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ORIGINAL

Integration of telemedicine and artificial intelligence in the use of 3D printing in facial reconstruction

Integración de la telemedicina y la inteligencia artificial en el uso de la impresión 3D en reconstrucción facial

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ABSTRACT

Facial reconstruction addresses congenital malformations and trauma through functional and aesthetic repair, but faces limitations due to the dependence on surgical skills. The integration of telemedicine, artificial intelligence (AI) and 3D printing have emerged as a solution to improve the accuracy and accessibility of treatments; the objective was to demonstrate the benefits of telemedicine and artificial intelligence in the use of 3D printing in facial reconstructions. A literary review was carried out using the PRISMA method, analyzing 20 studies from Scielo, Elsevier, PubMed, REDALYC and ERIC and taking into account the inclusion criteria: 1) Research period between 2020 and 2024 2) Textual studies 3) Review articles 4) Spanish, English and Portuguese language 5) Free open access articles, demonstrating that these technologies increase the quality of treatment in functional and aesthetic results. The findings were a decrease in hospital admissions (12,5 %) and medical costs (5,3 %), accuracy in facial reconstructions (90 % sensitivity) and economic benefits with 26 % returns on technological investment (4-6). It is concluded that there is an improvement in functional and aesthetic results in facial reconstruction and that it also transforms the accessibility and efficiency of the health system. However, the adoption of these technologies faces challenges such as limited access to resources and the need for more precise algorithms.

Keywords: Telemedicine; Artificial Intelligence; 3D Printing; Facial Reconstruction.

RESUMEN

La reconstrucción facial aborda malformaciones congénitas y traumas mediante la reparación funcional y estética, pero enfrenta limitaciones debido a la dependencia de habilidades quirúrgicas. La integración de telemedicina, inteligencia artificial (IA) e impresión 3D han emergido como solución para mejorar la precisión y accesibilidad a los tratamientos; el objetivo fue demostrar los beneficios de la telemedicina y la inteligencia artificial en el uso de la impresión 3D en reconstrucciones faciales. Se realizó una revisión literaria con el método PRISMA, analizando 20 estudios de Scielo, Elsevier, PubMed, REDALYC y ERIC y teniendo en cuenta los criterios de inclusión: 1) Período de investigación entre 2020 y 2024 2) Estudios textuales 3) Artículos de revisión 4) Idioma español, inglés y portugués 5) Artículos gratuitos de libre acceso, demostrando que estas tecnologías aumentan la calidad del tratamiento en resultados funcionales y estéticos. Los hallazgos fueron disminución en ingresos hospitalarios (12,5 %) y costos médicos (5,3 %), precisión en reconstrucciones faciales (90 % de sensibilidad) y beneficios económicos con retornos del 26 % en inversión tecnológica (4-6). Se concluye que existe mejora en los resultados funcionales y estéticos en la reconstrucción facial y que también transforma la accesibilidad y la eficiencia del sistema de salud, Sin embargo, la adopción de estas tecnologías enfrenta desafíos como acceso limitado a recursos y necesidad de algoritmos más precisos.

Palabras clave: Telemedicina; Inteligencia Artificial (IA); Impresión 3D; Reconstrucción Facial.

INTRODUCTION

Multiple congenital malformations or external factors such as trauma cause facial deformities in patients, which is why facial reconstruction is a diverse and varied multidisciplinary field that aims to provide both functional and aesthetic repair for patients. However, this process is directly dependent on the surgical skills of healthcare personnel, which causes significant limitations in the degree of accuracy and results in countless cases. As a result of this problem, telemedicine has been integrated with artificial intelligence to raise standards in facial reconstructive surgery, with 3D printing as a fundamental tool.

According to the World Health Organization (WHO), telemedicine is essential to ensure equity in access to advanced and personalized health services.[1] It has also become an indispensable tool for overcoming geographical barriers and enabling access to specialized medical care, which is essential for remote or low-income locations. It is also useful in the field of reconstructive surgery, as it allows for greater collaboration between medical personnel, adequate postoperative follow-up, optimization of time, and reduction of treatment costs.

In the field of facial reconstruction, deep learning algorithms can analyze medical images to design accurate anatomical models, improve surgical planning, and predict clinical outcomes with a high degree of accuracy.[2,3] Furthermore, the combination of AI with 3D printing technologies allows for the creation of prostheses, surgical guides, and customized structures that improve both functionality and aesthetics in patients.[6] For this reason, its use is essential for favorable patient outcomes and facilitates the work of healthcare personnel.

On the other hand, 3D printing has emerged as a decisive tool in reconstructive surgery, as it provides individualized resources for each patient's problem, addressing their specific needs. Its ability to manufacture detailed anatomical models and customized devices has been shown to reduce surgical times and improve operational precision.[4,5]

In light of these advances, the question arises: What are the benefits of telemedicine and artificial intelligence in the use of 3D printing in facial reconstruction? This question is justified because traditional methods of facial reconstruction surgery often have limitations in terms of precision, individualization, and accessibility, especially in regions with limited resources. That is why the integration of telemedicine, artificial intelligence (AI), and 3D printing technologies can transform this perspective by making use of advanced tools that aim to improve the quality of treatment, obtain better results, and reduce geographical and economic barriers, thereby generating a higher degree of patient satisfaction and providing better tools for healthcare professionals.

Therefore, the objective of this project is to demonstrate the multiple benefits offered by telemedicine and artificial intelligence in the use of 3D printing in facial reconstructions with the aim of optimizing surgical precision, accessibility to specialized health services, and both functional and aesthetic results in patients.

METHOD

In carrying out this project, exhaustive research and literature review were conducted with the aim of integrating the fundamental concepts of the project, respecting the parameters established by the PRISMA method and putting into practice the bases established in its regulations.

The following search engines were used as the main sources of information: Scielo, ELSEVIER, REDALYC, and PubMed. The search terms that made up the research equation were as follows: "telemedicine," "artificial intelligence," "facial reconstruction," and "3D printing." These keywords were combined using the Boolean term "AND" as a link, yielding results that contain these categories of analysis in either the title, abstract, or body of the information. In addition, the inclusion criteria are: 1) Research period between 2020 and 2024, 2) Textual studies, 3) Review articles, 4) Spanish, English, and Portuguese language, 5) Free and open-access articles. For this reason, any article that did not meet the selected filters and did not address the topic of study was excluded.

Of the 15,190 articles that appeared, only 20 met both the inclusion and exclusion criteria and were therefore considered in this literature review. Each of the articles was then analyzed to obtain their main ideas and integrate them into this project.

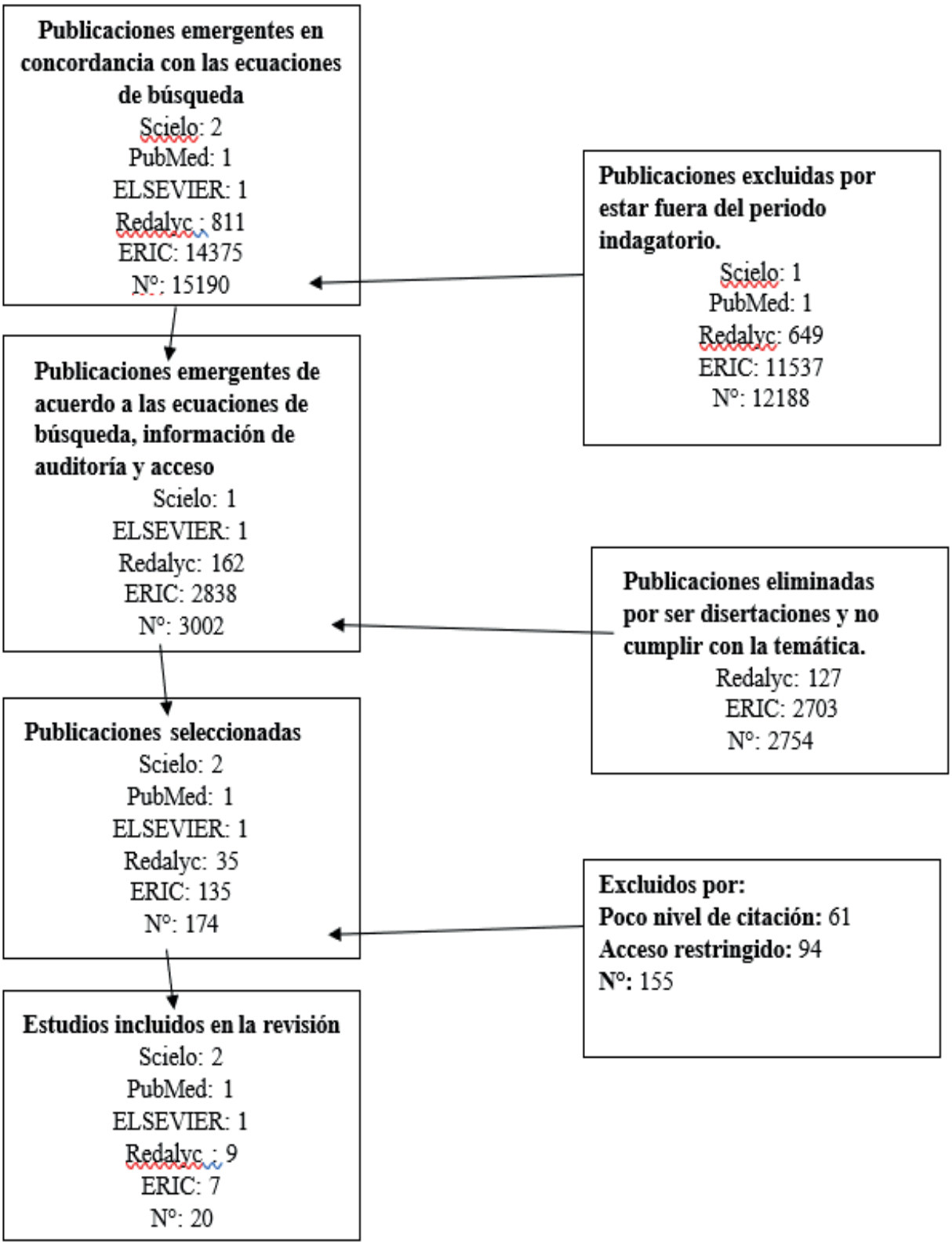

Figure 1. Flowchart of article selection

Table 1. Information

Links	Author/year	Title	Country	Findings
https://www.elsevier.com/es-es/connect/ improving-quality-and-safety-in-care-with-knowledge	Lais Junqueira (2021)	Improving Quality and Safety in Care with Knowledge and Technology	Spain	The use of telemedicine and AI has led to significant advances in treatment, with a 12,5 % reduction in hospital admissions and a 5,3 % reduction in overall medical costs compared to facial reconstruction models.
	Valentina Gómez Fonseca Victoria Helena Palacios Yucci Paula Camila Romero Lagos (2020)	Artificial intelligence in the diagnosis of facial malformations.	Mexico	The advantages of AI and telemedicine in the diagnosis of craniofacial malformations provide support to healthcare professionals in making specific and early diagnoses of genetic syndromes. AI-based diagnostic methods, such as the DeepGestalt program, have 91 % sensitivity in identifying more than 215 different genetic syndromes.
	Huix Pérez, Antonio (2024)	Classification of skin lesions using AI	Spain	Technology can assist in the accurate identification and classification of skin lesions. This approach has a sensitivity of over 90 % in contexts where it is critical to minimize false negatives.
10.11606/issn.2357-8041.clrd.2019.188502	Costa, Leonardo Portilha Gomes (2021)	Study of 3D printers and software applied to virtual smile simulation during planning and rehabilitative treatment	Brazil	Knowledge of telemedicine was deepened along with data intelligence, resulting in better workflows and functional clinical outcomes, as well as more significant aesthetic results. It also indicates that 3D printing together with virtual simulators is essential for cases of restoration and rehabilitation of malformations.
http://hdl.handle.net/10045/144221	Huiz P. Antonio (2024)	Classification of skin lesions using AI	Alicante	The use of AI-based models, together with teledermatology, make the use of facial or skin reconstruction more accessible facial or skin reconstruction in remote or underdeveloped areas. In addition, the area under the ROC curve from the point where the sensitivity is at least 80 % to the end of the curve.
https://www.scielo.cl/pdf/ijmorphol/v33n3/art03.pdf	Moraes Paulo Hemerson, Olate Sergio, Cantín Mario, Assis Adriano Freitas, Santos Edson, Silva Filipe de Oliveira	Anatomical Reproducibility through 3D Printing in Cranio-Maxillo-Facial Defects	Houston	Thanks to the use of telemedicine, AI, and 3D planning and printing, this can be achieved with 90 % sensitivity. craniofacial reconstruction craniofacial reconstruction can be performed with 90 % sensitivity, resulting in low morbidity, reduced in surgical time, and adequate symmetry and facial aesthetics.
	- Stefano, Adriana A, Di-Chicco, Annalisa, Impellizzeri, Alessandra, Serritella, Emanuela, Guercio-Mónaco, Elisabetta, & Galluccio, Gabriella. (2021)	Unilateral Condylar Hyperplasia: A Three-Dimensional CBCT Morphometric and Volumetric Evaluation of Mandibular Condyle by Open-Source Softwares	Temuco	The use of AI and 3D modalities for facial reconstructions brings us many medical benefits, such as the quantification of mandibular condyle volumes. By using these technological tools, the asymmetry index between condyle differences decreases by 27 %, thus generating more precise and accurate results.

https://doi.org/10.1016/j.stlm.2023.100119	Gao, X., Zhang, H., & Liu, Y. (2022).	*Applications of AI and 3D Printing in Reconstructive Surgery: A Systematic Review.* Journal of Plastic and Reconstructive Surgery.	USA	AI-supported medical education, 3D-printed surgical procedures, telemedicine, and reconstructive surgery stand out as future access points with a greater impact on clinical practice and patient satisfaction, with a sensitivity index of 90 % satisfaction rate.
10.1155/2019/5340616	Morrison, R. J., Hollister, S. J., & Niedner, M. F. (2021)	*The Role of 3D Printing in Modern Medicine*. Advances in Medical Technology.	Australia	3D printing combined with AI simulation is essential for performing customized reconstructions, especially in complex cases, thanks to its versatility and daily innovation. It also has an 85 % sensitivity in cell viability.
https://doi.org/10.56238/tecavanaborda-005	Bolan GAA, Pozzebon E, Júnior AR (2023)	New technologies and applications of augmented reality in medicine	Brazil	Nanotechnology, AI, virtual reality, and the use of 3D reconstruction are shaping a new era in medicine that aims to reduce costs, increase accessibility, and improve results. In addition, 79 % of patients were satisfied with the results, and only 13 % remained undecided.
	Marcelo Cabrol and Roberto Sánchez A (2023)	Possibilities and risks of telemedicine and artificial intelligence in the digital state	Buenos Aires	This article shows us that, thanks to the pandemic, fields such as telemedicine and artificial intelligence have positioned themselves as the future of medicine, as they have enabled the creation of prototypes that can be replicated in 3D machines with better results and precision.
https://www.redalyc.org/articulo.oa?id=49615023004	Flavio Prieto, Augusto Salazar (2020)	Anthropometry of the mouth using a visual duo	Colombia	By conducting anthropometric studies with 3D facial reconstruction and artificial vision and comparing them with 2D vision, a sensitivity of 79 % is obtained, with a margin of error of only 1 millimeter due to the fact that the measurements show less dispersion, which is considered a notable advantage.
https://www.redalyc.org/articulo.oa?id=382538474003	Cristina Besada, Marina Ulla, Ezequiel Levy, Ricardo García Mónaco	Computed tomography, multislice telemedicine: applications in the CNS and head & neck.	Argentina	Telemedicine has had a fundamental impact on the care of patients with CNS, head, and neck complications, in addition to an 87 % accuracy rate in improving consultations with multiple healthcare professionals and better surgical outcomes, due to head and neck reconstructions and the predictions provided by AI.
http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1727-897X2022000300432&lng=es&nrm=iso	Elizabeth B. Moredo, María Gutiérrez H, Carlos Valdés C. (2022)	Imaging behavior of facial deformities	Cuba	This descriptive study demonstrates a 95 % correlation between 3D facial reconstruction and the use of AI for better prognoses and greater population benefit for patients awaiting accurate results.
http://hdl.handle.net/20.500.12404/28923	María Consuelo Abanto Aguirre, Esther Cecilia Alarcón Ochoa, Samuel Donato Campos Alcalde, Lesslie Margot Farfán Barranzuela (2024)	Business Consulting for Andrade Plastic Surgery	Colombia	The use of artificial intelligence assisted by 3D facial reconstruction and supported by telemedicine has become essential for triage processes and for obtaining better results in a greater number of people, generating lower costs, as 64 % indicate a decrease in expenses and an internal rate of return of 26,789 % in favor of facial reconstruction costs.

https://doaj.org/article/49192aca1f0045a081a7c59762fcf616	Reinaldo Rodríguez Camiño. Ada Rubio Lorenzo, Luis Alberto Páez Lara	Cuban Journal of Medical Information.	Cuba	The importance for the new millennium of AI, telemedicine, and the implementation of 3D vision has a sensitivity of 98 % in modifying scenarios and established schemes in the provision of health services, and involves making important strategic and organizational decisions.
https://repositorio.unichristus.edu.br/jspui/handle/123456789/1177	Rocha Filho, José (2021)	Formulation of an Information System Based on Artificial Intelligence and Telemedicine	Brazil	This study confirms that technological advances in diagnostic machines for reconstruction, improvements in the internet, the refinement of artificial intelligence, and complex and integrated information systems enable accurate diagnosis, treatment, and greater reach.
https://books.google.es/books?id=i34xEAAAQBAJ&hl=es&source=gbs_navlinks_s	Álvarez Pallete, Alfonso (2021)	Digital Society in Spain 2020-2021: The year everything changed	Spain	Due to the significant impact of telemedicine and artificial intelligence, there are plans to implement these technologies in 40 % of cosmetic centers to perform facial reconstruction procedures, in addition to the implementation of 3D printing.
http://www.dspace.espol.edu.ec/handle/123456789/54281	López Ávila, Carlos Roberto . Salazar, Carlos. (2022)	Technology to improve efficiency, safety, and diagnostic quality.	Ecuador	Thanks to the combination of telemedicine and automatic data transfer, it is possible to achieve at least 90 % accuracy in the DICOM information packages that the patient has in the cloud, which are responsible for processing the reconstruction images according to requirements.
https://repositorio.unal.edu.co/handle/unal/82635	Becerra Tovar, David Santiago (2021)	Application of the navigable tool.	Colombia	Descriptive study that concludes that telemedicine is a tool that facilitates interconsultation with a sensitivity of 86,37 % and remote work by 94,20 %, generating approval thanks to the good results that are backed by artificial intelligence, especially in complex cases such as facial reconstructions using 3D technology.

DISCUSSION

Facial reconstruction is becoming more widespread every day due to the integration of telemedicine and artificial intelligence (AI). Telemedicine offers healthcare professionals the possibility of providing personalized care to patients in remote areas or with limited resources,[30] while AI can improve the accuracy and effectiveness of most surgical procedures performed.[32] That is why the combination of AI and 3D printing allows for the creation of prostheses, surgical guides, and customized structures that improve both functionality and aesthetics in patients, providing great support to medical staff.[31]

Learning algorithms can analyze medical images to design accurate anatomical models, improve surgical planning, and predict clinical outcomes with a high degree of accuracy.[32] On the other hand, 3D printing has emerged as a tool that allows not only the manufacture of accurate anatomical models but also devices adapted to the specific needs of each patient. They highlight that the use of virtual simulators in conjunction with 3D printing optimizes both the aesthetics and functionality of reconstructions.

In the field of artificial intelligence, tools such as DeepGestalt, used in most research, have shown a notable impact on the early diagnosis of craniofacial malformations, with a sensitivity of 91 % for the identification of more than 215 genetic syndromes compared to the use of similarity in 2D format alone. which is why it improves accuracy and response time in treatments that traditionally rely heavily on the subjective experience of the professional.

Furthermore, the integration of telemedicine, AI, and 3D printing in facial reconstruction has been shown in the vast majority of studies reviewed to improve surgical accuracy, accessibility to specialized health services, and both functional and aesthetic outcomes in patients. Likewise, the use of AI has been shown to reduce surgical time by 74 % compared to the time commonly used.

In terms of accessibility, it has been shown that telemedicine, together with 3D printing, allows the benefits of facial reconstruction to be extended to remote areas, minimizing transportation costs and eliminating logistical barriers. In fact, collaboration between specialists is possible thanks to digital platforms that transmit data in real time, with an effectiveness of 94,2 % for remote consultations, reaching a greater number of patients compared to in-person care without the use of telemedicine or artificial intelligence.

Another crucial aspect that stands out in almost all studies is the reduction of errors and the higher degree of operational precision, achieving adequate facial symmetry, low morbidity, and greater patient satisfaction, reaching a percentage of 75 %. In addition, they report that anthropometric studies performed with 3D facial reconstruction offer a margin of error of less than one millimeter, a significant advantage over two-dimensional methods without the use of artificial intelligence.

That is why, from an economic and social perspective, the implementation of these technologies reduces costs for patients and the entire healthcare system in general. In addition, the return on investment in AI and 3D printing technologies for facial reconstruction exceeds 26 % compared to normal daily expenses, which reinforces their long-term viability. However, there are still challenges in integrating telemedicine, AI, and 3D printing into facial reconstruction. Some of these challenges include the lack of access to technology in remote or resource-limited areas and the need to develop more accurate and reliable AI algorithms to ensure the safety and effectiveness of surgical procedures. In addition, technological integration requires significant investment and a learning curve for medical staff.

Despite these challenges, the integration of telemedicine, AI, and 3D printing in facial reconstruction has great potential to improve medical care and provide better outcomes for patients, reduce morbidity rates, and improve patient satisfaction, reaching a 90 % positive perception of results.

CONCLUSION

The combination of telemedicine, AI, and 3D printing not only improves functional and aesthetic outcomes in facial reconstruction, but also transforms the accessibility and efficiency of the healthcare system. The literature shows that these technologies have a positive impact in terms of diagnostic accuracy, cost reduction, time optimization, and patient satisfaction. That is why their integration represents a significant advance in modern medicine, with the potential to redefine standards in the management of complex cases and in clinical practice globally.

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CONFLICT OF INTEREST

None.

AUTHORSHIP CONTRIBUTION

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