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Compatibility between variable taper mechanized instruments and corresponding gutta-percha cones: photomicrograph analysis

Compatibilidade entre instrumentos mecanizados com conicidade variável e cones de guta-percha correspondentes: análise por meio de fotomicrografias

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ABSTRACT

Objective: This study aimed to assess the compatibility between variable taper NiTi instruments and corresponding gutta-percha cones. **Material and Methods:** Protaper Gold F2 (F2/PTG), Wave One Gold Primary (PRI/WOG), and Reciproc Blue R25 (R25/RB) instruments (n = 3) were included, along with corresponding gutta-percha cones (n = 10), produced by the manufacturers and from three other brands (Diadent, MK Life, and Tanari). Images of both instruments and cones were obtained through photomicrographs using a digital microscope (500x). The instruments were photographed at seven angles, rotating on their axis to record the maximum diameter at desired levels; the gutta-percha cones, due to their cross-section, were photographed only once. The images were analyzed using Image J software by a blinded operator at 1.0 (D1), 6.0 (D6), and 12.0 (D12) millimeters from their tip. ANOVA and Tukey tests were employed for statistical analysis, with significance set at 5.0%. **Results:** Considering the correspondence between F2/PTG and PRI/WOG instruments, significant differences were observed when the manufacturer's cones were analyzed ($P < 0.05$). In relation to R25/RB instruments, statistical differences were observed only for the Tanari cone at D1 ($P < 0.05$). **Conclusion:** Within the study's limitations, it can be concluded that the tested instrument systems and dedicated gutta-percha cones exhibited some dimensional variability among them. Furthermore, among the evaluated cones, the cones corresponding to F2/PTG and PRI/WOG instruments from the manufacturer itself showed the greatest discrepancies.

KEYWORDS

Endodontics; Gutta-Percha; Photomicrography; Root canal preparation; Root canal obturation.

RESUMO

Objetivo: O presente estudo teve como objetivo avaliar a compatibilidade entre instrumentos de NiTi de conicidade variável e cones de guta-percha correspondentes. **Material e Métodos:** Foram incluídos instrumentos Protaper Gold F2 (F2/PTG), Wave One Gold Primary (PRI/WOG) e Reciproc Blue R25 (R25/RB) ($n = 3$); ainda, cones de guta-percha correspondentes ($n = 10$), produzidos pelos fabricantes e de outras três marcas (Diadent, MK Life e Tanari). Imagens tanto dos instrumentos quanto dos cones foram obtidas por meio de fotomicrografias com microscópio digital (500x). Os instrumentos foram fotografados sete angulações, com giros em seu próprio eixo, a fim de registrar-se o maior diâmetro nos níveis desejados; os cones de guta-percha, em função de sua secção transversal, foram fotografados uma única vez. As imagens foram analisadas por meio do *software* Image J, por um operador cego, a 1,0 (D1), 6,0 (D6) e 12,0 (D12) milímetros de sua ponta. Para análise estatística foram empregados os testes ANOVA e Tukey, com significância estabelecida em 5,0%. **Resultados:** Considerando a correspondência entre os instrumentos F2/PTG e PRI/WOG, diferenças significantes foram observadas quando os cones do próprio fabricante foram analisados ($P < 0{,}05$). Em relação aos instrumentos R25/RB, diferenças estatísticas foram observadas unicamente para o cone Tanari em D1 ($P < 0{,}05$). **Conclusão:** Nas limitações do estudo pode-se concluir que os sistemas de instrumentos e cones de guta-percha dedicados testados apresentaram alguma variabilidade dimensional entre eles. Ainda, dentre os cones avaliados, os cones correspondentes aos instrumentos F2/PTG e PRI/WOG do próprio fabricante foram os que apresentaram as maiores discrepâncias.

PALAVRAS-CHAVE

Endodontia; Guta-Percha; Fotomicrografia; Preparo do canal radicular; Obturação do canal radicular.

INTRODUCTION

Root canal obturation is characterized by the filling, whenever possible hermetic and three-dimensional, of the pulp space with biocompatible obturation materials (gutta-percha and endodontic cements). The primary aim of this phase is to maintain the disinfection achieved during cleaning and shaping by closing all access routes to the canal system, favoring the biological process of periapical tissue repair [1].

Many techniques have been suggested for this purpose, ranging from “classic” techniques that do not use heat to the most currently recommended ones that seek, through plasticization, better adaptation of the obturation material to the canal walls [2,3]. Among the more recent suggestions is the use of instrumentation/obturation systems, which provide corresponding gutta-percha cones theoretically designed similarly to mechanized preparation instruments [4]. However, variations in gutta-percha cone tip diameters or mismatches in their taper compatibility with the preparations performed may pose difficulties in achieving working length by the cones or, conversely, provide a thicker cement layer. Both occurrences could hinder the treatment and jeopardize its success [5].

Over the years, Endodontics has undergone significant changes due to the incorporation of technological innovations. Companies increasingly invest in creating and launching new mechanized instruments, both rotary and reciprocating, some with very distinct characteristics. The Protaper Gold rotary system (PTG; Dentsply/Tulsa Dental Specialties, Tulsa, OK, USA), and the reciprocating systems, WaveOne Gold (WOG; Dentsply/Maillefer, Ballaigues, Switzerland) and Reciproc Blue (RB; VDW GmbH, Munich, Germany), are examples of systems that feature instruments with variable tapers and also offer clinicians the option of corresponding gutta-percha cones [6].

However, despite discussions about standardization of instruments and corresponding gutta-percha cones, clinical everyday practice raises questions about the accuracy of this correspondence. The study conducted by Vieira et al. 2019 [7] aligns with such inquiries, with their results pointing to significant differences when verifying this compatibility. Sometimes, after canal shaping and instrumentation, the corresponding cone does not match the diameter and taper of the last instrument used at the working length, potentially hindering canal obturation [7].

Due to the aforementioned issues, this study aimed to evaluate the compatibility of Protaper Gold F2, WaveOne Gold Primary, and Reciproc Blue R25 instruments with corresponding gutta-percha cones, both from the manufacturers themselves and from three other commercially available brands: Diadent, MK Life, and Tanari.

MATERIAL AND METHODS

Study type

This study is an experimental evaluation conducted in a laboratory setting, utilizing mechanized endodontic preparation systems' instruments and corresponding gutta-percha cones to investigate their compatibility in vitro through analysis via photomicrographs using a digital microscope.

Sample selection

Three instruments (n = 3) belonging to three mechanized instrumentation systems were selected based on their variable taper throughout the instruments. Protaper Gold F2 (#25/.08; F2/PTG), WaveOne Gold Primary (#25/.07; PRI/WOG), and Reciproc Blue R25 (#25/.08; R25/RB) instruments were evaluated, and all included rotary and reciprocating instruments were new. Next, ten gutta-percha cones (n = 10) from the respective manufacturers of the preparation systems, PTG (Dentsply/Tulsa Dental Specialties), WOG (Dentsply Ind. Com. LTDA, Petropolis, Brazil), and RB (VDW GmbH), were selected.

Additionally, gutta-percha cones from three other commercial brands producing cones compatible with the selected instruments were included: Diadent (Burnaby, BC, Canada), MK Life (Porto Alegre, RS, Brazil), and Tanari (Amazonas, AM, Brazil). Cones from two distinct lots, without deformities, with five cones acquired from each lot, were included. Cones displaying noticeable inclinations or imperfections during photomicrography were discarded.

Records of instruments and gutta-percha cones

The selected instruments were longitudinally arranged on a protractor individually and secured with utility wax for recording through photomicrographs using the digital microscope (FX-500; BWX, Shandong, China) (Figure 1). A millimeter ruler was used in parallel to the object under study for software calibration (Figure 2). Photographic records of each instrument were taken at angles of 0°, 30°, 60°, 90°, 120°, 150°, and 180° to capture the maximum diameter at each level due to their cross-sectional shape. Cones, having a circular cross-section, were photographed only once (Figure 3).

Determination of instrument and gutta-percha cone design

The captured images of both instruments and gutta-percha cones were then analyzed by a single calibrated and blinded operator regarding the cone's brand, using Image J software (NIH, Bethesda, MA, USA). The analyses were conducted at 1.0 mm (D1), 6.0 mm (D6), and 12.0 mm (D12) from the tips of the instruments and gutta-percha cones, aiming to determine the diameter in mm of the samples at these positions, as specified by ISO 6877:2006 standards.

Analysis of discrepancies between instruments and gutta-percha cones

After obtaining the diameter measurements, the data were tabulated and analyzed separately. For the instruments, the seven images of each instrument were analyzed at the three positions to determine the largest measured diameter at each, recorded as the instrument's diameter. This value was statistically considered when comparing with the other two evaluated instruments to obtain an average value for each tested instrument. For the gutta-percha cones, the measured diameters at each position for each specimen in the sample were considered to determine the discrepancy (mm)

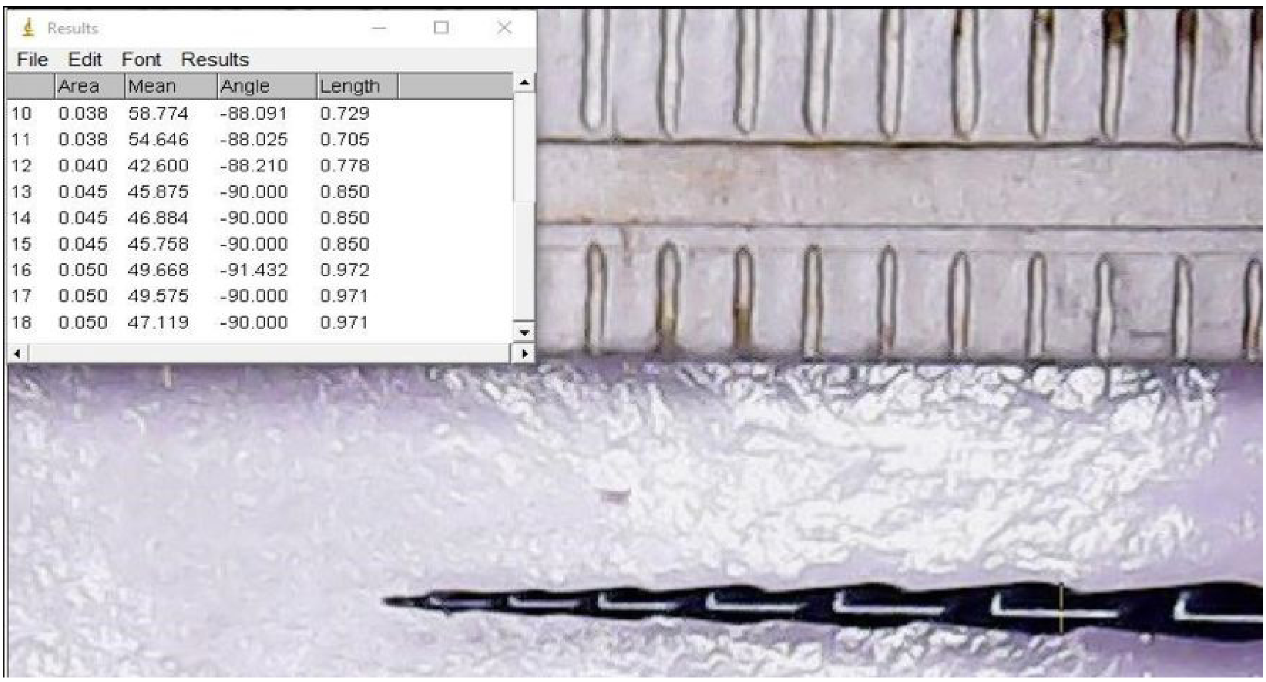

Figure 1 - Reciproc Blue file instrument positioned parallel to a millimeter ruler for calibrating the measurement software.

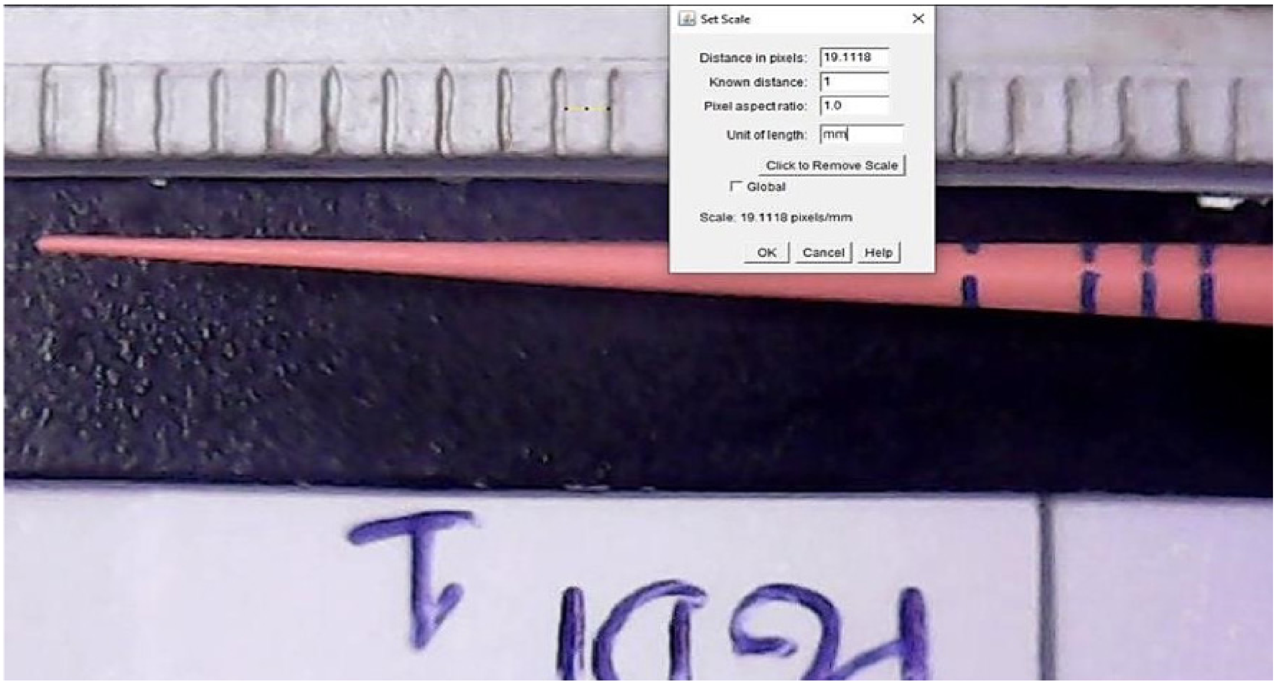

Figure 2 - Photomicrograph and calibration using Image J software of the gutta-percha cone.

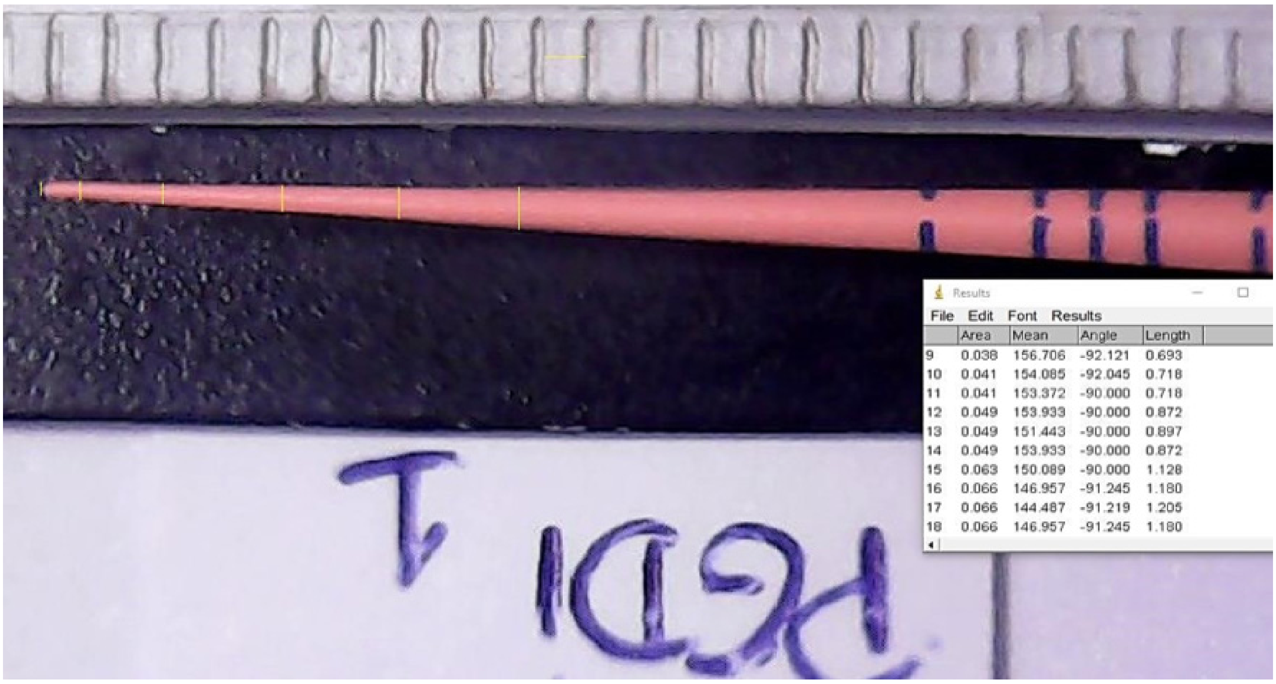

Figure 3 - Recording of gutta-percha cone diameters.

between the gutta-percha cones and the mean of the corresponding instruments.

Statistical analysis

For statistical analysis, conducted using Stat Plus for Windows software (Analyst Soft, Walnut, CA, USA), the average error values, considered as discrepancies measured in mm between the mean of the instruments and each gutta-percha cone, were subjected to a normality curve to determine the data's parametric nature. Accordingly, the values underwent evaluation through analysis of variance (ANOVA) and Tukey's individual comparison test, both at a significance level of 5.0%.

RESULTS

Tables I, II, and III present, respectively, the means and standard deviations in mm of the discrepancy between the F2/PTG, PRI/WOG, and R25/RB instruments and their corresponding gutta-percha cones from the evaluated brands. Analysis of the F2/PTG-compatible cones indicated that, in D1 and D6, the manufacturer's cones showed statistically significant discrepancies compared to the other evaluated brands ($P < 0.05$).

However, in D12, only the Tanari brand cone showed closer compatibility to the ideal, offering the lowest discrepancy values ($P < 0.05$). Regarding PRI/WOG instruments, in all three analyzed positions—D1, D6, and D12—the manufacturer, Denstply, consistently presented the highest discrepancy values, with significant differences in the conducted analyses ($P < 0.05$). Concerning R25/RB instruments, no statistically significant differences were observed between the groups at D6 and D12 ($P > 0.05$). However, at D1, the Tanari brand cones showed a significant difference compared to the other groups, presenting the highest discrepancy values ($P < 0.05$).

DISCUSSION

The present study aimed to assess the compatibility of NiTi instruments with variable tapers F2, Primary, and R25, belonging to the mechanized preparation systems Protaper Gold, Wave One Gold, and Reciproc Blue, respectively, with corresponding gutta-percha cones, from the manufacturer and three other brands available in the market. To date, few pieces of information are available in the literature regarding these systems and cones evaluated in this study.

Table I - Compatibility analysis of the Protaper Gold instrument and gutta-percha cones

Groups	*D1*		*D6*		*D12*	
	MEAN	*sd*	*MEAN*	*sd*	*MEAN*	*sd*
DENTSPLY	0.16 ^{b}	0.06	0.30 ^{c}	0.11	0.28 ^{b}	0.10
DIADENT	0.06 ^{a}	0.04	0.13 ^{ab}	0.03	0.27 ^{b}	0.03
MK LIFE	0.03 ^{a}	0.03	0.19 ^{b}	0.05	0.22 ^{b}	0.06
TANARI	0.04 ^{a}	0.04	0.10 ^{a}	0.04	0.11 ^{a}	0.04

^{a,b} Different superscript letters demonstrate significant differences between cones at the same level, according to the Tukey test ($P < 0,05$). sd: standard-deviation

Table II - Compatibility analysis of the WaveOne Gold instrument and gutta-percha cones

Groups	*D1*		*D6*		*D12*	
	MEAN	*sd*	*MEAN*	*sd*	*MEAN*	*sd*
DENTSPLY	0.08 ^{b}	0.04	0.12 ^{b}	0.06	0.17 ^{c}	0.04
DIADENT	0.04 ^{a}	0.03	0.06 ^{a}	0.04	0.08 ^{ab}	0.05
MK LIFE	0.03 ^{a}	0.02	0.06 ^{a}	0.03	0.10 ^{b}	0.04
TANARI	0.04 ^{a}	0.03	0.05 ^{a}	0.02	0.05 ^{a}	0.04

$^{a.b}$ Different superscript letters demonstrate significant differences between cones at the same level. according to the Tukey test ($P < 0.05$). sd: standard-deviation

Table III - Compatibility analysis of the Reciproc Blue instrument and gutta-percha cones

Grupos	*D1*		*D6*		*D12*	
	MEAN	*sd*	*MEAN*	*sd*	*MEAN*	*sd*
VDW	0.06 ^{a}	0.02	0.05 ^{a}	0.02	0.03 ^{a}	0.01
DIADENT	0.06 ^{a}	0.03	0.05 ^{a}	0.04	0.05 ^{a}	0.02
MK LIFE	0.04 ^{a}	0.03	0.04 ^{a}	0.03	0.03 ^{a}	0.02
TANARI	0.10^{b}	0.03	0.05 ^{a}	0.03	0.04 ^{a}	0.05

$^{a.b}$ Different superscript letters demonstrate significant differences between cones at the same level. according to the Tukey test ($P < 0.05$). sd: standard-deviation

Given that the goal of root canal obturation is to efficiently fill its space, preventing reinfection, and restoring periapical tissue health [8,9], the possibility of discrepancies between mechanized instruments and their corresponding gutta-percha cones, findings already reported in the literature [9], might become problematic considering the increasingly frequent suggestion of simplifying treatment steps [8,10]

In 1955, Ingle suggested that root canal instruments and filling materials should be standardized, ensuring that the gutta-percha cone matched the size of the last instrument used, thus ensuring better adaptation to the canal walls [11]. However, manufacturing failures of these cones have been previously reported by Mayne et al. [12], raising concerns. Consequently, an international standard (ISO 6877:2006) for gutta-percha cones for endodontic obturation was adopted in 2006 [13]. The sizes of obturator cones specified in this standard were aligned with corresponding sizes of root canal preparation instruments specified in ISO 3630-1 [14].

ISO 6877:2006 specifies, among other points, that gutta-percha cones should be tapered throughout their length, uniform in composition and color, with smooth surfaces and free from deformities unless indicated otherwise by the manufacturer. The standard allows a tolerance of +/- 0.05 mm in diameter for sizes #10 to #25 and 0.07 mm for sizes #30 to #140. It also dictates that the cone should be uniform for a minimum of 16 mm from the tip [12,15].

According to Hatch et al. [16], there are several possible reasons for different results in studies on dimensional variability of instruments and gutta-percha cones. One reason is that, even if manufacturers adhere to a standard, the wide variation allowed by the standards accepts diameter tolerances of up to 0.05 mm for cones, depending on the cone's diameter. Thus, cones of the same diameter may encompass a diameter above or below the stated size, resulting ultimately in unsatisfactory cone adaptation to the root canal wall.

Regarding the observed results, concerning F2 and Primary instruments from PTG and WOG systems, it was noted that the corresponding cones from the manufacturers themselves presented the largest discrepancies at the three evaluated levels, being significant in PTG both in D1 and D6 ($P < 0.05$). The Tanari cones showed the smallest diameter differences compared to F2 files. In the case of the Primary instrument from WOG, significant differences were observed at the three tested levels, also presenting the highest discrepancy values for the manufacturer's cones. Among the other brands tested, no consistent differences were observed. These findings raise concerns about the quality of fit of these cones in clinical conditions, mainly because they are the manufacturers' own cones.

The analysis of discrepancies between R25 cones and instruments from the RB system showed the smallest differences in diameters, presenting significance only in D1, where Tanari cones significantly diverged from the others, showing higher discrepancy values.

In Vieira et al.'s study [7], reciprocating instruments R25 (Reciproc; VDW GmbH) and #25/.06 (X1 Blue File; MK Life Dental Products) and corresponding gutta-percha cones from the manufacturers and Diadent brand were evaluated. It was observed that the instruments did not show statistically significant differences among themselves, but all gutta-percha cones, in all diameters, showed statistical differences in their dimensions.

The observed differences here are also in line with the studies of Mirmohammadi et al. [8], and Chesler et al. [10], where it was observed that the diameters of gutta-percha cones were significantly larger than the diameters of the corresponding instruments at all levels and for all brands. According to Mirmohammadi et al. [8], even though these findings may not be a significant problem for a skilled endodontist, an inexperienced clinician may find it frustrating and time-consuming. This is because having a larger diameter than the last instrument used in preparation would result in poor cone adaptation inside the canal, leading consequently to underfillings and thereby compromising the treatment's success.

On the other hand, smaller diameters could lead to recontamination problems inside the root canals. According to Chybowski et al. [17], the inability to effectively fill and seal anatomical spaces can have a detrimental effect on the success of endodontic treatment. Therefore, the presence of empty spaces between the obturator material and the canal walls may adversely affect the physical properties of the materials and facilitate the penetration of microorganisms and metabolites into periapical tissues [18].

Despite limitations as a laboratory study, the present study reinforces the need for understanding the materials used in everyday endodontic practice. Although the preparation and shaping of the canal do not always correspond solely to the design of the last instrument used in this phase, such incompatibility can generate a series of difficulties, especially for less experienced professionals. Undoubtedly, further investigations are necessary to observe whether such discrepancies can indeed interfere with the clinical use of these gutta-percha cones.

CONCLUSION

Under the study conditions and considering its limitations, it can be concluded that dedicated instrument systems and gutta-percha cones showed some dimensional variability among them, notably among the cones evaluated, with Dentsply cones exhibiting significant discrepancies.

AUTHOR'S CONTRIBUTIONS

GMRR, NV-G, BCV: Conceptualization. MESDF, GMRR, SML-C, NV-G, BCV: Methodology. MESDF, GMRR, SML-C: Validation. MESDF, GMRR, SML-C: Investigation. ECP-J, NV-G, BCV: Formal Analysis. MESDF, GMRR, SML-C: Writing – Original Draft Preparation. ECP-J, NV-G, BCV: Writing – Review & Editing. BCV: Supervision.

CONFLICT OF INTERESTS

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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REGULATORY STATEMENT

The study does not involve teeth, animals, or human beings.

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