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Comparative Evaluation of Fracture Resistance, Deformation and Patency Efficiency of Reciprocating and Rotary Glide Path Files: An *In vitro* Study

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: To evaluate the performance of reciprocating and rotary Glide Path files in human permanent mandibular molars, focusing on instrument fracture, deformation, and patency rates.
Study Design: The study was a comparative analysis conducted to evaluate the incidence of instrument failure and the success rates in reaching working length using different file systems.
Place and Duration of Study: The study was conducted on human permanent mandibular molars at the University of Fortaleza, from January 2024 to June 2024.
Methodology: A total of 150 human permanent mandibular molars were selected and randomly assigned into three groups (n=50). The groups were treated with R-Pilot®, Wave One Gold Glider®, and ProDesign Logic® 15.03 files. Instrument fracture and deformation rates were recorded, and the percentage of Glide Path instruments that reached the working length was noted. Data were managed and analyzed using Excel and statistical analyses were performed using Stata 10 software.
Results: The Wave One Gold Glider® group exhibited the highest incidence of fractures and deformations, with only 4 intact files at the conclusion of the study, showing statistically worse results compared to the other file systems. No significant differences were found between the R-Pilot® and ProDesign Logic® groups. The mesiobuccal root canals had the highest failure rate in achieving foraminal patency, with 24 canals not reaching patency. Conversely, the mesiolingual root canals were the most successful, achieving initial exploration in 102 canals.
Conclusion: The reciprocating system Wave One Gold Glider® did not show superiority over the rotary system Pro Design Logic® under the conditions tested. The findings also highlight the high patency rates achieved by Glide Path files and the differences in performance between the various systems tested. The Glide Path files demonstrated high patency rates, ranging from 81% to 88%.

Keywords: Endodontic; root canal preparation; fracture resistance.

1. INTRODUCTION

The composition of the alloy, anatomical complexity, and manipulation technique used by the dental surgeon, among other factors, can contribute to the increased risk of fractures of endodontic files inside root canals. Thus, the literature is constantly seeking new discoveries to associate the speed of treatment with a low rate of these accidents, as they negatively influence the treatment prognosis (Jamleh et al., 2014; Capar et al., 2015).

Despite great advances, instrument fracture remains a significant concern in endodontic treatment. According to Dioguardi et al. (2019), sterilization directly influences the physical and chemical properties of instruments, as this process involves several steps that can reduce their durability.

The literature reports two main types of endodontic file fractures: torsional fractures, where the end of the instrument is trapped in the root canal while the rest continues to move, and rotational fractures, which occur due to continuous rotation in a curved canal, causing cycles of tension and compression until reaching the maximum point of flexion (Martin et al., 2003; Pedulla et al., 2015; Inan et al., 2019).

With the advancement of thermomechanical treatments, "memory control" files (CM-WIRE) were introduced to the market. These files have greater resistance to cyclic fatigue than M-Wire and conventional NiTi instruments, and the special thermomechanical process reduces the incidence of errors in root canal preparation and shaping (Capar et al., 2015; Al Hadlaq et al., 2010; de Morais et al., 2024). Additionally, the lower nickel content (52%) provides not only high flexibility but also the ability for the instrument to be "pre-bent," making it safer for use in curved root canals (Topçuoğlu et al., 2019).

Yared (2008) suggested using a reciprocating movement in root canal preparation with a single instrument to reduce fatigue and minimize cross-contamination from inadequate cleaning and sterilization of endodontic instruments. In this context, several exploratory NiTi files with reciprocating kinematics were developed to

speed up endodontic treatment, reduce fractures, and consequently increase the success rates of treatments (İnan & Keskin, 2019; Santos et al., 2019; Uslu & İnan, 2019).

The development of mechanized NiTi instruments exclusively for exploring root canals was crucial for shortening procedure duration, reducing postoperative pain, and preserving the root canal's original anatomy compared to stainless steel files. De Deus et al. (2016) emphasized the importance of creating a glide path, showing satisfactory results with rotary instruments. In this clinical stage, the ScoutRace demonstrated an efficiency of 68.3%, attributed to its tip (ISO #10) and continuous low taper (0.02mm/mm) compared to other systems tested.

Exploratory files have been improving, as this clinical step remains challenging, especially in curved canals. Glide Path files, with their greater flexibility, maintain the root canal anatomy, increase exploratory speed, facilitate the use of larger caliber files, and reduce risks of perforations, stops, or deviations (Ha et al., 2012; Ajuz et al., 2013; Česaitienė et al., 2019).

The R-Pilot® file is a recently developed reciprocating instrument for root canal exploration, made of M-WIRE alloy, with an S-shaped cross-section, a constant 4% taper, and a tip diameter of 0.125mm. The Wave One Gold Glide file® (Dentsply Sirona, Ballaigues, Switzerland, 2018) features a special thermomechanical treatment of gold wire, with a tip diameter of 0.15mm and a variable taper from 2 to 6%, with a parallelogram horizontal cross-section with two cutting edges (Keskin et al., 2018; Serefoglu et al., 2018; Santos et al., 2019).

Another instrument developed with advances in NiTi thermal treatment is the ProDesign Logic 15.03 file® (Easy Equipamentos Odontologistas, Belo Horizonte, MG, Brazil), which includes a controlled memory (CM) feature, providing great flexibility. It is designed to adapt to any market engine and is recommended for continuous rotation. It features a quadrangular helix cross-section, a taper of 0.03mm, and a tip diameter of 0.15mm (Stringheta et al., 2019).

Thus, the aim of this study was to analyze the ability of Glide Path files to achieve apical patency and their resistance to fracture during root canal exploration.

2. METHODOLOGY

The goodness-of-fit model of the Chi-Square test was adopted to determine the ideal sample size. The analysis indicated a minimum sample size of 133 teeth, with a critical chi-square value of 9.49 as the threshold for accepting the null hypothesis.

A total of 150 human first mandibular molars, extracted with fully formed and moderately curved roots ranging between 10º and 20º, were selected and stored in saline solution, which was renewed weekly until use. The teeth were randomly distributed into three experimental groups (n=50). For each group of teeth, a specific file type was assigned.

To perform the experiment, 30 NiTi endodontic files were selected to represent different types of mechanized exploratory files with varying heat treatments, such as M-Wire and CM-Wire. The chosen files were R-Pilot® 12.04, Wave One Gold Glider® 15.02-06, and Pro Design Logic 15.03®.

Initially, a digital radiography sensor system (Fit T2, Micro Image, Brazil) was used to estimate the working length and confirm root canal angulations, following the Schneider method (Schneider, 1971). The teeth were then measured from the apex to the occlusal surface using a digital caliper (DIGIMESS, São Paulo, Brazil) (Fig. 1), ensuring standardization at 18 mm with a maximum variation of ±1 mm in working length. The crowns were sectioned with a precision diamond disk (American Burrs, Santa Catarina, Brazil) after marking the established standard length.

Coronal access was performed using a 1012 diamond round drill (KG Sorensen, São Paulo, Brazil) with a high-speed handpiece under cooling (KaVo Dental Excellence, Brazil). The teeth were then inserted into a custom specific apparatus (IM do Brasil, São Paulo, SP, Brazil) that simulated the alveolar socket and allowed connection of the metal lip clip of an apex locator (Root ZX; J Morita USA Inc, Irvine, CA) to enable the electronic measurement of the working length.

For every three entry movements, the canals were irrigated with 2.5 mL of 2.5% sodium hypochlorite (NaOCl; Biodinamic Chemicals and Pharmaceuticals Ltd, Ibiporã, PR, Brazil) using a 10 mL disposable syringe (Descarpack, São Paulo, SP, Brazil) and a NaviTip 31ga needle (Ultradent). The Glide Path mechanized files, specific to each experimental group, were introduced into all root canals after the use of K-File #10 manual files.

Fig. 1. Apparatus simulating the alveolar cavity
Source: Authors (2024)

Initially, the Glide Path files were inserted up to the apparent length of the tooth minus 4 mm. They were then advanced apically, coupled to the apex locator, to confirm the working length. Subsequently, the files were advanced until reaching the working length (zero point), which was confirmed using the file stop, ensuring complete exploration and patency of the canals.

All procedures were performed by the same operator, following the manufacturers' instructions. Each file was used up to five times on different teeth from the same group. After each use, the files underwent a cleaning and sterilization process in an autoclave. Subgroups were formed based on file usage, with each subgroup containing one file and a maximum of five teeth. If an instrument fractured or deformed during use, its subgroup was terminated, the event recorded, and a new subgroup initiated.

After each use, the files were examined microscopically (Alliance, São Carlos, São Paulo) at 40× magnification to check for deformation or fracture (Fig. 2).

The acquired data were organized into Excel spreadsheets and analyzed statistically using the BioEstat 5.3 software (Marimauá Institut, Manaus, Brazil). Due to significant differences between group variances, the non-parametric Kruskal-Wallis test was used, followed by the Mann-Whitney U test for multiple comparisons, with a significance level of 5%.

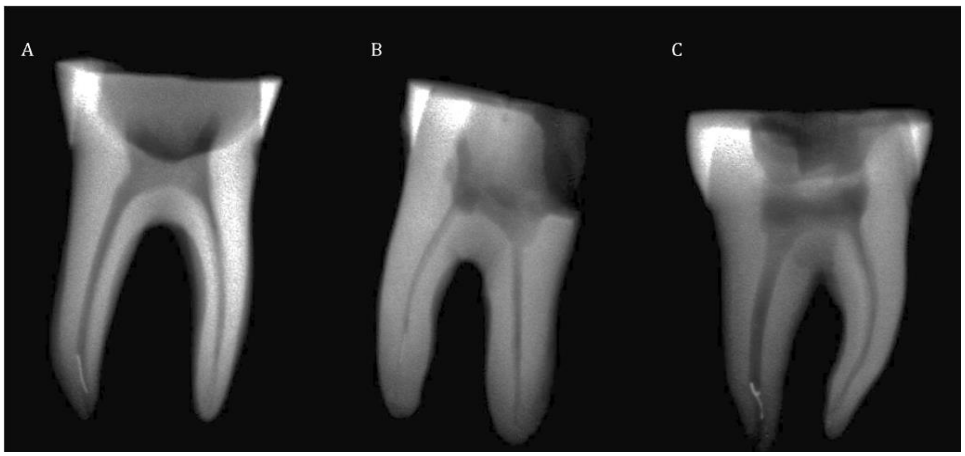

Fig. 2. Radiographic images (A-C) of fractured instruments in the root canal after exploration with Wave One Gold Glider (A-B) and R-Pilot (C)
Source: Authors (2024)

3. RESULTS

When analyzing the resistance to fracture or deformation of a total of 30 NiTi endodontic files from different brands and heat treatments during use in 150 teeth, the Wave One Gold Glider group showed statistically worse results when compared to the Pro Design Logic and R-Pilot systems (p=0.0001), as only four out of 10 Wave One Gold Glider files remained intact at the end of the study. The three fractures of the Wave One files occurred during the first and second use.

Statistically significant differences (p=0.022) were found between the R-Pilot and ProDesign Logic groups, with the ProDesign Logic group showing better results than the R-Pilot group. There was one fracture and one deformation in the R-Pilot group (20%), while no instruments in the ProDesign Logic group were altered after five uses (Table 1).

A total of 382 root canals, corresponding to approximately 127 teeth, were analyzed, as 23 teeth were not used in this research due to the instrumentation being interrupted after the instrument suffered a fracture or deformation.

Foraminal patency was not achieved in 64 out of 382 root canals, with 20 in the R-Pilot group, 17 in the Wave One group, and 27 in the ProDesign group (Table 2). When analyzing the patency capacity with the #10 manual file, the buccal middle canals (MB) had the greatest difficulty in achieving patency, with 24 root canals not reaching foraminal patency. Conversely, the mesiolingual canals (ML) were easier to explore manually with the #10 file, as out of the 314 canals subjected to manual foraminal exploration, 102 were ML.

The non-parametric Kruskal-Wallis test was used, and statistical analysis showed no significant difference. That is, when the canal is explored manually with a #10 file and an increment is made with the mechanized system, it does not increase the chance of locating the foramen when compared to the manual technique (p=0.073). Therefore, neither system is significantly better at increasing the number of apical patency. The use of the mechanized glide file significantly improved the success rate in locating the foramen in 18 canals, a result not achieved with the manual technique, as demonstrated in Fig. 4. Thus, R-Pilot reached 3 apical foramina, Wave One reached 3, and Pro Design reached 12 foramina, with 17 canals in the R-Pilot group, 14 in the Wave One group, and 15 in the Pro Design group without patency (Table 3).

Regarding the combined use of a manual file and a mechanized file to obtain foraminal patency, foraminal patency was achieved in 108 canals (86.4% of the total) with R-pilot, 72 (81.8%) with WaveOne Gold Glider and 115 (88.4%) with Pro Design.

Table 1. Comparison of groups between intact files and fractured or deformed files after the experiment

	Intact Files	Fractured Files	Deformed Files
R-Pilot [b]	8(80%)	1(10%)	1(10%)
Wave One Glider [a]	4(40%)	3(30%)	3(30%)
ProDesign Logic [c]	10(100%)	0(0%)	0(0%)

Source: Authors (2024)

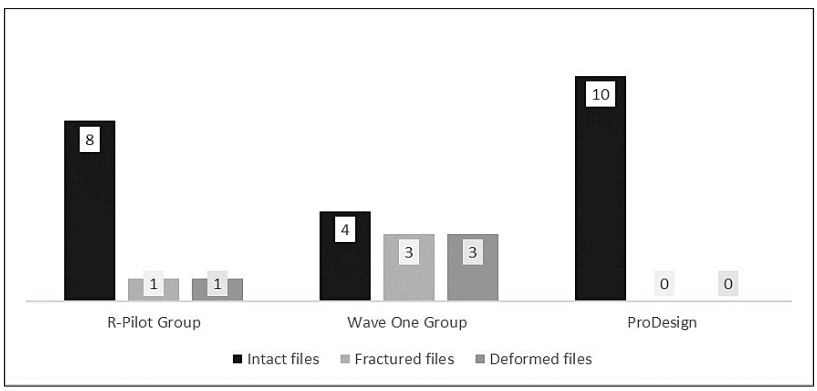

Fig. 3. Comparison of groups between intact, fractured and deformed files after the experiment
Source: Authors (2024)

Table 2. Non-patency capacity according to the root canals with the #10 manual file

Brand	Non-Patent canals with File #10 manual file						
	MB	ML	D	DL	DB	M	TOTAL
R-Pilot Group	10(50%)	4(20%)	5(25%)	1(5%)	0(0%)	0(0%)	20
Wave One Group	7(41%)	5(29%)	4(24%)	1(6%)	0(0%)	0(0%)	17
ProDesign Group	7(28%)	8(32%)	10(32%)	1(4%)	0(0%)	1(4%)	27
TOTAL	24	17	19	3	0	1	

MB, Mesiobuccal; ML, Mesiolingual; D, Distal; DL, Distolingual; DB, Distobuccal; M, Mesial.
Source: Authors (2024)

Table 3. Patency and non-patency with the glide path file

Brand	Non-Patent canals with Manual Glide path and mechanized glide file						
	MB	ML	D	DL	DB	M	TOTAL
R-Pilot	9(53%)	2(12%)	5(29%)	1(6%)	0(0%)	0(0%)	17
Wave One	5(36%)	3(21%)	5(36%)	1(7%)	0(0%)	0(0%)	14
ProDesign	1(7%)	5(33%)	7(47%)	1(7%)	0(0%)	1(7%)	15

MB, Mesiobuccal; ML, Mesiolingual; D, Distal; DL, Distolingual; DB, Distobuccal; M, Mesial.
Source: Authors (2024)

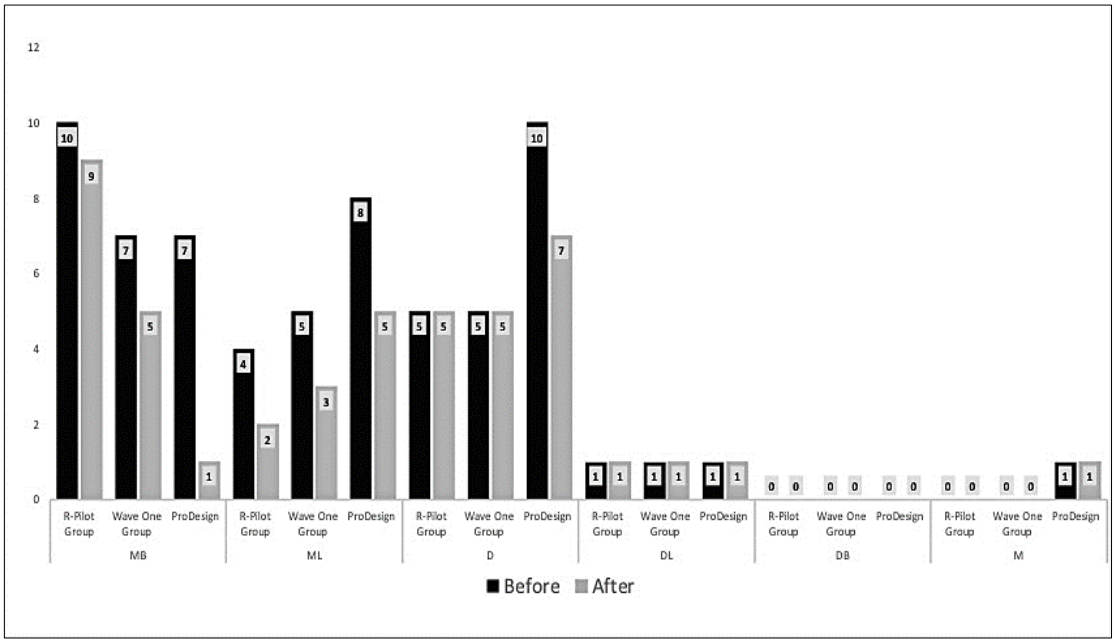

Fig. 4. Non-patent canals before and after the use of the mechanized Glide Path file
Source: Authors (2024)

4. DISCUSSION

The aim of this study was to evaluate the patency ability and fracture rate of Glide Path files on extracted human permanent mandibular molars.

The choice of a specific apparatus (IM do Brasil, São Paulo, SP, Brazil) that represents the alveolar cavity, along with the sterilization step after each use, aimed to align this research more closely with the clinical routine of endodontists. This is important since some studies show results using resin blocks, which do not have the same dentin structure as natural teeth (Berutti et al., 2012a; Berutti et al., 2012b).

Regarding sterilization, Dioguardi et al. (2019) and Silva et al. (2020) have shown that heat sterilization can cause changes in the physical and chemical structures of instruments, potentially affecting their cutting capacity and resistance to cyclic and torsional fatigue. In a more recent study, Dioguardi et al. (2021) concluded that NiTi instruments subjected to autoclave sterilization over five times may

experience reduced cutting efficiency. On the other hand, Peraça et al. (2021) and Ragozzini et al. (2024) observed different results, concluding that sterilization did not influence the estimated number of uses and that file fractures occurred due to repetitive use.

The choice of the dental group to be studied (lower molars) with curvatures varying between 10º and 20º was based on studies showing these teeth are the most commonly treated in endodontics and that this range of angulation is not rare (Gambarini et al., 2018).

Alternating movement in clockwise and counterclockwise directions at different angles before completing the rotary movement helps prevent the accumulation of stress in the instruments, thus reducing the risk of cyclic fatigue and extending the instrument's useful life. This reduction in stress allows the professional to use a single instrument to prepare the entire root canal (Ferreira et al., 2016).

Topçuoglu et al. (2018) and Kirici et al. (2019), in their studies with stainless steel files in highly curved canals, observed difficulties in treating these canals and found that the Wave One Gold Glide (WOGG) file showed greater resistance to cyclic fatigue due to its reciprocating motion and gold wire technology, which provides greater durability compared to conventional NiTi files. These findings were supported by Dias et al. (2022), who showed that WOGG had higher cyclic fatigue resistance than ProGlider and TruNatomy Glider. Additionally, Uslu and İnan (2019) found that reciprocating movement with the R-Pilot (RP) file exhibited a lower fracture rate compared to HyFlex EDM and PathFile, which aligns with the observations made by Yared (2008). However, the RP group did not show statistical differences when compared to the rotary group, ProDesign Logic (PDL), suggesting that the reciprocating movement was not superior to the rotary method in this study.

According to De-Deus et al. (2016), the taper of an instrument is directly related to the likelihood of fracture, as the file's tip has a greater tendency to lock in the root canal. This may explain why the WOGG file group had a higher rate of fractures and deformations, as its taper varies from 2% to 6%, while the PDL has a taper of 3% and the RP has a taper of 4%. The cut area is also a contributing factor, as the parallelogram shape of the WOGG file generates more stress, leading to higher fracture rates, unlike the S- and quadrangular-shaped files found in RP and PDL, respectively (Lopes et al., 2020; Santos et al., 2019; Pedulla et al., 2020). Furthermore, there were two fractures in the RP group (20%) and none in the PDL group, indicating a statistical difference between these groups.

It is essential to emphasize that only a manual K-File #10 was used before the Glide Path file. Alcalde et al. (2018) reported that, although reciprocating movement takes longer to reach the foramen than rotary movement, it did not yield better results, as the reciprocating instrument cannot advance to the working length without an established path of exploration. This justifies the use of a manual file before the mechanized instrument in the present study.

The high number of deformed WOGG files serves as a safety indicator, alerting the endodontist to the potential for fracture under additional stress (Pereira et al., 2021). This may explain why the WOGG group showed the greatest number of deformations and fractures, with statistically significant differences in fracture and deformation rates when compared to other systems ($p < 0.05$).

In a recent study comparing RP and WOGG, Pereira et al. (2021) concluded that there were no significant differences in preparation time, plastic deformation, or apical patency gain. However, while the RP group showed greater resistance to torsion than the WOGG group, it also exhibited fewer deformations. This suggests that RP files may fracture without prior deformation, underscoring the need for careful examination before use due to high torsional stress.

De Deus et al. (2016) showed that mechanized files have high patency rates, ranging from 51.6% to 68.3%, aligning with this research, where 81% to 88% of the total 295 root canals reached the working length using all mechanized files. In the same study, mandibular molars showed the highest rates of foraminal patency (68.3% to 76.7%), with the distal and mesiobuccal canals showing the highest patency rates. These findings were consistent with this study, as no difference was found between manual and mechanized instrumentation. This indicates that using a #10 file manually before using the mechanized system does not significantly increase the likelihood of locating the foramen compared to the manual technique.

The findings of Iqbal et al. (2006) on instrument fractures in mandibular molars showed that mesiobuccal canals had the highest fracture rates, aligning with this study's results. Our results showed that the mesiobuccal canals proved to be the most challenging in terms of apical permeability, with 24 canals failing to achieve foraminal patency using the manual technique.

Finally, the importance of further research with mechanized systems is highlighted. Limitations of the present study include the use of extracted teeth (ex vivo), which poses challenges in standardizing root canal lumen diameter, apical foramen size, and dentin moisture. Future in vivo studies are recommended for comparisons, providing conditions more similar to clinical practice. Another limitation is the small number of studies involving PDL, as this instrument was recently introduced to the market.

5. CONCLUSION

After completing the study and considering the methodological limitations, it can be concluded that the ProDesign Logic group demonstrated better results compared to the R-Pilot and the Wave One Gold Glide groups. However, the Wave One Gold Glide files exhibited the highest rates of fracture. Interestingly, the study found that the mechanized system did not increase the likelihood of locating the foramen when compared to the manual technique. Additionally, teeth treated with manual and Glide Path files showed high patency rates, ranging from 81% to 88%. These findings emphasize the efficacy of Pro Design Logic instruments, highlight concerns regarding the fracture rates associated with Wave One Gold Glide files, and indicate comparable patency rates between manual and mechanized techniques in root canal procedures.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that the AI technology, GPT-4o, has been used fairly and solely for the rewriting and editing of this manuscript, specifically for the purpose of correcting the English grammar of the translated text, which was initially written in Brazilian Portuguese. Details of the AI usage are given below:

1. The original manuscript, written in Brazilian Portuguese, was translated into English, and the AI was employed to ensure that the final text met the grammatical standards of academic English.
2. Specific prompts were designed to guide the AI in providing grammatical corrections. For instance, the AI was instructed to adjust the text's grammar to align with academic conventions.

CONSENT

As per international standards or university standards, Participants' written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

This study was approved by the Ethics Committee of the University of Fortaleza (CAAE: 40662620.0.0000.5052).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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