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# Innovative learning in dental education: integrating narrative and 3D industrial design for teaching caries health disease processes

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## Abstract

**Introduction** Dental education requires innovative pedagogical tools to understand the evolution of the health-disease process in individuals with dental caries. “The Origin of Teeth” integrates narrative storytelling with industrial character design to address this need.

**Aim** To create and implement industrial designs based on characters from “The Origin of Teeth” to improve teaching outcomes and student engagement with the health-disease process of caries.

**Materials and methods** Using Computer-Aided Design (CAD) and high-precision 3D printers, four anthropometric character models were developed and legally registered. A quasi-experimental study was conducted with 30 dental students from the Universidad Nacional Toribio Rodríguez de Mendoza. Pre- and post-intervention knowledge assessments were conducted using a validated multiple-choice questionnaire, and data were analyzed using paired t-tests to evaluate the effectiveness of the intervention.

**Results** The educational intervention significantly increased students’ understanding of dental caries processes, with posttest scores demonstrating a mean improvement of 35% compared to pretest scores ( $p < 0.001$ ). The characters successfully embodied educational content, facilitating learning through tactile and visual interaction.

**Conclusion** Integrating narrative storytelling with 3D industrial design is a powerful educational approach, enhancing student comprehension and engagement in dental education. This methodology holds promise for broader applications in health education.

**Keywords** Industrial design, Teaching and learning process, Educational tool, Dental education

## Introduction

The integration of storytelling and industrial character design is itself an innovative and effective strategy in the field of teaching and learning [1]. Stories, by offering rich and immersive narratives, capture students’ attention and

facilitate the understanding of complex concepts by placing them in familiar and emotionally resonant contexts [2]. On the other hand, industrial character design translates these narratives into visual and tactile representations, creating tangible educational tools that enhance multisensory learning [3]. By combining these two disciplines, a holistic learning experience is promoted where students can interact with both the theoretical content and its physical representations, which significantly improves knowledge retention and application.

Intellectual production from a classroom is vast. Intellectual production ranges from invention patents and

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industrial designs to the production of literary works [4]. The production of literary works implies that students link creation with curricular content [5]. At the undergraduate level, intellectual production represents an opportunity to translate curricular content into a tangible product, and in this way, teachers will be able to develop their own didactic materials [6].

Identifying an opportunity for intellectual production is the first step. Then, the type of intellectual production is chosen. Writing a narrative work of the space genre could be a great option. Making an imaginary character tangible is a challenge in achieving unpublished didactic material to carry out a learning session [7].

In the field of dental education, understanding complex processes such as dental caries and its prevention can be a significant challenge [8]. Traditional teaching methodologies, focused on theory and memorization, are often insufficient to motivate students and ensure a deep understanding of the concepts [9]. This is where narrative techniques and industrial design can play crucial roles. By personifying abstract elements and medical processes in narrative characters, students can establish clearer and more lasting connections to the study material. Results from recent studies highlight the potential of virtual reality (VR) to transform the teaching of dental anatomy, offering more interactive and engaging learning experiences compared to methods based solely on lectures [10]. However, VR does not completely replace hands-on experience, which is essential for developing clinical skills.

Today, dental educational models are evolving towards an approach that integrates advanced technologies, such as CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) systems, to improve practical learning and the acquisition of clinical skills. Previous studies have shown that these digital tools not only facilitate personalization of learning, but also optimize accuracy and efficiency in clinical procedures [11, 12]. These trends highlight the need to evaluate their impact on student performance and the quality of educational outcomes.

In addition, the use of computer-aided design (CAD) tools and 3D printing technologies allows the creation of accurate and detailed three-dimensional models, which not only reflect character features but also represent physiological processes in an intuitive and accessible manner [13]. These models can be manipulated and examined by students, providing an additional dimension to learning that two-dimensional representations cannot offer [14].

Educational programs in 3D industrial design have the opportunity to address global challenges such as sustainable development. This approach integrates technologies

such as CAD/CAM with responsible practices that optimize the use of resources, reduce waste and promote the creation of sustainable products. This study explores how these technologies can be effectively incorporated into teaching to foster technical and ethical competencies.

The present study was based on the null hypothesis that the integration of CAD/CAM technologies in the teaching curriculum does not present a statistically significant difference in the performance of students in the planning and fabrication of dental restorations, compared to traditional methods. The research aimed to explore the impact of this combination of narrative and industrial design in dental education. In particular, it focuses on the transformation of characters from the story “The Origin of Teeth” into industrial designs to enhance the teaching of the health-disease process of dental caries [15]. This strategy aims not only to enrich the educational experience but also to provide a novel pedagogical tool that can be replicated and adapted in other areas of health education.

## Procedure for writing the narrative work

### Working meetings

The team was made up of professors from the School of Stomatology of the Universidad Nacional Toribio Rodríguez de Mendoza of Amazonas. To write the narrative work, we began with a brainstorming of ideas, easter eggs background and influences. A first manuscript was subsequently drafted, and each member of the team agreed with the final state of the text.

### Obtaining the intellectual production item

We proceeded to print the book in a physical form; likewise, we obtained the legal deposit N° 2018–13,034 from the national library; we also obtained the codification of the Peruvian agency with ISBN N° 978–612–00–3924–3; and finally, we obtained the literal item N° 01623–2021 from INDECOPI.

### Selection of the design team

To ensure a multidisciplinary approach, an eight-member design team was formed. The team included:

- Three professors from the professional school of stomatology, selected for their expertise in dental anatomy, stomatological prevention and patient education.
- Two primary school teachers, chosen for their knowledge of children’s pedagogy and their ability to adapt the content to a younger audience.
- Two former students of the professional school of stomatology, who brought innovative perspectives

and practical knowledge from recent academic and clinical experiences.

- A graphic designer, responsible for creating visually appealing and scientifically accurate character illustrations.

The selection process emphasised the qualifications of each member, ensuring that their roles complemented the objectives of the project. The team's main task was to relate to the book 'The origin of teeth', which involved conceptualising and selecting the main and secondary characters. Sketches of the characters were made and the colour white was chosen as a symbolic element of vindication. The finalised characters, which included three types of anthropomorphic teeth (molars, incisors and canines) and a toothbrush as the main character, were incorporated into industrial designs. These designs were aligned with processes related to dental caries and stomatological prevention and subsequently protected with intellectual property rights.

### Methods and materials

The development of industrial designs was framed within the category of the entertainment industry in general and specifically for intellectual property, taking into account the Locarno classification (14th edition), focusing on class 21-01 [13], which serves as an international standard for categorising industrial designs. The design of the study to obtain the prototypes of the industrial designs is shown in Fig. 1.

To characterize the industrial designs, a thorough reading of the book "El origen de los Dientes" was carried out,

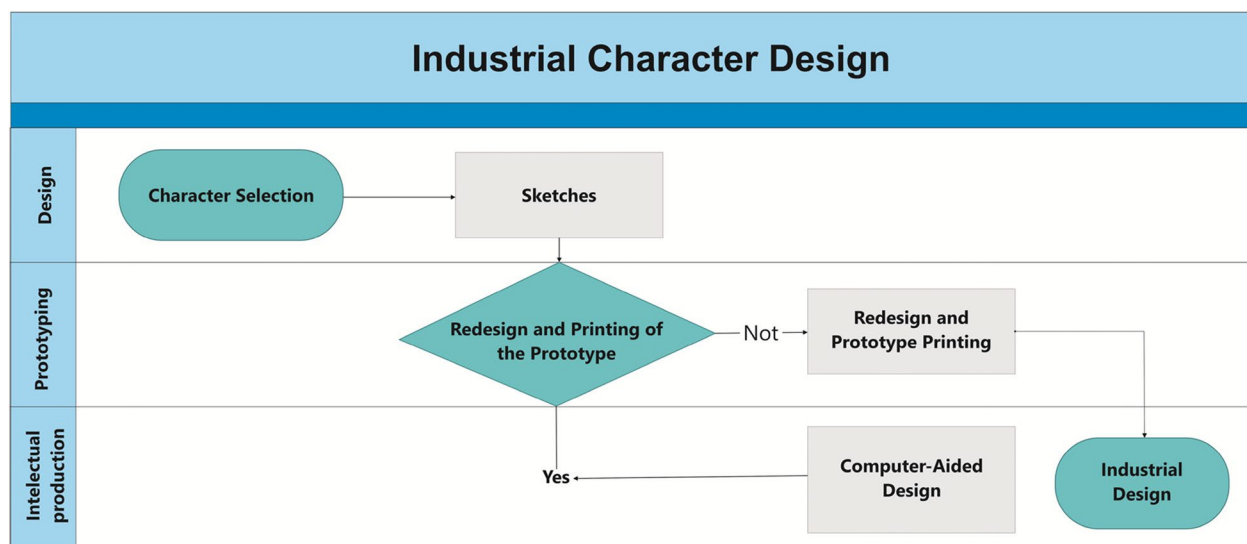
with the purpose of engaging and identifying main and secondary characters. A preliminary list of characters was subsequently selected, regardless of whether they were main or secondary characters. The final list was reduced to four characters. The selection was made with the purpose of locating those characters that best represented the processes related to dental caries and dental prevention and that have a potential positive impact on the members of the dental education community of the Universidad Nacional Toribio Rodríguez de Mendoza (UNTRM). The characters chosen were four natives of the planet Adamantem, three of which were identified with teeth, namely, molars (molars), incisors (primors) and canines (Canini), as well as the main character, Setis, which is a toothbrush. All the characters were conceived in anthropomorphic form to facilitate their identification and connection with the students.

### Industrial design of the characters

After the reading, hand and paper sketches were made to obtain a preliminary design. They were subsequently submitted to the team for consideration to evaluate whether the selected sketch characters reflected the individual characteristics and their roles in the narrative. The study of shapes, proportions and expressions allowed iterative adjustments to be made in collaboration with the design team, resulting in an agreed-upon preliminary design.

### Computer-aided design (CAD) and 3D modeling

The next step was to digitise the preliminary designs. The sketches approved by the team were digitised using a computer-aided design (CAD) programme for



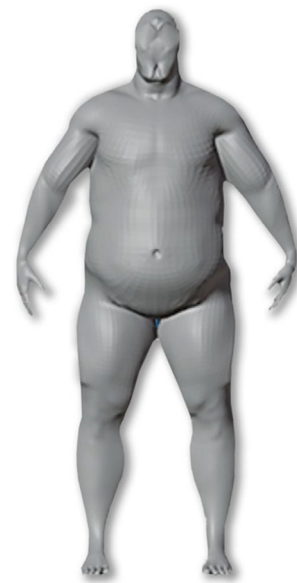
**Fig. 1** Design and prototyping of narrative characters

2D drawing and 3D modelling, developed by Autodesk Inc. called Autodesk Inventor 2020. The company ITAS PERU S.A.C. was in charge of carrying out the design and prototyping processes for each character, taking into account their anatomy and differential characteristics.

We then proceeded to model the characters in 3D with the purpose of being presented to the team to refine and optimize the models. As a result of this meeting, additional iterations were performed to refine the 3D models, adjusting anatomical details, proportions and facial expressions with dento-humanoid features to improve the fidelity to the original characters and their ability to communicate educational concepts effectively. The first prototype to be printed was representative of incisors (primors), as shown in Fig. 2.

Subsequently, work began on the molar representative. As a result, the team decided that the three representatives would be represented by the Kretschmer typology, proposed by the German psychiatrist Ernst Kretschmer [16]. The representative molars are the pignic type, whereas the representative canines (Canini) are presented in Figs. 3 and 4.

For the modeling of the toothbrush character (Setis), characteristics far removed from the other characters



**Fig. 3** Industrial design of molars. Source: Gaceta Electronica INDECOPI (2024)



**Fig. 2** Industrial design of primors. Source: Gaceta Electronica INDECOPI (2024)



**Fig. 4** Industrial design of molars. Source: Gaceta Electronica INDECOPI (2024)

were chosen since this characteristic could cover educational aspects related to patient education, particularly with pediatric patients.

### 3D printing and prototyping

After finalising the digital designs, polylactic acid (PLA) filaments were selected as the main material for 3D printing due to their durability and precision. High-resolution 3D printers were used to create physical prototypes of the industrial designs, ensuring compliance with the digital specifications agreed by the design team.

The initial prototype produced was the character 'Setis' (Toothbrush), depicted in Fig. 5. Subsequent prototypes followed, using iterative printing processes to refine anatomical details and assess the educational applicability of each model. Quality testing was performed to verify the accuracy and performance of the prototype. These included dimensional validation using digital measurement tools to compare the CAD/CAM design specifications to the physical prototype. Additionally, functional performance was evaluated through simulations in controlled clinical environments, and a panel of dental experts reviewed the prototype to validate its applicability.

### Legal protection and registration of industrial designs

To register intellectual property, the necessary legal procedures were carried out to protect industrial designs in our country of origin: Peru. The office where the procedures were carried out was the National Directorate of Inventions and New Technologies (DIN), which belongs to the National Institute for the Defense of Competition and Protection of Intellectual Property (INDECOPI).



**Fig. 5** Industrial design of setis. Source: Gaceta Electronica INDECOPI (2024)

After all the procedures were completed, the intellectual property registrations were obtained by the DIN as follows: the industrial design Primores with property title N°6282; the industrial design Molars with property title N°6283; the industrial design Canini with property title N°6270; and the industrial design Setis with property title [17]. E. Diseños industriales en la práctica educativa odontológica.

### Evaluation of educational impact

#### Sample selection

The study sample was made up of 30 students from the Stomatology program at the National University Toribio Rodríguez de Mendoza (UNTRM). The selection was made by convenience, considering its accessibility, willingness to participate and representativeness in terms of the project's objective educational profile. This sample allowed us to evaluate the effectiveness of narrative industrial designs in a real educational environment, guaranteeing the validity of the results in a practical context.

#### Educational intervention

The intervention involved the use of industrial designs as didactic tools during educational sessions. These sessions incorporated narrative storytelling and physical models of the characters to teach-disease process of dental caries.

#### Design, validation and application of the evaluation instrument

To evaluate the educational impact of the narrative designs and the text "The Origin of Teeth", a multiple choice test-type evaluation instrument was developed. This test was designed to measure students' knowledge about the health-disease process of caries, its prevention and treatment.

**Instrument design** The test included 20 multiple choice questions with a progressive level of difficulty, covering theoretical and practical aspects related to the topic. The questions were developed by a panel of experts in stomatology and education, ensuring coverage of the educational objectives.

**Validation of the instrument** The validation of the test was carried out through a pilot test with a group of 10 students who were not part of the final sample. The clarity of the questions, internal consistency using Cronbach's Alpha coefficient (0.85), and the relevance of the contents addressed were evaluated. Feedback from the piloting was incorporated to refine the final instrument.



**Application of the instrument** The test was administered in Spanish, the native language of the participants, in two moments: an initial pretest before the educational intervention, and a posttest after it. The intervention consisted of educational sessions using industrial designs and narrative text as teaching tools. Students received clear instructions about the importance of the activity and gave informed consent prior to the evaluation.

Results

A study was designed to evaluate the effectiveness of an innovative educational tool based on the industrial design of narrative characters to teach dental caries to stomatology students. Thirty students from the Universidad Nacional Toribio Rodríguez de Mendoza (UNTRM) were selected to participate in the study. The participants were informed about the purpose of the study and gave their informed consent to participate.

For data collection, a knowledge test on the health-disease process of dental caries was designed and applied, both before (pretest) and after (posttest) the educational intervention. The test consisted of multiple-choice

questions covering various aspects of dental caries and its prevention and treatment.

Before the knowledge test was administered, the reason for the study was explained to the students. The pretest was subsequently administered to assess the level of prior knowledge about dental caries. The educational intervention consisted of sessions in which industrial designs of narrative characters were used as a didactic tool. After the intervention, the same knowledge test was applied to evaluate any changes in the students' level of knowledge. The results are presented in Table 1 and Fig. 6.

Microsoft Excel and SPSS version 27 were used to perform the statistical analysis of the data. Excel was used for the initial organization and cleaning of the data, allowing efficient manipulation and the creation of descriptive graphs. SPSS version 27 was subsequently used to perform the detailed statistical analysis, including the related samples (paired) t test, which allowed for the evaluation of significant differences between the pretest and posttest scores.

Statistical analysis revealed a highly significant difference in pupils' knowledge levels before and after the intervention, as evidenced by a t-value of 10.12 and

Table 1 Pretest vs Posttest knowledge assessment

	Number of Students	Mean	Median	Standard Deviation	t Student	p
Pretest	30	63.27	64.23	4.88	10.12	$2.5 \times 10^{-10}$
Posttest	30	76.43	75.47	4.57		

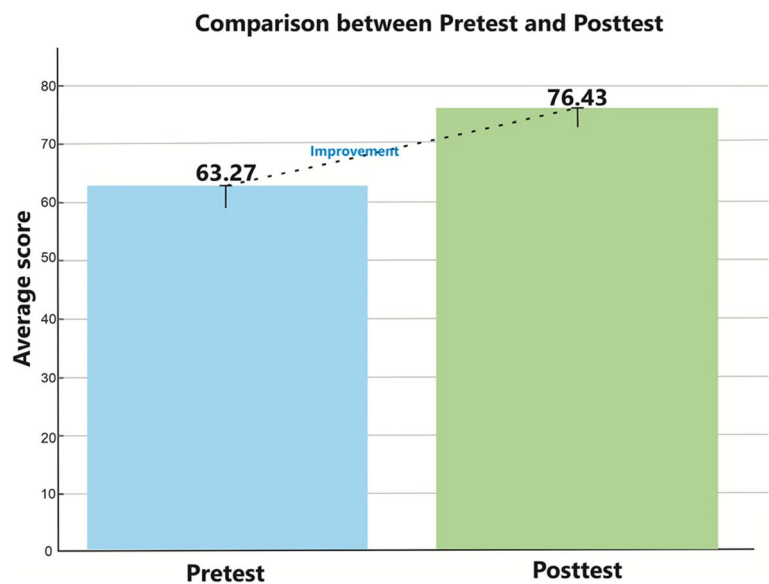


Fig. 6 Pretest vs. Posttest average scores. Fuente: Farje (2024)

an extremely low  $p$ -value ( $2.5 \times 10^{-10}$ ), well below the standard threshold of 0.05. This indicates a negligible probability that the observed differences were due to chance. Posttest scores showed an increase in both mean and median compared to the pretest, reflecting a marked improvement in understanding of the health-disease process of dental caries following the educational intervention.

These findings suggest that an educational tool based on the industrial design of narrative characters has a positive effect on students' learning about the health-disease process of dental caries. The improvement in the posttest scores compared with the pretest scores suggests that the educational tool not only captured the students' attention but also facilitated a deeper and more lasting understanding of the concepts taught.

## Discussion

This intellectual production process, which combines copyrights and industrial designs, is an innovative and effective approach in dental education, especially in public health and pediatric dentistry. The transformation of imaginary characters into industrial designs has proven to be relevant to educational practice in dentistry. The integration of narratives with design in education has enabled the creation of a unique educational tool that captivates students' attention and facilitates the understanding of complex concepts related to oral health. The mission of the narrative is to provide an emotional context, whereas the industrial designs visually and tactilely represent the theoretical concepts, creating a holistic and multisensory learning experience.

These findings are consistent with those of previous studies highlighting the effectiveness of innovative teaching methods that combine visual and narrative elements to enhance learning. This is similar to the advances observed in dental implantology education and the use of new technologies such as augmented reality and artificial intelligence [18–21]. Our research demonstrates that innovative methodologies can significantly enrich teaching and knowledge retention in dentistry. Like the evolution of dentistry 4.0 during the COVID-19 pandemic, which underscores the importance of advanced technologies for efficiency and accuracy in dental practice [22, 23], the incorporation of narrative and industrial design elements in education provides a holistic, multisensory approach.

Analysis of precedents in other areas of health reveals the need to strengthen health systems to achieve ambitious goals, such as the Sustainable Development Goals and the Every Woman Every Child strategy [24]. Similarly, the COVID-19 pandemic has highlighted the importance of flexible educational approaches, including

hybrid and blended learning methods, to address emerging challenges in higher education [25]. In this context, innovative tools such as the creative, cognitive and qualitative model for creativity (CCQ) have been shown to increase scientific creativity among students, highlighting the influence of social and cultural factors on the creative process [26]. The integration of audiovisual technologies and inquiry-based learning (IBL) has shown significant benefits in biomedical education, enhancing creative and research skills through stimulating techniques and interprofessional education [27, 28]. Finally, the use of resources such as YouTube in medical education underscores the need for evidence-based evaluations to maximize their effectiveness [29, 30]. These studies underscore the importance of inclusive and community-based approaches to improve public health and health education.

The use of these industrial designs is intended to positively influence learning through knowledge retention. The narrative induces familiarity with the characters and their association with specific concepts of dental caries, which facilitates the assimilation and application of information, promoting deeper and longer-lasting learning. In addition, this combination has the potential to be applied in other areas of education. Although this study focused on the teaching of dental caries, the principles and methodologies used can be applied to other disciplines, from medicine to engineering, offering new ways to communicate complex concepts and encourage active student participation.

Teaching 3D industrial design, when combined with advanced technologies such as CAD/CAM, allows students to apply sustainability principles. This includes optimizing resources in production, reducing waste through digital prototyping, and designing more durable and efficient products. These approaches are aligned with the Sustainable Development Goals (SDGs), specifically in the areas of responsible production and consumption (SDG 12). The prototype developed in this study exemplifies how future professionals can integrate 3D technologies to reduce environmental impact. By incorporating recyclable materials and emphasizing waste reduction in the design, the educational process not only addresses technical skills, but also environmental awareness.

This study has several limitations that should be taken into account. The small sample size, 30 students from a single institution, limits the generalisability of the results, as it does not take into account demographic or educational variations, future studies should include larger and more varied samples to improve external validity. The lack of a control group prevents direct comparisons with traditional teaching methods, hindering the ability to isolate the specific impact of the intervention.

Immediate post-intervention evaluation does not take into account long-term knowledge retention. Longitudinal studies with follow-up evaluations are needed to better understand sustained impact. These limitations have also been identified in other studies [21, 23]. Variability in the implementation of the intervention and the use of context-specific tests may have introduced biases, such as observer effects or social desirability. In addition, the study's focus on dental caries restricts the applicability of the results to other educational topics, and the resources required to produce industrial designs and narratives may pose difficulties for wider application in resource-limited settings, highlighting the need for cost-effective strategies to ensure wider applicability. Future studies will need to address these issues to validate and extend the results.

### Implications for practice

Despite these limitations, the results of the study suggest that the use of industrial designs of narrative characters can be an effective strategy to improve teaching and learning in dentistry. This educational tool not only facilitates the understanding of complex concepts but also promotes more active and participatory learning.

Future studies should address the aforementioned limitations by exploring the effectiveness of this intervention in different contexts and with different groups of students. In addition, research could be extended to other areas of health education to assess whether the benefits observed in this study are replicable in other disciplines.

In conclusion, the integration of narratives and industrial designs in dental education offers an innovative and potentially transformative approach that deserves to be explored and refined in future research.

### Conclusion

This study demonstrated that the integration of creative storytelling and 3D design technology can serve as a promising educational tool to improve dental students' understanding of the health-disease process of dental caries. The results indicate a significant improvement in knowledge after the intervention. However, further studies with larger sample sizes and long-term follow-up are needed to confirm these results and assess their wider applicability. This approach has the potential to complement traditional dental teaching methods and improve educational outcomes.

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### Authors' contributions

Conceptualization, C.A.F.-G.; methodology, F.T.C.-Z. and O.P.S.; software, F.T.C.-Z., and O.P.S.; validation, F.T.C.-Z., C.A.F.-G., and O.P.S.; formal analysis, F.T.C.-Z.;

investigation, F.T.C.-Z., C.A.F.-G., and O.P.S.; resources, C.A.F.-G. and O.P.S.; data curation, F.T.C.-Z., and O.P.S.; writing—original draft preparation, C.A.F.-G.; writing—review and editing, C.A.F.-G. and F.T.C.-Z.; visualization, O.P.S.; supervision, C.A.F.-G.; project administration, C.A.F.-G.; funding acquisition, O.P.S. All authors have read and agreed to the published version of the manuscript.

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This research has not received external funding.

### Data availability

The dataset supporting the conclusions of this article is included in this article. However, additional information is available from the corresponding author upon reasonable request.

### Declarations

#### Ethics approval and consent to participate

This study was conducted in accordance with the ethical standards of the Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas. No formal ethical approval was required, as the university's ethics committee does not mandate approval for studies that do not involve animal experimentation, human clinical procedures, or interventions affecting health outcomes. However, in compliance with data protection regulations and ethical research practices, all collected data were anonymized to ensure participant confidentiality. No personally identifiable information was recorded or stored, and responses were processed following the data anonymization guidelines established in the Guide to Basic Anonymisation by the Personal Data Protection Commission (PDPC) of Singapore. Informed consent was obtained from all subjects participating in the study.

#### Consent for publication

Not applicable.

#### Competing interests

The authors declare no competing interests.

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