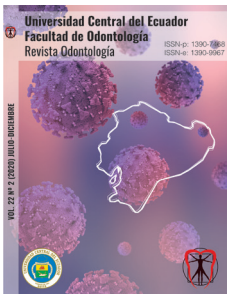
Conditioning, bonding, and cementation of orthodontic appliances in teeth with enamel alterations. Literature review



Acondicionamiento, adhesión y cementado de aparatología ortodóncica en dientes con alteraciones del esmalte. Revisión de literatura

Catherine Andrea Vallejo Monrroy[1]; Jackeline Beatriz Pedrosa Astudillo[2]; Miriam Fernanda Ortega López[3]; Lorenzo Puebla Ramos[4]; Andrés Kenichi Noborikawa Kohatsu[5]; Ronald Roossevelt Ramos Montiel[6]

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[1] General Dentistry of the Catholic University of Cuenca. Academic Unit of Health and Wellbeing. Cuenca, Ecuador.
https://orcid.org/0000-0003-4304-361X
[2] General Dentistry of the Catholic University of Cuenca. Academic Unit of Health and Wellbeing. Cuenca, Ecuador.
https://orcid.org/0000-0001-8235-482X
[3] General Dentistry, Specialist in Dental Clinical Teaching, Specialist in Pediatric Dentistry. UTE University. Quito, Ecuador.
https://orcid.org/0000-0001-7736-3617
[4] Specialist in Orthodontics. Hospital Infantil Federico Gómez de México.
https://orcid.org/0000-0002-0527-9990
[5] Specialist in Restorative Dentistry, Master in Stomatology, Professor of Postgraduate and Specialties "Wilson Delgado" Peruvian University Cayetano Heredia.
https://orcid.org/0000-0002-2705-6667
[6] Doctor of Dental Sciences. Coordinator of the Specialization in Orthodontics and Graduate Teacher of the Academic Unit of Health and Well-being of the Catholic University of Cuenca. Ecuador.
https://orcid.org/0000-0002-8066-5365

**Autor de correspondencia:*
jcmartinezod@es.uazuay.edu.ec

Abstract

Objective: Carry out a narrative review on the information available about the conditioning, bonding, and cementation of orthodontic appliances in teeth with enamel alterations. **Materials and methods:** Descriptive, retrospective research with a documentary design was carried out. 178 scientific articles were found in reliable sources such as Google Scholar, Scielo, PubMed, Scopus, Springer, Scientific Reports, and Elsevier related to the conditioning, bonding, and cementation of orthodontic appliances in teeth with enamel alterations; of which, 29 articles met the inclusion criteria and were selected. **Results:** Etching with 37% phosphoric acid plus composites remineralizing ingredients were more effective during orthodontic treatment in teeth with enamel alterations than other studied materials such as sodium hypochlorite, hydrochloric acid, bromelain gel, and papain gel. **Conclusion:** The materials that improve the conditioning, bonding, and cementation of orthodontic appliances in teeth with enamel alterations are phosphoric acid and sodium hypochlorite (NaOCI) with a concentration of 5.25%. Also, using deproteinizing agents could improve the resistance of the composite to eviction.

Palabras Clave: Orthodontic bonding, adhesion enamel, amelogenesis imperfect, dental fluorosis, hypomineralization, enamel hypoplasia.

Resumen

Objetivo: Realizar una revisión narrativa sobre la información disponible acerca del acondicionamiento, adhesión y cementado de aparatología ortodóncica en dientes con alteraciones del esmalte. **Materiales y métodos:** Estudio retrospectivo, se encontraron 178 artículos científicos disponibles en fuentes fiables y efectivas como Google Académico, Scielo, PubMed, Scopus, Springer, Scientific Reports y Elsevier relacionados con el acondicionamiento, adhesión y cementado de aparatología ortodóncica en dientes con alteraciones del esmalte; de los cuales, se seleccionaron 29 artículos que cumplen con los criterios de inclusión. **Resultados:** El grabado con ácido fosfórico al 37% con el uso de resinas y componentes remineralizantes son más efectivos que otros materiales estudiados como el hipoclorito de sodio, el ácido clorhídrico, gel de bromelina y gel de papaína durante el tratamiento ortodóncico en órganos dentales afectados por alteraciones del esmalte. **Conclusión:** Los materiales que mejoran el acondicionamiento, adhesión y cementado de aparatología ortodóncica en dientes con alteraciones del esmalte son el ácido fosfórico, hipoclorito de sodio (NaClO) al 5,25% y que el uso de agentes desproteinizantes podrían mejorar la resistencia de la resina al desalojo.

Keywords: Aparatología ortodóncica, amelogénesis imperfecta, fluorosis dental, hipomineralización.

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Introduction

Dental enamel (DE) is an epithelial-derived tissue that covers the anatomical crown of the tooth. It is semi-translucent and its color can vary from bluish white to hues of yellow. It is related to the other dental tissues through the dentin-enamel junction and the cementoenamel junction. Its formation process derives from the oral ectoderm, in which two stages are distinguished: partial mineralization and maturation. During these phases, the enamel matrix proteins are gradually degraded by the metalloproteinase-20 (MMP20) and the kallikrein-4 (KLK-4) forming unique enamel prisms; therefore, enamel development defects are visible enamel alterations due to affections in the matrix and mineralization of this hard tissue; in this way the thickness of the enamel varies according to the location. In other words, it reaches the maximum thickness at the incisal edge or the cusps, from where it decreases towards the cervical line, providing the tooth with a hard surface and also protecting the underlying tissues[1,2,3].

Dental enamel is a hard tissue made up of millions of mineralized prisms that run throughout its thickness, from the dentin-enamel junction to the external surface which is in contact with the oral environment. DE is composed of 94% inorganic material, 4% organic, and 1% water (this distribution of the enamel composition is according to its weight; this must be mentioned because it could also be described according to its volume). The inorganic part of the tooth is made up of calcium phosphate, called hydroxyapatite, which contains impurities of sodium, magnesium, and chlorine; while the organic part of the enamel is distributed in the spaces left free by the inorganic material, whose main elements are the proteins called amelogenins and enamelins. On the other hand, the basic structure of enamel is prisms formed by hydroxyapatite that adopt a crystalline arrangement, creating elongated crystals; thus, any alteration during enamel formation leads to permanent marks because the ameloblast (the cell that forms enamel) has a little reparative capacity[1,4,5].

These changes in the basic structure of enamel provide information about the nature and time of evolution of the adverse factors that caused them; so, the clinical appearance of the defects is associated with the stage of enamel formation in which the alteration was caused, and the intensity and duration of the causal factor. The alterations of the embryological development of the teeth are known as dental anomalies (anomalous means unequal, different); therefore, a dental anomaly is understood as a deviation from normality due to alterations in the embryological development of the tooth, affecting any aspect of it: shape, number, size, structure, color, position in the arch, among others[5,6].

Enamel defects have been described, understood as the set of clinically visible alterations, generated during its mineralization or during the secretion of the enamel matrix. Its diagnosis is important in order to avoid problems such as the presence of dental caries, dental fractures, sensitivity, wear surfaces, aesthetic affectation, among others.5 In these cases, the hydroxyapatite crystals found in dental enamel are usually less compacted and organized in the porous areas. This leads to an alteration in the maturation phase that generates this condition due to the retention of proteins that interferes with the formation of crystals and also due to the lack of space required for the deposition of the minerals. Firstly, the defects occur in the composition of the DE, in which the mechanical properties of hardness and modulus of elasticity are altered, in addition, the dental pulp presents a certain degree of inflammation. So that, the hypersensitivity is generated due to the penetration of bacteria in the dentin tubules. In this context, the exposed conditions are affected with a higher proportion in those patients undergoing orthodontic treatments; since the teeth are subjected to a series of procedures that involve the modification of the structure of the dental enamel (bonding and debonding of brackets and other orthodontic appliances), which leads to the presence of fissures and microfractures[9,10].

In order to minimize adverse effects during the use of orthodontic appliances, it is important to condition the tooth enamel. This process consists of the application of a demineralising agent on the tooth surface. Demineralising agents contain approximately 35% to 37% phosphoric acid, resulting in a heterogeneous, porous structure; this means that during a diagnosis of hypomineralization in patients whose molars are erupting, glass ionomer cements can be used as a sealant and as soon as the tooth completes the eruption it should be replaced with a resin-based pit and fissure sealant[11].

It is important to mention that in addition to the evident diversity of enamel development defects caused by the secretion of the enamel matrix or during enamel mineralization as mentioned; several authors have also mentioned that some health problems that pregnant women present during the embryonic period (at which time teeth are formed) can interact during the formation of enamel, among them: systemic diseases such as

asthma, celiac disease, malnutrition, kidney diseases, chickenpox virus, cigarette exposure, otitis, toothpaste consumption, and body mass index[7,8].

The most common enamel alterations due to the aforementioned health problems are:

Hypoplasia: The enamel surface is affected giving a reduced and localized thickness; occurs in the form of single or multiple pits, superficial or deep, isolated or organized horizontally across the tooth surface, and can be translucent or opaque[5].

Molar Incisor Hypomineralization (MIH): It occurs in the first permanent molars associated with the incisors, during the initial stage of enamel maturation. It presents asymmetric severity with opacities that vary in hue from white to yellow / brown, with a demarcation between the affected and healthy enamel[2].

Amelogenesis Imperfecta (AI): Causes quantitative structural defects, or hypoplasia, that is associated with a localized and reduced thickness of the enamel; whereas if they affect the maturation processes, they lead to qualitative defects or hypomineralization known as opacities[9].

Enamel Hypomineralization: In the hypomineralization of the enamel the crystals seem to be less compacted and organized in the porous areas, which implies an alteration in the maturation phase[9].

Dental fluorosis: It is an alteration in the translucency of the enamel to a variable degree, due to a high concentration of fluoride. It can be distributed in the tooth structure in several ways; white lines that follow the development lines of the teeth; as dull patches or irregular areas; and confluent, as diffuse irregularities that blend into a white area[5].

Patients with enamel disorders present difficulties when cementing orthodontic appliances due to the fact that, when bonding through acid etching, the aforementioned alterations directly affect the thickness of the enamel, which generates a rough and porous texture. This causes the tooth enamel to chip and as a consequence, the loss and subsequent removal of orthodontic appliances are obtained[8].

Adhesion to tooth enamel is an important field of study in orthodontics, necessary to ensure that the brackets remain attached to the teeth resisting the forces required for the execution of orthodontic movements during any stage of the treatment; therefore, adhesion to tooth enamel is carried out with different adhesive systems, which require the prior application of an etching acid, whose concentration varies from 30 to 40% and the application time varies depending on the substrate to which it is to be applied. The objective of this action is to modify the surface contour by cleaning it and removing approximately 10 µm of non-reactive crystals, to subsequently increase the surface energy in search of greater wetting and consequently a smaller contact angle between the adhesive and the dental tissue[12,13].

Conditioning the enamel for the use of orthodontic devices should first contemplate the deproteinization of the enamel tissue with sodium hypochlorite at 5%, 10%, or even 5.25% for at least one minute, this can be modified depending on the enamel alteration presented; secondly, the enamel surface should be etched with 37% phosphoric acid for the subsequent application of the adhesive systems commonly used by the treating professional[14-17].

In orthodontics, adhesion is the result of a set of interactions that make it possible to join two surfaces, on one hand the enamel surface and on the other hand, the mesh located at the base of the bracket. According to the aforementioned, this is achieved in two ways: one, through a mechanical or physical union; and the other, through a chemical union; and these allow the correct union and/or cementation of the orthodontic appliances. At present, adhesive systems are applied to cement the brackets to tooth enamel; however, the main concern when employing bonding methods is the failure of the dental structural bond. Failures in adhesion are caused by factors such as poor operator technique, enamel surface variations, contamination by saliva, poor patient habits, and bite strength. At the end of the orthodontic treatment, the dental enamel must recover the normal conditions, it had before the cementation of the brackets; however, enamel alterations could occur due to the procedures performed during the treatment and it will depend on the method chosen for the adhesion and removal of the appliances and if the procedure produces enamel affections or not[16,17].

It should be noted that through the orthodontic treatments it is possible to prevent, diagnose, and treat dental conditions or anomalies; therefore, orthodontists have several different appliances to achieve this, and according to the importance, severity, and/or complexity of the anomaly to be treated, care should be taken

when choosing the adhesive technique. In other words, the choice of the orthodontic technique or appliance to treat an anomaly or pathology is as important as the selection of the adhesion technique of the orthodontic appliance. This study is justified from the academic and scientific perspective by constituting an informative reference for both students and orthodontists. This allows us to know what materials are effective for orthodontic treatment in teeth with enamel alterations, in a way that makes it possible to guarantee a correct conditioning process, bonding, and cementation of orthodontic appliances; therefore, the objective of this study was to carry out a narrative review of the available literature on the dental materials and methods used in the conditioning, bonding, and cementation of orthodontic appliances in teeth with enamel alterations.

Materials and Methods

Retrospective research with a documentary design was carried out, narrative review type. Databases such as Google Scholar, Scielo, PubMed, Scopus, Springer, Scientific Reports, and Elsevier were used. This article presents the results of a narrative review that identifies dental materials that improve the conditioning, bonding, and cementing process of orthodontic appliances in teeth with enamel alterations. On the other hand, the procedure in the present research was carried out by following a sequence of steps, detailed below:

Process of preparing the bibliographic review:

1. Identification of the study topic.
2. Identification of bibliographic material.
3. Document's selection.
4. Data extraction.
5. Collection, summary, and data analysis.

Selection criteria:

The inclusion criteria established for this review were articles on conditioning, bonding, and cementation of orthodontic appliances in teeth with enamel alterations, and/or articles with experimental designs; both carried out from 2015 to March 2021, published in Spanish, English, and Portuguese, thus excluding review articles.

Ethical aspects:

This study was classified as a risk-free investigation since it was a study carried out with secondary data taken from documentary sources, and it did not require informed consent since there was no type of clinical intervention with human people.

Results

The results presented in this section were derived from a narrative review. Table 1 shows the total number of articles obtained (178), which were reduced to 29 articles after applying the inclusion and exclusion criteria (Table 1).

Table 1. Type of article / Documents selected for the review (2015 - 2021)

Tabla 1. *Tipo de artículo / Documentos seleccionados para la revisión (2015 - 2021).*

Type of Article / Document	n	%
Research articles	66	37,17%
Reviews	73	41,02%
Declarations / Guidelines	27	15,38%
Texts	12	6,4%
Total	178	100,0

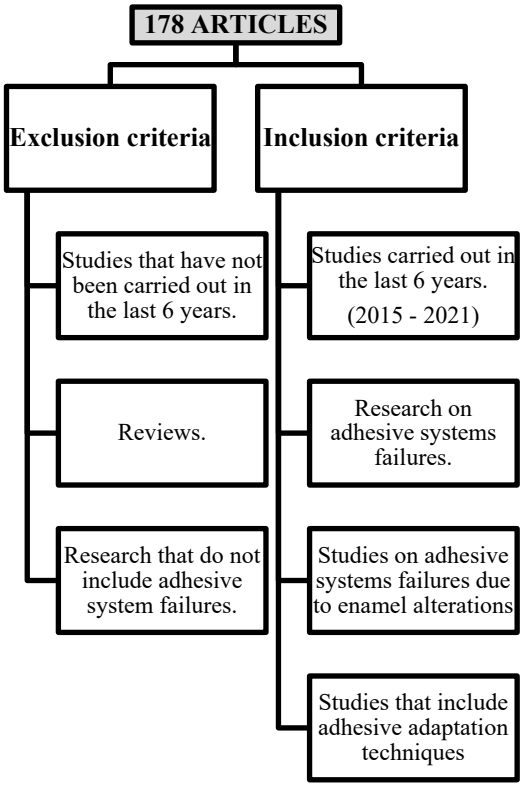

Figure 1. Inclusion and exclusion criteria.

Figure 1. *Los criterios de inclusión y exclusión.*

The presented criteria allowed an objective review of investigations related to the study area, which made it possible to carry out a study focused on methods of conditioning, bonding, and cementation of the orthodontic appliances in teeth with enamel alterations. Of the 178 articles found, 78 coincided with the inclusion criteria (Fig. 1). In addition, the design of the studies was analyzed for this review (Table 2).

Type of Article / Document	n
Cross-sectional	9
Cuantitative	30
Comparative	27
Experimental	3
***In vitro* essay**	9

The studies considered focused on quantitative analyzes on the effectiveness of conditioning methods related to adhesion techniques. The procedure for the selection of the sample was carried out in stages. The preselected articles were first subjected to the filters of the inclusion and exclusion criteria, obtaining a total of 78 articles considered relevant for the present investigation. Later, in the second stage, the 78 studies were reviewed, of which 19 were repeated and 30 were eliminated as they did not contain complete information, obtaining a total of 29 scientific articles. In this sense, and based on the final sample.

The literature review shows that one of the most effective materials for conditioning teeth with enamel alterations is phosphoric acid. According to the analyzed studies, 37% phosphoric acid and conventional phosphoric acid etching produce a much less pronounced etching pattern in affected enamel, and shear bond strength was reduced in fluoridated teeth. Likewise, the findings reflect that the bracket detachment procedure does not produce clinically relevant damage. However, the related alterations are irreversible since progres-

sive restoration is evident from one year on. In synthesis, the chemical compound substantially reduces the demineralization of the enamel adjacent to orthodontic brackets, producing a shallower lesion, and greater enamel hardness under acid attacks, being promised in a wide range of preventive and restorative enamel applications[21,22,25,27,30,32,34,40].

Another outstanding material is sodium hypochlorite, which has excellent results since the levels of resistance to displacement were determined in an experimental study in a sample of 20 teeth exposed to conditioning solutions; and later, the orthodontic appliances were cemented with adhesive systems and composite resins. The findings showed that the use of 5.25% sodium hypochlorite and the resins reported better levels of adhesion on adamantine surfaces with conventional orthodontic appliances. In conclusion, when using the deproteinizing agent based on sodium hypochlorite, an improvement in the level of resistance to displacement was obtained in teeth evaluated in vitro. The foregoing suggests that using sodium hypochlorite prior to conventional acid etching facilitates the formation of an excellent topography on the enamel surface[16].

In the analyzed studies, a compound was found that works to measure the level of influence of the etching time when using 15% hydrochloric acid. This compound is used for the destruction of the enamel surface. When evaluating 12 incisors etched with 15% hydrochloric acid with regular etching cycles, it was identified that in the application of 15% acid there is a mean enamel loss of 34.02 µm. The lengthening of the application time increases the depth of erosion, ending with an average enamel loss of 77 µm. In short, the use of this acid increases the etched surface of erosion, although the result is considered insignificant.29 In the same line of research, they state that the bromelain gel at 3% and 6%, and the papain gel at 10% increased the bracket bonding to the tooth. In addition, when combined with papain, the adherence increased significantly, therefore, the authors recommend using bromelain combined with papain before placing the brackets. Furthermore, the results showed that bromelain had the greatest effect, while the one with the least adherence was phosphoric acid[15,35,36].

Regarding indirect cementation, this is considered a safe technique for brackets cementation in any type of malocclusion. For this reason, Pedrosa et al., carried out research with the objective of designing a protocol for indirect cementation, allowing a closer approach to the materials required for brackets cementation. In this research, materials such as bracket cementing composite, acrylic insulator to separate the brackets from the plaster model, and liquid silicone to separate the brackets from the thermoplastic support were used. Basically, it was shown that the use of these components was successful since the loss of orthodontic appliances was not identified[18].

Concerning debonding, it was shown that the use of rubbers for the removal of residual composites in orthodontic appliances was more effective compared to the use of discs. In summary, composite resins improve the bonding strength of orthodontic brackets, but conservative removal methods would be needed to reduce damage to tooth enamel[17,18,20,23,24,28,33,38,41]. Other studies analyzed other materials than those mentioned, including the adhesive residue remover and the tungsten carbide bur, which is the most aggressive for enamel. Likewise, studies have shown that dental fluorosis has a negative impact on the tensile strength and length of enamel microcracks after bracket detachment. The application of Rely-X U200 type bonding cement along with the ER, CR: YSGG laser is also efficient for the removal of aesthetic elements caused by the brackets bonding on the teeth, without causing harmful effects on the enamel[19,26,31,39,42].

Finally, the adhesion on the enamel of standard Clarity brackets was compared with Clarity APC Plus brackets using the shear strength test on 45 premolar teeth. The shear strength of the standard Clarity brackets was 40.7 MPa while the Clarity APC Plus brackets had an average of 35.16 MPa; although, no significant differences were found between both groups. However, the adhesive did not cause any type of fracture to the dentin[43].

Discussion

The present study aimed to carry out a narrative review of dental materials and methods used in the conditioning, bonding, and cementation of orthodontic appliances in teeth with impaired enamel, in particular alterations generated by hypoplasia, amelogenesis imperfecta, dental fluorosis, and hypomineralization. In relation to the aforementioned, several investigations were identified in which the fundamentals used in each method of conditioning, bonding, and cementation are exposed.

Thus, Hasija et al. affirms that bromelain has a greater effect on the adhesion of brackets to the teeth with enamel alterations after testing multiple materials, which does not coincide with Krämer et al., and Nalçacı since they suggest that phosphoric acid improves adhesion in porous structures; while for Gracco et al. phosphoric acid causes irreversible damage to enamel. Hasija et al., disagree with Salasy et al. who affirms that sodium hypochlorite provides greater efficacy when bonding orthodontic appliances to surfaces with enamel alterations, not agreeing with Pithon et al., who found that papain had a greater effect than bromelain, but together they show an even greater adhesion effect since the aforementioned effect is considerably increased, finally agreeing with Krämer et al. and Sharafeddin and Safari who state that there is an improvement in adhesion when using bromelain gel[16,,22,27,30,15,35,36].

Finally, the findings reported by Pedrosa et al., together with Gorucu et al., reveal that indirect cementation is a safe technique for the cementation of brackets in teeth with any type of enamel alteration. However, the first ones emphasize the use of bonding agents for an adequate adhesion of the brackets, such as composite resins, acrylic insulator to separate from the plaster model and liquid silicone to separate from the thermoplastic support; instead, the second used acid etching techniques, 12 and 24 blade tungsten carbide burs, and polishing discs, on tooth color changes during orthodontic treatment, applying 37% phosphoric acid, adhesive primer and self-etching. The application of these materials proved to be effective, since the percentage with visible and clinically unacceptable color alteration decreased from 63.6% to 60.5%[18,21].

Conclusions

There are currently different materials for improving the adhesion of orthodontic appliances in teeth with enamel alterations, such as hydrochloric acid, bromelain, and papain gels, among others. However, given the remarkable scientific evidence published around the world about the conditioning, bonding, and cementation of orthodontic appliances in teeth with enamel alterations. The authors conclude that “Phosphoric acid and sodium hypochlorite at 5.25 %” provide better adhesion properties for orthodontic appliances and that the use of deproteinizing agents could improve the resistance of composite resins to displacement. In addition, the authors mention about a Protocol for conditioning, bonding and cementation of orthodontic appliances with emphasis in teeth with enamel alterations:

1. Mechanical cleaning of the tooth enamel surface using pumice powder and a rubber cup at low speed (removal of particulates and oily substances).
2. Washing and drying for 4 to 10 seconds.
3. Application of 5.25% sodium hypochlorite on the enamel surface for 40 to 60 seconds, using a nylon or natural bristle brush with a low-speed handpiece.
4. Washing and drying for 4 to 10 seconds.
5. Application of 37% phosphoric acid for 20 seconds on the enamel surface (acid adamantine conditioning).
6. Washing and drying for 4 to 10 seconds.
7. As an optional step, and at the discretion of each professional, the authors suggest performing the “Enamel microabrasion” with a mechanical technique using H3PO4 to 37% and pumice powder (improvement of the enamel surface and removal of microparticles in teeth with MILD enamel alterations).
8. Washing and drying for 4 to 10 seconds (dry without desiccation at professional’s discretion)
9. Application of self-curing or light-curing adhesive system (following the manufacturer’s recommendations).
10. Placement of the orthodontic appliances preloaded with composite resin on the enamel surface (light curing according to the manufacturer’s recommendations and with the recommended power and intensity of the polymerization lamp).

Finally, it is recommended to carry out more research on the adverse effects and irreversible damages from the use of phosphoric acid on enamel, very evident in some cases, despite the notable improvement in the efficiency of the adhesion of orthodontic appliances.

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Authors' contributions

Catherine Vallejo Conceptualization, Methodology, Research, Resources, Data curation, Writing- original draft, Writing-Review and Edition, Visualization. Jackeline Pedrosa Review and Research. Fernanda Ortega Conceptualization, Review and Edition, Supervision. Lorenzo Puebla Conceptualization, Review and Edition. Andrès Noborikawa Conceptualization, Review and Edition. Ronald Ramos Conceptualization, Review and Edition, Supervision.

Competing interests

The authors declare that they have no conflicts of interest.

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