underscored the value of incorporating AI into orthodontic treatment planning.

After conducting the study, the following findings were revealed:

I. Group A:

Patients Group A	Used as an interface		Performance		Adaptability	
	Classic software	Soft AI	Classic software	Soft AI	Classic software	Soft AI
1	6	9	7	9	0	9
2	6	9	8	9	0	10
3	6	8	6	9	0	8
4	7	9	7	10	0	9
5	7	9	6	9	0	8
6	6	10	7	10	0	7

Patients Group A	Used as an interface		Performance		Adaptability	
	Classic software	Soft AI	Classic software	Soft AI	Classic software	Soft AI
7	7	9	8	9	0	8
8	7	10	7	9	0	9
9	6	9	6	9	0	9
10	7	10	7	10	0	9
11	7	10	7	9	0	10
12	6	9	8	10	0	9
Total	78	111	84	112	0	105

The adaptability was quickly noticed after each use when the software found the facial points of interest and the points of synchronization with the oral cavity much faster.

The performance helped a lot to shorten the working time, the processing of the

II. Group B

information faster, and the results offered faster than in the classic version.

The verbal communication with the software interface helped the doctor to stop putting his hand on the keyboard/mouse, and the working time was also reduced [14]

Patients Group B	Used as an interface		Performance		Adaptability	
	Classic software	Soft AI	Classic software	Soft AI	Classic software	Soft AI
1	5	9	7	10	0	8
2	6	10	6	9	0	8
3	6	9	7	10	0	7
4	5	10	7	10	0	8
5	7	9	6	9	0	7
6	6	10	6	10	0	7
7	6	9	7	10	0	10

Patients Group B	Used as an interface		Performance		Adaptability	
	Classic software	Soft AI	Classic software	Soft AI	Classic software	Soft AI
8	6	10	6	10	0	9
9	5	10	7	9	0	8
10	6	10	7	10	0	9
11	7	10	7	9	0	9
12	7	9	6	10	0	9
Total	72	115	79	116	0	99

Using verbal commands to communicate with the software interface was really helpful and convenient. It eliminated the need for the doctor to constantly wash their hands after touching the keyboard or mouse. Additionally, digital assistance was very comfortable, making it an ideal tool for doctors and healthcare professionals.

We have also noticed that the AI version performs much better than the classic version, especially for its adaptability. In the classic version, it often feels like you are working with a machine that follows the same predefined steps over and over. But with the AI version there was a level of flexibility that proved it was a much more dynamic and efficient tool [15,16].

III. Group C

Patients Group C	Used as an interface		Performance		Adaptability	
	Classic software	Soft AI	Classic software	Soft AI	Classic software	Soft AI
1	6	10	5	10	0	8
2	6	10	6	10	0	8
3	5	9	6	9	0	8
4	6	8	7	9	0	9
5	6	9	6	9	0	8
6	6	10	7	10	0	7
7	5	9	7	10	0	7

Patients Group C	Used as an interface		Performance		Adaptability	
	Classic software	Soft AI	Classic software	Soft AI	Classic software	Soft AI
8	6	10	7	9	0	9
9	6	10	6	9	0	8
10	6	10	7	10	0	9
11	6	10	7	9	0	10
12	6	9	8	10	0	8
Total	70	114	79	114	0	99

Verbal communication was the most pleasant part of using the AI-based software, the workflow being much shortened and much easier. The adaptability stood out in the AI version, where the response time sometimes seemed faster [17,18].

For the classic version, the character of adaptability was not noticed. The performance stood out much better in the AI version. In the classic version, the performance was lower.

IV. Group D

Patients Group D	Used as an interface		Performance		Adaptability	
	Classic software	Soft AI	Classic software	Soft AI	Classic software	Soft AI
1	7	9	7	10	0	8
2	6	9	6	10	0	8
3	7	9	7	9	0	9
4	6	9	7	10	0	9
5	6	9	7	9	0	9
6	6	10	7	10	0	9
7	6	9	7	10	0	9
8	6	10	7	9	0	9
9	7	10	7	10	0	9
10	6	10	7	10	0	9

Patients Group D	Used as an interface		Performance		Adaptability	
	Classic software	Soft AI	Classic software	Soft AI	Classic software	Soft AI
11	7	10	7	10	0	10
12	6	10	8	10	0	9
Total	76	114	84	117	0	107

We found communicating with the software interface through verbal commands a helpful and pleasant experience when interacting with patients [19]. We noticed the adaptability of the interface compared to the

classic version, where the workflow was always the same.

Additionally, the AI version seemed to perform better as it could quickly and consistently detect facial points of interest [20].

Final results:

Groups	Used as an interface		Performance		Adaptability	
	Classic software	Soft AI	Classic software	Soft AI	Classic software	Soft AI
Group A	78	111	84	112	0	105
Group B	72	115	79	116	0	99
Group C	70	114	79	114	0	99
Group D	76	114	84	117	0	107
Total	296	454	326	459	0	410

The interface use of the IA application scored 454 points, while the classic application scored 296 points. With the help of verbal communication based on AI, the application use became more interesting. It also made the preparation workflow for using the application much easier and faster.

The performance of the AI application of 459 points is significantly higher than the classic

application with 326 points. In the classic version, the user and the patient had to manually apply the symmetrical points of the face and synchronization points, which was time-consuming and often inaccurate. However, with the AI application, the OpenCV Haar Cascades function automatically detects facial information, eliminating the need for manual selection.

Moreover, the analysis of facial information by the AI version provides more consistent and safer guidance information.

The classic application scored 0 points in adaptability, while the AI application scored 410 points. That is because the classic software version showed no sign of actual software learning by each case and user, while the adaptation was felt in using the AI application. It reduced the working time with the application, and the software assistance was much more valuable.

The ORTHO AI application offers a unique combination of advanced detection and design technology along with an intuitive voice interface that allows communication with the dentist. This powerful tool enables doctors to plan and implement dental treatments with greater accuracy, ensuring that the final result is in perfect harmony with the patient's facial characteristics.

According to the study, the evaluation of doctors assisted by the two software versions of the ORTHO AI application revealed that the doctors were impressed by the use of the interface through verbal communication, the performance of the analysis of the detected facial information, and the ability to create of the AI software.

Conclusions

Technology has a significant role in modern orthodontic treatments thanks to a new AI-

based software application. One such solution promises to make an impact by helping orthodontists determine the optimal direction of teeth for facial aesthetics. It can lead to spectacular results and contribute to the patient's satisfaction, especially from an aesthetic standpoint. These technological advancements can significantly improve our overall well-being.

AI-powered facial analysis has the potential to enhance the accuracy of orthodontic diagnosis and treatment planning significantly. By optimizing the treatment process, this technology can also help to reduce the associated costs and efforts.

AI software can analyze user behavior and tailor the experience to users' needs and preferences. It makes it easier for users to learn and use digital apps. In orthodontic care, this could result in increased accuracy and efficiency.

The use of AI applications in orthodontics has multiple advantages, including interactive verbal communication, the performance of the analysis of detected facial information, and the ability to improve AI software. In contrast, classic software is more difficult to use for users with limited knowledge in the digital field. By integrating artificial intelligence, this software becomes more accessible and can provide confidence in the digital domain.

References

1. Christou T, Betlej A, Aswad N, Ogdon D, Kau CH. Clinical effectiveness of orthodontic treatment on smile esthetics: a systematic review. *Clin Cosmet Investig Dent*. 2019 May 2;11:89-101. doi: 10.2147/CCIDE.S189708.
2. Kumar Y, Koul A, Singla R, Ijaz MF. Artificial intelligence in disease diagnosis: a systematic literature review, synthesizing framework and future research agenda. *J Ambient Intell Humaniz Comput*. 2023;14(7):8459-8486. doi: 10.1007/s12652-021-03612-z.
3. Johnson KB, Wei WQ, Weeraratne D, Frisse ME, Misulis K, Rhee K, Zhao J, Snowdon JL. Precision Medicine, AI, and the Future of Personalized Health Care. *Clin Transl Sci*. 2021 Jan;14(1):86-93. doi: 10.1111/cts.12884.
4. Kunz F, Stellzig-Eisenhauer A, Boldt J. Applications of Artificial Intelligence in Orthodontics—An Overview and Perspective Based on the Current State of the Art. *Applied Sciences*. 2023; 13(6):3850. <https://doi.org/10.3390/app13063850>.
5. Agrawal P, Nikhade P. Artificial Intelligence in Dentistry: Past, Present, and Future. *Cureus*. 2022 Jul 28;14(7):e27405. doi: 10.7759/cureus.27405.
6. Assis MAL, Tavares LDF, Bernardino AP, Rocha BA, Abreu LG, Oliveira DD, Pithon MM, Soares RV. Information and Communications Technology in Dentistry: an informative and educational approach for patients with fixed orthodontic appliances. *Dental Press J Orthod*. 2022 Jul 4;27(3):e22spe3. doi: 10.1590/2177-6709.27.3.e22spe3.
7. Available online: <https://pyimagesearch.com/2021/04/12/opencv-haar-cascades/> (accessed on 10 May 2022).
8. Available online: <https://www.linkedin.com/pulse/face-detection-using-python-shradha-seth> (accessed on 09 May 2022).
9. Available online: <https://www.techtarget.com/searchcustomerexperience/definition/voice-recognition-speaker-recognition> (accessed 10 May 2022).
10. Available online: <https://github.com/sfzhang15/FaceBoxes> (accessed on 11 May 2022).
11. Available online: https://docs.opencv.org/4.x/d9/df8/tutorial_root.html (accessed on 11 May 2022).
12. Caruso S, Caruso S, Pellegrino M, Skafi R, Nota A, Tecco S. A Knowledge-Based Algorithm for Automatic Monitoring of Orthodontic Treatment: The Dental Monitoring System. Two Cases. *Sensors (Basel)*. 2021 Mar 7;21(5):1856. doi: 10.3390/s21051856.
13. Ren R, Luo H, Su C, Yao Y, Liao W. Machine learning in dental, oral and craniofacial imaging: a review of recent progress. *PeerJ*. 2021 May 17;9:e11451. doi: 10.7717/peerj.11451.
14. Zhu Y, Kim YC, Proctor MI, Narayanan SS, Nayak KS. Dynamic 3-D visualization of vocal tract shaping during speech. *IEEE Trans Med Imaging*. 2013 May;32(5):838-48. doi: 10.1109/TMI.2012.2230017.
15. Svensson AM, Jotterand F. Doctor Ex Machina: A Critical Assessment of the Use of Artificial Intelligence in Health Care. *J Med Philos*. 2022 Feb 8;47(1):155-78.
16. Crook BS, Park CN, Hurley ET, Richard MJ, Pidgeon TS. Evaluation of Online Artificial Intelligence-Generated Information on Common Hand Procedures. *J Hand Surg Am*. 2023 Sep 7:S0363-5023(23)00414-8.

17. Marin Vargas A, Cominelli L, Dell'Orletta F, Scilingo EP. (2021). Verbal Communication in Robotics: A Study on Salient Terms, Research fields and Trends in the Last Decades Based on a Computational Linguistic Analysis. *Front. Comput. Sci.* 2, 63. 10.3389/fcomp.2020.591164.
18. Kumar S, Savur C, Sahin F. Survey of Human-Robot Collaboration in Industrial Settings: Awareness, Intelligence, and Compliance. *IEEE Trans. Syst. Man. Cybern, Syst.* 2021;51:280–97. 10.1109/tsmc.2020.304123.
19. Chiang YC, Wu F, Ko SH. Effective Patient-Dentist Communication with a Simulation System for Orthodontics. *Healthcare (Basel)*. 2023 May 15;11(10):1433. doi: 10.3390/healthcare11101433.
20. Arjmand H, Clement A, Hardisty M, Fialkov JA, Whyne CM. Artificial Intelligence-Based Modeling Can Predict Face Shape Based on Underlying Craniomaxillofacial Bone. *J Craniofac Surg.* 2023 Oct 1;34(7):1915-1921. doi: 10.1097/SCS.00000000000009597.