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| REVIEW

# Influence of self-etching adhesive on the bond strength of irradiated teeth

## *Influência do adesivo autocondicionante na resistência de união em dentes submetidos à radiação*

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## ABSTRACT

This study aimed to conduct a literature review about the influence of self-etching adhesives on the bond strength of restorative procedures for irradiated teeth. The search for articles was carried out on six databases (PubMed, Scopus, Web of Science, Embase, LILACS, Cochrane). Gray literature (Google Scholar) and reference lists of included studies were evaluated. The keywords used were: "Radiotherapy" OR "Radiation Therapy" OR "Radiation Treatment" OR "Radiation Effects" OR "Radioterapia" OR "Terapia por radiação" OR "Tratamento por radiação" OR "Efeitos da Radiação" OR "Terapia por Radiación" OR "Tratamiento por Radiación" OR "Efectos de Radiación" AND "Dentin-Bonding agent" OR "Adesivos Dentinários" OR "Recubrimientos Dentinarios". The inclusion criteria were laboratory and clinical studies, dissertations, literary and systematic reviews, and no time and language restrictions. Three hundred and eighteen studies were identified in the databases, 30 in the gray literature, and 5 from the reference list of included articles. 40 were excluded for being duplicates. After reading the title and abstract, 28 articles remained for complete analysis. In the end, 21 articles were included in this study. Self-etching could be a good option for irradiated teeth restorations. However, further clinical studies are needed.

**Indexing terms**: Dentin-bonding agents. Dentistry. Radiotherapy.

## RESUMO

*O objetivo deste trabalho foi realizar uma revisão integrativa da literatura sobre a influência de adesivos autocondicionantes na resistência de união de restaurações de dentes submetidos à radiação. A busca da literatura foi realizada em seis bases de dados (PubMed, Scopus, Web of Science, Embase, LILACS, Cochrane). A literatura cinza (Google Scholar) e as listas de referências dos estudos incluídos foram avaliadas. A pesquisa foi realizada com as palavras-chave: "Radiotherapy" OR "Radiation Therapy" OR "Radiation Treatment" OR "Radiation Effects" OR "Radioterapia" OR "Terapia por radiação" OR "Tratamento por radiação" OR "Efeitos*

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*da Radiação" OR "Terapia por Radiación" OR "Tratamiento por Radiación" OR "Efectos de Radiación" AND "Dentin-Bonding agent" OR "Adesivos Dentinários" OR "Recubrimientos Dentinarios". Os critérios de inclusão foram estudos in vitro e clínicos, dissertações, revisões sistemáticas e literárias, sem restrições de período e de idiomas. Foram identificados 318 estudos nas diferentes bases de dados, 30 na literatura cinzenta e 5 da lista de referências dos artigos incluídos, dos quais 40 foram excluídos por serem duplicatas. Após a leitura do título e do resumo, permaneceram 28 artigos para análise completa. Ao final, 21 artigos foram incluídos neste trabalho. Os adesivos autocondicionantes podem ser uma boa alternativa em restaurações de dentes submetidos à radiação. Todavia, ainda existem poucos trabalhos sobre o tema e ratifica-se a necessidade de mais estudos clínicos.*

***Termos de indexação***: *Adesivos dentinários. Odontologia. Radioterapia.*

## INTRODUCTION

Radiotherapy is one of the main treatments for malignant neoplasms in the head and neck region [1]. However, patients with radiotherapy - primary, adjuvant, combined, or palliative - are more susceptible to oral complications, such as mucositis, xerostomia, hyposalivation, dysgeusia, trismus, oropharyngeal candidiasis, osteoradionecrosis, periodontitis and radiation-related caries [1].

Radiation-related caries have atypical biological behavior, being found mainly in the third cervical and with rapid evolution for the entire dental circumference [2]. Moreover, these carious lesions provide changes in hard dental tissues, which increases dental friability and facilitates the appearance of coronorradicular fractures and generalized dental destruction [2]. Thus, radiation-related caries can affect the oral function and quality of life of patients [3].

The severity of the lesion is related to the dose of radiation applied to the dental element [4]. Therefore, patients with head and neck cancer should have their oral health monitored before, during, and after radiotherapy [4]. The oral adequacy protocols of these patients include multiple dental restorations before and after radiotherapy [3]. Nevertheless, these restorations frequently present adhesive failures and, therefore, it is necessary to use materials that minimize this problem [3].

Currently, there are several adhesive systems available. Self-etching adhesives have shown good results and significant advantages, such as reducing working time and error risks during their application, as well as promoting the infiltration of functional monomers simultaneously to the self-conditioning process [5]. Besides that, these materials have good stability, high adhesion force, and dental substrate compatibility [5].

Therefore, this study aims to carry out an integrative review to analyze the influence of self-etching adhesive on the bond strength of irradiated teeth.

## METHODS

The inclusion criteria were laboratory and clinical studies, dissertations, literary and systematic reviews that investigated the self-etching adhesive performance on the bond strength of resin composite restorations in irradiated teeth, with no time and language restrictions.

The search for articles was carried out on six databases: PubMed, SCOPUS, Web of Science, EMBASE, LILACS e Cochrane, using the combination of descriptors "Radiotherapy" OR "Radiation Therapy" OR "Radiation Treatment" OR "Radiation Effects" OR "Radioterapia" OR "Terapia por radiação" OR "Tratamento por radiação" OR "Efeitos da Radiação" OR "Terapia por Radiación" OR "Tratamiento por Radiación" OR "Efectos de Radiación" AND "Dentin Bonding agent" OR "Adesivos Dentinários" OR "Recubrimientos Dentinarios". Gray literature (Google Scholar) and reference lists of included studies were evaluated. An online bibliographic manager (EndNote Web) was used to organize references and for the deletion of duplicates.

As exclusion criteria were used: (a) Studies that evaluated glass ionomer cement; (b) Studies that evaluated laser irradiated teeth; (c) Studies that evaluated the adhesion of root dentin; (d) Editorials, annals resumes, clinical cases, and secondary studies; and (e) Complete texts not available.

Three hundred and eighteen studies were identified in the databases, 30 in the gray literature and 5 were added to the reference list of included articles. 313 studies remained after the removal of duplicate records.

Then, to select the articles for the review, 2 steps were performed: (1) Titles and abstracts analysis of the references found. Studies without the inclusion criteria were excluded. (2) Reading of the full articles and application of the eligibility criteria.

After reading the title and abstract, 285 articles were excluded and 28 articles remained for complete analysis. At the end, 21 articles were included in this study. The data of these studies were recorded: (a) Study characteristics (type, author, year, local); (b) Population characteristics (sample, number of groups and participants); (c) Intervention characteristic (procedure), and (d) Denouement (results and conclusion).

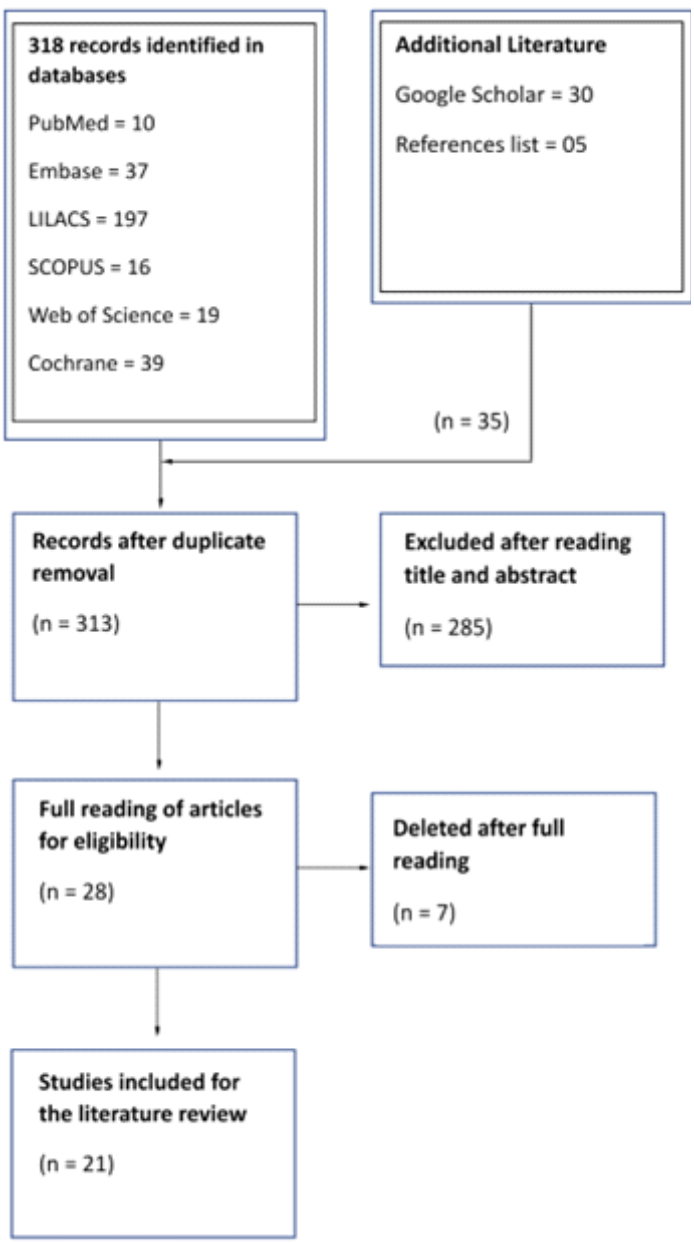


**Figure 1**. Flowchart of selection of articles in databases and additional literature.

There is still much divergence in the literature regarding adhesion in irradiated teeth [3]. Evaluating the biomechanical properties of dentin and the microtensile bond strength in adhesive restorations performed before and after radiotherapy, Rodrigues et al. [6] found that the procedure alters the absorption ranges of the adhesive material and observed, by means of an electronic microscope, a disorganization of the dentin structure. The study showed that radiotherapy changes the biomechanical properties of dentin, with an increase in microhardness and a decrease in the modulus of elasticity, and these changes contribute to low adhesive strength.

Bulucu et al. [7] evaluated in vitro the shear bond strength of adhesive systems to irradiated dentin. Thirty human teeth were divided into irradiated by 60 Gy (gray) and non-irradiated, and subdivided according to the adhesive system: conventional (Prime & Bond NT (Dentsply Sirona, New York, United States) and self-conditioning (Clearfil SE Bond (Kuraray, Umeda, Osaka, Japan). The authors clamed that the self-etching adhesive improved bond strength in irradiated teeth, even though the adhesion of both adhesive systems was impaired by radiation.

In another in vitro study, Bulucu et al. [8] verified the effect of radiotherapy on the microleakage of a conventional adhesive system and two self-etching agents with different strategies. 84 human teeth were prepared with class V cavities and divided into groups: conventional adhesive (Prime & Bond NT, Dentsply Sirona, New York, United States), self-etching with 1 step (Clearfil S3 Bond, Kuraray, Umeda, Osaka, Japan) e self-etching with 2 steps (Clearfil SE Bond, Kuraray, Umeda, Osaka, Japan). After restoration, the groups were subdivided into irradiated (60 Gy) and non-irradiated. The samples were thermocycled, stained by dyes and the data was analyzed by Kruskal-Wallis and Mann-Whitney U tests. There was no statistically significant difference between the irradiated and non-irradiated groups. However, the conventional adhesive showed better infiltration into dentin than the self-etching adhesives.

Bernard et al. [9] performed an in vitro study, where 40 human teeth were randomly divided into irradiated (50 Gy) and non-irradiated, aiming to analyze the microtensile bond strength promoted by a conventional (Optibond FL, Kerr France, Créteil, France) and self-etching adhesive system (Optibond XTR, Kerr France, Créteil, France). In the results obtained, when irradiated, there was a 33% reduction in the bond strength of the conventional adhesive, while in the self-etching adhesive, this bond strength was reduced by only 16%. Thus indicating better effectiveness of self-etching adhesives in restorations of irradiated teeth.

Marie et al. [10] carried out an in vitro study to evaluate the influence of radiotherapy on the microtensile bond strength to dentin of three adhesive systems and whether the time between radiotherapy application and restoration affects bond strength. Ninety human molars were divided into 3 groups: control (no irradiation), restoration before irradiation, and restoration after irradiation, and subdivided into three subgroups, according to the adhesive system tested: Optibond FL (Kerr, Orange, United States), Clearfil SE Bond (Kuraray-Noritake, Kurashiki, Japan) e G-Bond (GC, Tokyo, Japan). The teeth restored were cut into 403 rectangular sticks, which were evaluated by the microtensile test. Data were statistically analyzed using linear mixed models. In this study, it was not possible to observe the association between radiotherapy and bond strength to dentin. As for the failure mode, teeth restored after radiotherapy had a lower percentage of adhesive failures. Clearfil SE Bond self-etching adhesive showed significantly greater microtensile bond strength to dentin than conventional Optibond FL, however, it presented the highest percentage of cohesive failures in all tested groups. It was not possible to compare G-Bond adhesives with other adhesives.

Paiola et al. [11] evaluated in vitro the shear bond strength of Single Bond Universal (3M ESPE, St. Paul, Minnesota, United States), with the acid-etching or self-etching strategy, according to the fabricator's instructions, on irradiated and non-irradiated teeth. The authors found that the bond strength was lower in irradiated teeth, presenting an irregular hybrid layer and shorter resin tags. The application of self-etching adhesive provided greater bond strength. For the authors, self-etching adhesives are more favorable in the restoration of irradiated teeth.

An in vitro study performed by Arid et al. [12] aimed to evaluate the effects of radiotherapy on enamel and dentin, determine the most suitable adhesive system, and the best time to perform a restoration of irradiated teeth. 120 enamel and 120 dentin samples were evaluated, and divided into 4 groups: control, only with restorative procedure; restorative procedure immediately before radiotherapy; restorative procedure immediately after radiotherapy; and with the restorative procedure six months after radiotherapy. Each group was divided into subgroups according to the adhesive

system: conventional (Adper™ Single Bond 2, 3M ESPE, St. Paul, Minnesota, United States) and self-etching adhesive (Clearfil SE Bond, Kuraray, Umeda, Osaka, Japan). The specimens were submitted to confocal microscopy and microshear bond strength test. It was possible to identify that radiotherapy considerably altered the morphological surface of hard dental tissues and then the higher the irradiated dose, the greater the identifiable effects. For the authors, the most appropriate time to restore an irradiated tooth is after radiotherapy, and the self-etching adhesive provides better results than the conventional system.

Mellara et al. [13] performed an in vitro study to evaluate morphological changes in irradiated hard dental tissues, determine the best adhesive technique and the best time to perform the restoration. Thirty fragments of enamel and dentin were divided into 4 groups: control, non-irradiated and only with restorative procedure; restorative procedure immediately before radiotherapy; restorative procedure 24 hours after radiotherapy; and restorative procedure 6 months after radiotherapy. Each group was divided into 2 subgroups according to the adhesive system: conventional (Adper™ Single Bond 2, 3M ESPE, St. Paul, Minnesota, United States) and self-etching (Clearfil SE Bond, Kuraray, Umeda, Osaka, Japan). The specimens were submitted to the microshear bond strength test and evaluated by confocal microscopy. Restorations performed immediately after radiotherapy had lower bond strengths than restorations performed six months after radiotherapy. Both adhesive systems showed the same bond strength on enamel. However, the self-etching showed better performance on dentin.

To evaluate the microtensile bond strength of different modes of universal adhesives on irradiated dentin, Ozan et al. [14] performed an in vitro study with 120 non-irradiated teeth and 120 irradiated teeth (50 Gy). Teeth were equally divided into study groups according to the mode of application (total acid-etching and self-etching) of the universal adhesive systems: Single Bond Universal (3M ESPE, St. Paul, Minnesota, United States) e Prime & Bond Universal (Dentsply Sirona, New York, United States). After the restorative procedure, the samples were submitted to the microtensile bond strength test, and the data was analyzed by the T test. On irradiated teeth, Single Bond Universal applied with acid-etching showed the highest bond strength, followed by Prime & Bond Universal self-etching. Unlike the others, Prime&Bond Universal self-etching showed better results in irradiated teeth than in non-irradiated. In all groups, the total acid etching mode showed the lowest bond strength.

Yoshikawa et al. [15] carried out an in vitro study to evaluate the effect of irradiation on the bond strength of composite resin to dentin and on its adaptation to the dentin cavity wall. Sixteen bovine mandibular incisor teeth were irradiated (60 Gy) and flat dentin surfaces were prepared. Half of these surfaces were used as controls, without adhesive material, and the other half were treated with self-etching adhesive Clearfil SE Bond (Kuraray, Umeda, Osaka, Japan), both later restored with composite resin cylinders Clearfil AP-X (Kuraray, Umeda, Osaka, Japan). The samples were submitted to microtensile and pigmentation tests. The bond strength data were evaluated by the Bonferroni test and the pigmentation was analyzed by the tests U de Kruskal-Wallis e Mann-Whitney. The self-etching adhesive showed complete marginal sealing, regardless of irradiation. There was no significant difference in the bond strength of composite resin to irradiated and non-irradiated dentin. Irradiation significantly reduced the adaptation of composite resin to the cavity, due to the destruction of collagen fibers in dentin and factor C.

Harhash et al. [16] investigated in an in vitro study the influence of different irradiation doses on the bond strength to enamel and dentin using different adhesive systems. Enamel and dentin surfaces were obtained from 40 human premolars, which were divided into two groups according to the adhesive system and restorative material: conventional adhesive (Adper Scotch Bond Multi-Purpose, 3M ESPE, St. Paul, Minnesota, United States) + composite resin Filtek 250 XT (3M ESPE, St. Paul, Minnesota, United States) or self-etching adhesive (Primer&Bond, 3M ESPE, St. Paul, Minnesota, United States) + composite resin Filtek LS (3M ESPE, St. Paul, Minnesota, United States). Subsequently, the specimens were divided into two groups, according to the applied radiation dose: 35 Gy or 70 Gy. The microshear test was performed and the data were submitted to a three-way ANOVA, the Tukey test, and the T test. The group irradiated by 70 Gy showed a significant reduction in bond strength. The conventional adhesive system showed significantly higher bond strength values than the self-etching adhesive.

Munoz et al. [17] performed an in vitro study with specimens of human enamel and dentin irradiated by 20 Gy, 40 Gy, and 70 Gy to evaluate the impact of radiation doses on the Vickers microhardness of hard dental tissues and on the microtensile bond strength of the adhesive system Scotch Bond Universal (3M ESPE, St. Paul, Minnesota, United States), following the acid-etching or self-etching strategy, according to the fabricator's instructions. The higher the dose of ionizing radiation, the lower the microhardness of hard dental tissues, especially from 40 Gy onwards. In addition, the acid-etching strategy showed better adhesive performance than self-etching and more chance of enamel fractures.

In order to evaluate the influence of irradiation on dentin bond strength, Gernhardt et al. [18] performed an in vitro study with 120 irradiated (60 Gy) and non-irradiated human teeth. The specimens were randomly distributed into experimental groups, according to the adhesive systems: Scotchbond 1 (3M ESPE, St. Paul, Minnesota, United States), Solobond Plus (Voco, Cuxhaven, Germany), Prime & Bond 2.1 (Dentsply Sirona, New York, United States) and Syntac (Ivoclar Vivadent, Schaan, Liechtenstein, Germany). The samples were submitted to microshear tests and analyzed by the bidirectional ANOVA test. There were no significant differences in the bond strength of the different adhesive systems on irradiated and non-irradiated teeth.

Galetti et al. [19] evaluated in vitro the influence of radiotherapy on the bond strength to dentin in irradiated patients. Thirty six samples were divided into two groups: irradiated and non-irradiated, and subsequently subdivided according to adhesive systems: conventional (Single Bond 2, 3M ESPE, St. Paul, Minnesota, United States) and self-etching (Easy Bond, 3M ESPE, St. Paul, Minnesota, United States) and Clearfil SE Bond, Kuraray, Umeda, Osaka, Japan). The restorative procedure was performed with Filtek Supreme resin composite Filtek Supreme (3M ESPE, St. Paul, Minnesota, United States). Samples were tested for microshear and fracture patterns were analyzed microscopically. There was no statistically significant difference between the irradiated and non-irradiated groups in both presented adhesive systems, which indicates that radiotherapy did not affect the dentin bond strength.

On the other hand, Da Cunha et al. [20] evaluated the effect of different doses of radiation (irradiated by 20 Gy, 40 Gy e 70 Gy) on the self-etching adhesive system (Universal Single Bond, 3M ESPE, St. Paul, Minnesota, United States) and conventional (Adper™ Single Bond 2, 3M ESPE, St. Paul, Minnesota, United States) in hard dental tissues. There was no significant change in enamel bond strength for both adhesives applied, however, adhesive failures were observed at all applied radiation doses. The self-etching adhesive showed a negligible increase in bond strength to dentin compared to the conventional and showed no changes in the three different doses of radiation. Therefore, the choice between the two adhesives did not interfere in adhesion.

Soares et al. [21] investigated in vitro the effect of radiotherapy, doxycycline, and adhesive systems on bond strength to dentin microtensile. Sixty human teeth were divided between the conventional adhesive system Adper™ Scotchbond MP (3M ESPE, St. Paul, Minnesota, United States) and self-etching Clearfil SE Bond (Kuraray, Umeda, Osaka, Japan). Subsequently, they were subdivided according to the doxycycline application or not and the time of application of radiotherapy (60 Gy): before or after the restorative procedure and non-irradiated. Microtensile tests were performed. The failure mode was evaluated under light microscopy and the binding interface under scanning electron microscopy. There was no significant difference between the bond strength of conventional and self-etching adhesives on irradiated teeth.

According to a systematic review carried out by Troconis et al. [3], only two clinical trials, performed by Bernard et al. [9] and Galetti et al. [19], previously reported, were performed after radiotherapy, evaluating the bond strength of adhesive systems on irradiated teeth. However, there are still few studies to allow a conclusion.

## DISCUSSION

Radiotherapy causes significant damage to the enamel and dentin adherence, with side effects on the morphological, mechanical, and chemical properties of the teeth [4]. Allied with an oral environment with hyposalivation and xerostomia, radiotherapy also promotes the biological degradation of collagen fibrils, which can impair the integrity

of the hybrid layer and reduce adhesive restorative longevity [6]. Therefore, emphasizing the justification of this study in determining the adhesive system most suitable for restorative procedures in irradiated teeth.

Based on the literature review, there are few studies about the theme, which majority are in vitro and favorable to self-etching adhesives [7-15]. This can be explained due to a strong connection between functional monomers of self-etching adhesives, especially 10-MDP, with calcium ions from dental hydroxyapatite, which favors greater infiltrated resin cohesion after polymerization and better resistance during hydrolysis [10]. In addition, self-etching and acid-etching adhesives have similar bond strengths to dentin, however, the self-etching primer does not have the same enamel demineralization capacity as phosphoric acid [12,13]. This can be a self-etching advantage because the irradiated teeth already present a previous demineralization and the self-etching prime does not promote excessive demineralization of the dental tissue [12,13]. Allied with this, conventional adhesives may have lower adhesion resistance due to acid etching increasing the porosity of enamel that has previously undergone changes by radiotherapy, which also makes it more porous, thus harming the adhesive interface, which could lead to an even earlier failure of composite resin restorations [12,13]. In addition, self-etching adhesives have a faster and more practical application protocol, so fewer technical errors should occur [10]. This is a positive feature for irradiated teeth because excessive acid conditioning of hard tooth tissues is one of the most common errors during conventional adhesive application [10]. Acid super conditioning could promote exacerbated dehydration of the already irradiated dentin, result in collagen matrix collapse, and aggravate its demineralization [10].

On the other hand, studies showed divergent results, where adhesive restorations with conventional adhesives showed better bond strength than self-etching in irradiated teeth [16,17]. This fact may be associated with the well-established mechanical interlocking of the polymerized adhesive in the spaces between the enamel crystallites, generated by the previous acid conditioning [17]. Another possible explanation would be for acid conditioning to expose a microporous collagen cluster that is almost totally devoid of hydroxyapatite and, as a result, the primary adhesion mechanism of these adhesives is based on diffusion [16].

In some other studies, the choice between conventional or self-etching adhesives did not interfere with the bond strength of the resin composite in the irradiated substrate [18-21].

The shortage of scientific articles about the theme and the need for further research are emphasized. Laboratory studies direct procedures, but limitedly, and highlight the importance of further clinical studies to determine the best adhesive protocol for restorations in irradiated teeth.

## CONCLUSION

After this review literature, it was concluded that self-etching adhesive could be a good option for irradiated teeth restorations. However, there are still few published studies, so more clinical studies are needed.

### Collaborators

ZML Wanghon, project administration, formal analysis, conceptualization, data curatorship, writing - first writing, methodology. RP Pereira, formal analysis, data curatorship, methodology, writing - review and editing, supervision, validation and visualization. AR Camargo, writing review, supervision, validation and visualization. LJ Grando, writing review and editing, supervision, validation and visualization. R Gondo, writing review and editing, supervision, validation, visualization and orientation.

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