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Comparative evaluation of the dimensional compatibility of ISO #30/.06 gutta-percha cones from four different manufacturers using an endodontic gauge

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Abstract

Aim: Gutta-percha is the most commonly used biocompatible obturation material in endodontics for the three-dimensional and hermetic sealing of the root canal system. However, despite the dimensions defined in the ISO 6877 standard, dimensional discrepancies between gutta-percha cones and endodontic files have been reported. The aim of this study was to comparatively evaluate the dimensional variability of ISO #30/.06 gutta-percha cones from four different manufacturers using an endodontic gauge.

Methodology: A total of 240 ISO #30/.06 gutta-percha cones (n = 60 per brand) from four manufacturers (ProTaper Ultimate, MetaBiomed, Diadent, and EndoArt) were evaluated. Cone diameters were measured at the D0, D5, D10, and D15 levels using a Woodpecker R1 Plus endodontic gauge. Based on the ISO 6877 nominal dimensions, measurements were categorized as undersized, within the nominal range, or oversized. Statistical analysis was performed using Pearson's chi-square and Fisher's exact tests with Bonferroni correction ($p < 0.05$).

Results: Dimensional discrepancies from the nominal ISO values were observed across all measurement levels, with statistically significant differences among the brands ($p < 0.05$). ProTaper Ultimate and MetaBiomed showed the highest compatibility with nominal dimensions, whereas EndoArt exhibited a consistently high proportion of undersized cones (57.1–67.2%) across all regions. Diadent showed a notably high proportion of oversized cones at the D15 level (66.7%). Effect sizes for between-brand comparisons were large at every level (Cramer's V = 0.386-0.503).

Conclusion: ISO #30/.06 gutta-percha cones from different manufacturers did not show complete dimensional compatibility. These discrepancies may adversely affect apical adaptation, particularly in single-cone obturation techniques, potentially reducing clinical success. The use of an endodontic gauge provides a practical means of objectively verifying cone-canal adaptation in clinical practice, helping to prevent microleakage and obturation errors.

Keywords: Gutta-percha, endodontic gauge, dimensional compatibility, root canal treatment, dimensional accuracy, ISO 6877, root canal obturation

Introduction

Gutta-percha is a biocompatible obturation material widely used in root canal treatment, and its primary purpose is to seal the root canal system in a three-dimensional and leak-proof manner. It provides a hermetic seal in the apical and lateral regions, preventing microorganisms and tissue fluids from entering the canal (1). Thus, it contributes to the healing of periapical tissues by preventing bacterial contamination. Its adaptation to the canal walls minimizes voids and sealing material shrinkage (2). Proper adaptation in the apical region directly affects the long-term stability and functional success of the filling. Therefore, the size and taper of the gutta-percha, which must match the files used for canal preparation, are critical factors in ensuring sealing (1).

Gutta-percha cones are obturation materials that must be manufactured in sizes and tapers specified by the ISO 6877 standard. However, the literature reports significant differences in diameter and taper between gutta-percha cones manufactured to standard sizes and endodontic files (3, 4). These dimensional inconsistencies can complicate apical adaptation, particularly in single-cone filling techniques, and indirectly negatively affect sealability. Therefore, verifying the suitability of the main cone to the canal dimensions prior to filling is important in clinical practice (5). The endodontic gauge is a ruler developed for clinical measurement that allows for the verification of the diameters of gutta-percha cones used in root canal treatment and, when necessary, their resizing. Accurate determination of the apical diameter is critical for ensuring an apical seal and minimizing void formation between the filling material and canal walls. Endodontic gauges, which are widely used in clinical practice, are easily accessible and practical measurement tools (2, 3).

The findings of this study are intended to provide scientific evidence for the objective evaluation of cone fit, which directly affects the success of apical sealing and the prevention of clinical problems, such as microleakage, underfilling, or overfilling, that may develop due to the use of poorly fitting cones. The aim of this study was to comparatively evaluate the dimensional variability of ISO #30/.06 gutta-percha cones from four different manufacturers using an endodontic gauge.

The null hypothesis of our study was that ISO #30/.06 gutta-percha from different manufacturers would show complete conformity with the nominal measurements and that there would be no statistically significant differences between the brands.

Materials and Methods

In this study, ISO #30/.06 taper gutta-perchas from four different manufacturers (Diadent Dia-ProT Plus, ProTaper Ultimate, EndoArt, and MetaBiomed) were evaluated (Fig. 1). A total of 240 cones (60 from each brand) were included. All samples were obtained directly from the manufacturers, stored under the same environmental conditions, and measured on the same day to avoid any variability. Measurements were performed using a Woodpecker R1 Plus endodontic gutta-percha gauge (Woodpecker Medical Instrument Co., Guilin, China), a calibration-based measuring device designed for the assessment of gutta-percha cone diameters (Fig. 2). The gauge contains predefined calibration holes and operates on a go/no-go principle, rather than providing continuous digital measurements. Measurements were performed using a go/no-go assessment approach by determining whether the gutta-percha cone matched, exceeded, or remained below the corresponding calibration diameter at each measurement level. The diameter of each cone was determined at the apical tip (D0) and at 5 mm (D5), 10 mm (D10), and 15 mm (D15) from the tip. To ensure methodological reliability, all measurements were independently performed in a blinded manner by two researchers, and the mean values obtained for each region were used for the statistical analysis. Cohen's kappa coefficient was calculated to assess interrater reliability.

Figure 1. Gutta-percha cones used.

Figure 2. Endodontic gutta-percha gauge.

According to ISO 6877, the nominal dimensions for ISO #30/.06 gutta-percha cones, the theoretical diameters were defined as 0.30 mm at D0, 0.60 mm at D5, 0.90 mm at D10, and 1.20 mm at D15 (Table 1). Based on these reference values, cones were categorized as undersized (smaller than the nominal ISO diameter; the cone passes through the calibration hole without resistance), within nominal range (matching the nominal ISO diameter and providing proper cone-to-canal adaptation) and oversized (larger than the nominal ISO diameter; the cone does not pass through the calibration hole, indicating dimensional incompatibility) (Fig. 3).

Table 1. Theoretical ISO #30/.06 Dimensions.

Measurement Level	Theoretical ISO #30/.06 Diameter
D0	0.30 mm
D5	0.60 mm
D10	0.90 mm
D15	1.20 mm

The classification was based on the cone passage through the calibration hole corresponding to the ISO 6877 nominal diameter for each measurement level.

Figure 3. Measurement of gutta-percha cones.

Statistical Analysis

Data analysis was performed using the IBM SPSS 27 software (IBM Corp., Armonk, NY, USA).

Descriptive statistics were expressed as numbers and percentages. The Pearson Chi-Square test was used when expected frequencies were >5, and Fisher's exact test was applied otherwise. Given the descriptive and comparative nature of this study, separate pairwise comparisons were performed for each brand and region. To control for type I error inflation arising from multiple comparisons, the Bonferroni correction was applied throughout. Although multivariable approaches, such as log-linear analysis or mixed-effects models, allow for the simultaneous estimation of brand-by-region interaction effects, such modeling was beyond the scope of this study, which aimed to characterize dimensional distribution patterns within each brand and region independently. The pairwise comparison approach employed in this study is consistent with the methodologies used in comparable gutta-percha standardization studies in the literature (3, 5, 6). To quantify the magnitude of association beyond statistical significance, Cramer's V was calculated for each chi-square analysis. Effect size was interpreted as small ($V \leq 0.10$), moderate ($0.10 < V \leq 0.30$), or large ($V > 0.30$).

Results

The kappa analysis yielded a coefficient of 0.91, indicating a substantial agreement between the observers. Cramer's V effect sizes for between-brand comparisons within each region (Table 3) were large across all levels (D0: V=0.421; D5: V=0.503; D10: V=0.386; D15: V=0.478).

This indicates practically significant differences among brands. Within-brand regional comparisons (Table 2) showed negligible to moderate effect sizes (EndoArt: V=0.083; Diadent: V=0.104; ProTaper Ultimate: V=0.222; MetaBiomed: V=0.321), reflecting varying degrees of dimensional consistency across measurement levels within each brand. In the D0 region, undersized cones were most frequently observed in EndoArt cones (57.1%), followed by Diadent (28.6%), ProTaper Ultimate (10%), and MetaBiomed (4.3%) cones (Fig. 4). Dimensionally compatible cones were most common in ProTaper Ultimate (35.7%) and MetaBiomed (26.4%), whereas lower values were recorded for Diadent (25%) and EndoArt (12.9%) (Fig. 5). Oversized thickness was particularly high in MetaBiomed (66.7%), with lower proportions detected in Diadent (16.7%), ProTaper Ultimate (10%), and EndoArt (6.7%) (Fig. 6).

In the D5 region, undersized predominated in EndoArt (66.1%) and Diadent (33.9%) but was not observed in ProTaper Ultimate or MetaBiomed. Dimensionally compatible cones were highest in MetaBiomed (35.8%) and ProTaper Ultimate (30.2%), while Diadent and EndoArt demonstrated lower percentages of 22.8% and 11.1%, respectively. Oversized was most frequent in ProTaper Ultimate (68.8%) and less common in MetaBiomed (12.5%), Diadent (12.5%), and EndoArt (6.3%).

In the D10 region, the highest proportion of undersized cones was again observed in EndoArt (61.4%), followed by Diadent (28.1%), while ProTaper Ultimate (8.8%) and MetaBiomed (1.8%) showed relatively low values. Dimensionally compatible cones were greatest in MetaBiomed (34.3%) and ProTaper Ultimate (29.1%), Diadent, and EndoArt showed 23.3% and 13.4%, respectively. Oversized cones were predominant in ProTaper Ultimate (45.5%) and Diadent (36.4%), whereas EndoArt showed 18.2%, and MetaBiomed showed no thick cones (0%) at this level.

Finally, in the D15 region, the highest proportion of undersized cones was observed in EndoArt (67.2%) and lower in Diadent (25%) and MetaBiomed (7.8%), whereas it was not observed in ProTaper Ultimate. Dimensionally compatible cones were most frequent in ProTaper Ultimate (36%), followed by MetaBiomed (32.9%), Diadent (22%), and EndoArt (9.1%). Oversized was particularly high in Diadent (66.7%), while lower proportions were found in EndoArt (16.7%), ProTaper Ultimate (8.3%), and MetaBiomed (8.3%).

Table 2. Regional distribution by thickness across brands and their correlations.

Brand	Region	Undersized			Dimensionally compatible			Oversized			Test statistic	p
		n	%	C%	n	%	C%	n	%	C%		
EndoArt	D0	40	66.7	25.2	18	30.0	24.3	2	3.3	28.6	3.334 V=0.083	0.786
	D5	41	68.3	25.8	18	30.0	24.3	1	1.7	14.3		
	D10	35	58.3	22.0	23	38.3	31.1	2	3.3	28.6		
	D15	43	71.7	27.0	15	25.0	20.3	2	3.3	28.6		
Diadent	D0	20	33.3	27.4	35	58.3	23.6	5	8.3	26.3	5.240 V=0.104	0.515
	D5	21	35.0	28.8	37	61.7	25.0	2	3.3	10.5		
	D10	16	26.7	21.9	40	66.7	27.0	4	6.7	21.1		
	D15	16	26.7	21.9	36	60.0	24.3	8	13.3	42.1		
ProTaper Ultimate	D0	7^{aA}	11.7	58.3	50^{bA}	83.3	24.0	3^{bAB}	5.0	15.0	23.712 V=0.222	<0.001*
	D5	0^{aB}	0.0	0.0	49^{aA}	81.7	23.6	11^{bB}	18.3	55.0		
	D10	5^{aAB}	8.3	41.7	50^{aA}	83.3	24.0	5^{aAB}	8.3	25.0		
	D15	0^{aB}	0.0	0.0	59^{aB}	98.3	28.4	1^{aA}	1.7	5.0		
MetaBiomed	D0	3^{aA}	5.0	33.3	37^{aA}	61.7	17.8	20^{bA}	33.3	87.0	49.583 V=0.321	<0.001*
	D5	0^{aA}	0.0	0.0	58^{aB}	96.7	27.9	2^{aB}	3.3	8.7		
	D10	1^{abA}	1.7	11.1	59^{bB}	98.3	28.4	0^{aB}	0.0	0.0		
	D15	5^{aA}	8.3	55.6	54^{abB}	90.0	26.0	1^{bB}	1.7	4.3		

*p<0.05. %: Row percentage; C%: Column percentage for thickness.
Superscript lowercase letters (a, b) indicate differences in column percentages among thickness categories within the same row. Superscript uppercase letters (A, B) indicate differences in row percentages among regions within the same column. Different letters indicate statistically significant differences (p<0.05, Bonferroni-corrected). Cramer's V values are reported below each chi-square statistic as a measure of effect size (small: V≤0.10; moderate: 0.10<V≤0.30; large: V>0.30).

Table 3. Regional thickness distribution by brand and correlations.

Region	Brand	Undersized			Dimensionally compatible			Oversized			Test statistic	p
		n	%	C%	n	%	C%	n	%	C%		
D0	EndoArt	40^{aA}	66.7	57.1	18^{bA}	30.0	12.9	2^{bA}	3.3	6.7	84.939 V=0.421	<0.001*
	Diadent	20^{aB}	33.3	28.6	35^{aB}	58.3	25.0	5^{aA}	8.3	16.7		
	ProTaper Ultimate	7^{aC}	11.7	10.0	50^{bC}	83.3	35.7	3^{aA}	5.0	10.0		
	MetaBiomed	3^{aC}	5.0	4.3	37^{bB}	61.7	26.4	20^{cB}	33.3	66.7		
D5	EndoArt	41^{aA}	68.3	66.1	18^{bA}	30.0	11.1	1^{bA}	1.7	6.3	121.262 V=0.503	<0.001*
	Diadent	21^{aB}	35.0	33.9	37^{aB}	61.7	22.8	2^{aA}	3.3	12.5		
	ProTaper Ultimate	0^{aC}	0.0	0.0	49^{bB}	81.7	30.2	11^{cB}	18.3	68.8		
	MetaBiomed	0^{aC}	0.0	0.0	58^{bC}	96.7	35.8	2^{bA}	3.3	12.5		
D10	EndoArt	35^{aA}	58.3	61.4	23^{bA}	38.3	13.4	2^{bA}	3.3	18.2	71.606 V=0.386	<0.001*
	Diadent	16^{aB}	26.7	28.1	40^{aB}	66.7	23.3	4^{aA}	6.7	36.4		
	ProTaper Ultimate	5^{aC}	8.3	8.8	50^{bB}	83.3	29.1	5^{bA}	8.3	45.5		
	MetaBiomed	1^{aC}	1.7	1.8	59^{bC}	98.3	34.3	0^{abA}	0.0	0.0		
D15	EndoArt	43^{aA}	71.7	67.2	15^{bA}	25.0	9.1	2^{bA}	3.3	16.7	109.795 V=0.478	<0.001*
	Diadent	16^{aB}	26.7	25.0	36^{aB}	60.0	22.0	8^{bA}	13.3	66.7		
	ProTaper Ultimate	0^{aC}	0.0	0.0	59^{bC}	98.3	36.0	1^{abA}	1.7	8.3		
	MetaBiomed	5^{aC}	8.3	7.8	54^{bC}	90.0	32.9	1^{abA}	1.7	8.3		

*p<0.05. %: Row percentage; C%: Column percentage for thickness.
Superscript lowercase letters (a, b, c): indicate differences in column percentages among brands within the same row. Superscript uppercase letters (A, B, C) indicate differences in row percentages among regions within the same column. Different letters indicate statistically significant differences (p<0.05, Bonferroni-corrected). Cramer's V values are reported below each chi-square statistic as a measure of effect size (small: V≤0.10; moderate: 0.10<V≤0.30; large: V>0.30).

Table 4. Regional distribution by brand for thicknesses and their correlations.

Thickness	Brand	D0 n	D0 %	D0 C%	D5 n	D5 %	D5 C%	D10 n	D10 %	D10 C%	D15 n	D15 %	D15 C%	Test statistic	p
Undersized	EndoArt	40^{A}	25.2	57.1	41^{A}	25.8	66.1	35^{A}	22.0	61.4	43^{AB}	27.0	67.2	19.147 V=0.159	0.013*
	Diadent	20^{A}	27.4	28.6	21^{A}	28.8	33.9	16^{A}	21.9	28.1	16^{AB}	21.9	25.0		
	ProTaper Ultimate	7^{A}	58.3	10.0	0^{A}	0.0	0.0	5^{A}	41.7	8.8	0^{B}	0.0	0.0		
	MetaBiomed	3^{A}	33.3	4.3	0^{A}	0.0	0.0	1^{A}	11.1	1.8	5^{A}	55.6	7.8		
Dimensionally compatible	EndoArt	18	24.3	12.9	18	24.3	11.1	23	31.1	13.4	15	20.3	9.1	6.082** V=0.056	0.739
	Diadent	35	23.6	25.0	37	25.0	22.8	40	27.0	23.3	36	24.3	22.0		
	ProTaper Ultimate	50	24.0	35.7	49	23.6	30.2	50	24.0	29.1	59	28.4	36.0		
	MetaBiomed	37	17.8	26.4	58	27.9	35.8	59	28.4	34.3	54	26.0	32.9		
Oversized	EndoArt	2^{aA}	28.6	6.7	1^{aABC}	14.3	6.3	2^{aA}	28.6	18.2	2^{aAB}	28.6	16.7	40.770 V=0.444	<0.001*
	Diadent	5^{aA}	26.3	16.7	2^{aC}	10.5	12.5	4^{abAB}	21.1	36.4	8^{bB}	42.1	66.7		
	ProTaper Ultimate	3^{aA}	15.0	10.0	11^{bB}	55.0	68.8	5^{abAB}	25.0	45.5	1^{aA}	5.0	8.3		
	MetaBiomed	20^{aB}	87.0	66.7	2^{bAC}	8.7	12.5	0^{bB}	0.0	0.0	1^{bA}	4.3	8.3		

*p<0.05. **Pearson's Chi-square test. %: Row percentage; C%: Column percentage for thickness.
Lowercase letters indicate differences among column percentages within rows, and uppercase letters indicate differences among row percentages within columns.

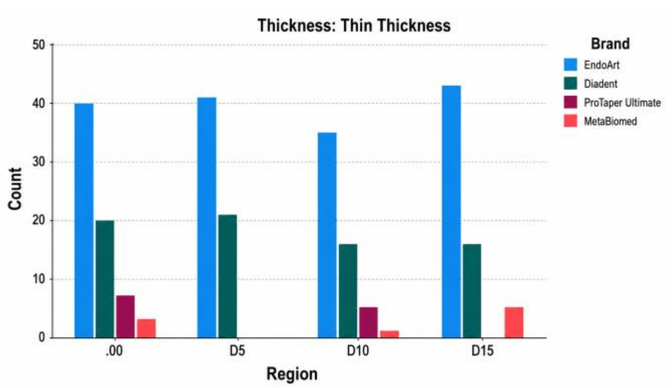

Figure 4. Distribution of undersized thickness ratios by brand in the D0, D5, D10, and D15 regions.

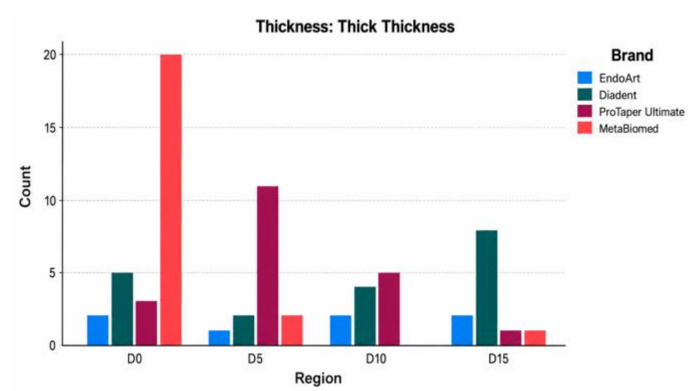

Figure 6. Distribution of oversized ratios by brand in the D0, D5, D10, and D15 regions.

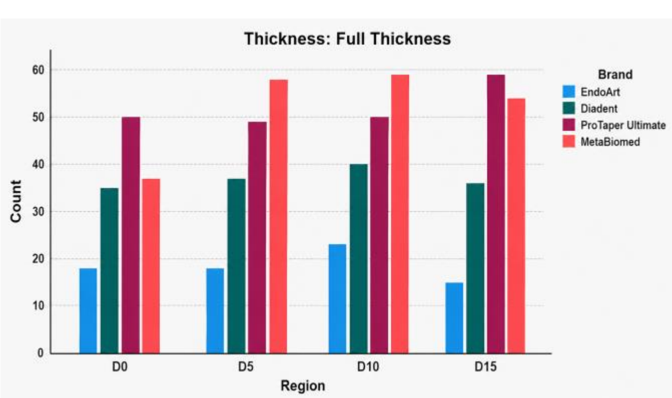

Figure 5. Distribution of dimensionally compatible ratios by brand in the D0, D5, D10, and D15 regions.

Discussion

In this study, we comparatively evaluated the dimensional variability of ISO #30 gutta-percha cones from four different manufacturers using an endodontic gauge. Inadequacies in the dimensional standardization of gutta-percha pose a significant problem in terms of coronal, mid-canal, and apical sealing in root canal treatment. Although ISO 6877 and ANSI/ADA standards define specific ranges, these ranges can lead to significant deviations between gutta-perchas in practice (1). The literature shows that diameter mismatches range from 7% to 21% (1). It has been reported that mismatches are more pronounced in the 6% taper group and that gutta-percha often exhibits larger diameters than the corresponding file (1, 5). This situation reveals that inconsistencies can occur not only between manufacturers but also within the same system. Furthermore, the fact that some brands show higher compliance with standards while significant differences are observed in others highlights the variability in quality control processes (5, 6).

Our findings demonstrated the standardization issues reported in the literature; therefore, our null hypothesis was rejected. When examining the nominal range rates, the ProTaper Ultimate (29–36%) and MetaBiomed (26–36%) groups showed the highest compliance. Diadent presented moderate results, particularly at the D10 (23.3%) and D15 (22%) levels, whereas EndoArt had the lowest rates across all levels (9–13%). This incompatibility is particularly evident in the single-cone technique and is associated with incomplete obturation and an increased risk of leakage (1). Failure to achieve hermetic sealing in the apical region may lead to increased sealer thickness and reduced adaptation, which may be clinically relevant during obturation procedures. Furthermore, the lack of standardization in gutta-percha may not only represent a technical production issue but may also potentially affect cone-canal adaptation and obturation quality, particularly in single-cone techniques (5).

Endodontic gauges are clinical measuring instruments developed to verify and, if necessary, resize the tip diameter of gutta-percha used in root canal treatment. Due to their ease of use and accessibility, they are widely preferred in both clinical practice and research (6). Bueno et al. reported that endodontic gauges provided results with similar accuracy when compared to advanced techniques such as microscopes, profilometers, or digital calipers (6). Hoffman et al. also evaluated gutta-perchas of different sizes and taper using two different calibration gauges and showed that these devices provided measurement results close to ISO standards (7). According to the manufacturer's data, the Woodpecker R1 Plus model used in our study can measure gutta-percha diameter with an accuracy of 0.01 mm using 18 different calibration holes. These features provided a suitable method for examining the dimensional standardization of gutta-percha in this study. However, advanced measurements using digital or optical systems may contribute to revealing micron-level deviations caused by production processes. Therefore, while our study opted for a method that is suitable and applicable in clinical conditions, its generalizability would increase if supported by more precise devices.

In current endodontic practice, 30/.06 gutta-percha points are one of the most frequently preferred sizes, particularly in terms of the spread of the irrigation solution within the canal and apical adaptation. Srirekha et al. reported that irrigation penetration in mandibular molar distal canals was significantly higher with 30/.06 preparations compared to 30/.04 (8). Alongside these clinical advantages, 30/.06 gutta-perchas stand out as one of the groups most frequently reported in the literature for standardization issues (1). Turan Gökduman et al. revealed that production differences and taper variability in ISO 30/.06 gutta-perchas lead to significant deviations (1). Similarly, Galán et al. drew attention to the inconsistencies between larger taper gutta-perchas and standard values and emphasized that such gutta-perchas should be routinely checked before clinical use (9). Martínez et al. reported the highest rates of incompatibility in the 6% taper group in their study examining file-gutta-percha compatibility (5). The reason for choosing 30/.06 gutta-perchas is that this size is one of the most frequently used groups in current endodontic practice and that the taper value most frequently reported in the literature as having standardization issues is the 0.06 taper value (5). This allowed for a detailed examination of both the most commonly used gutta-percha sizes clinically and the size group considered most critical in terms of mismatch.

The dimensional mismatch of gutta-percha tips in the D0–D1 region has been frequently reported in the literature. Cunha et al. evaluated gutta-perchas of different sizes (#30, #40, and #50) using an endodontic gauge and reported deviations from the specified D0 value in all groups (10). Similarly, Aguiar et al. found that 36% of the gutta-perchas they examined were not compatible with the file size corresponding to the D0 diameter (11). Therefore, many researchers recommend verifying the D0 diameter of the main gutta-percha with an endodontic gauge and, if necessary, recutting the tip to ensure compatibility (9). The findings of our study are largely consistent with those reported in the literature. Regarding D0, a significant proportion of the gutta-percha samples in the ProTaper Ultimate (83.3%), MetaBiomed (61.7%), and Diadent (58.3%) groups were within the ideal size range. In the EndoArt group, an ideal fit was detected in 30.0% of cases, which was lower than that of the other brands. This result supports the wide variation range reported in the literature and indicates that dimensional differences may exist depending on the manufacturers.

When examining the D5 level, there has been no evaluation of the D5 region in the literature, making our study unique in this respect. In our analyses, the highest level of oversized was observed in the ProTaper Ultimate group at a rate of 18.3%, while undersized was significantly prominent in the EndoArt group at a rate of 68.3%. In the Diadent group, the undersized was at a moderate level (35.0%), whereas in the MetaBiomed group, the within-nominal-range rate was the highest (96.7%). These results clearly demonstrate the differences between brands in the D5 region and show that our study provides an innovative contribution to the literature.

Different findings have been reported in the literature regarding the D10 level. Eskibağlar et al. reported that the file diameter was larger than the gutta-percha diameter up to D10, whereas the gutta-percha diameter exceeded the file diameter from D11 onwards (12). The literature also reports that in some systems, the file diameter is wider than the gutta-percha in the apical region, in some, there is no significant difference, and in others, the gutta-percha exceeds the file diameter (12). In our study, 58.3% of the gutta-percha cones in the EndoArt group were found to be undersized, which is consistent with the findings of Eskibağlar et al., indicating that the file diameter may be larger, especially at the D10 level. In contrast, Salles et al. reported different results, finding that gutta-percha diameters were larger than those of files at the D11 level in some size and taper combinations (13). In our study, a higher rate of fit than that reported in the literature was observed in the ProTaper Ultimate (83.3%) and MetaBiomed (98.3%) groups at the D10 level, whereas a rate of 66.7% was determined in the Diadent group, which is close to the standard values. At the D10 level, oversized gutta-perchas were detected at a very limited level across all groups.

The D15 level is an important reference point for evaluating the diameter and taper match of gutta-percha points and files. The coronal seal is as critical as the apical seal for the long-term success of root canal treatment (14). Inadequate coronal sealing can negatively affect the treatment prognosis by increasing the risk of microleakage and reinfection. The clinical significance of measurements at the D15 level is limited, particularly for canines and teeth with exceptionally long roots, because the root length is longer than that of other teeth, and therefore, tug-back will occur in the coronal region (15). While some systems report minimal differences in the literature, others report significant deviations exceeding tolerance limits (5, 12). Similarly, in our study, incompatibilities were observed between different brands; ProTaper Ultimate (98.3%) and MetaBiomed (90.0%) showed a high degree of complete dimensional compatibility, whereas EndoArt showed a high proportion of undersized cones (71.7%), and Diadent demonstrated within the nominal range at a rate of 60.0%. These results are consistent with those reported in the literature and may support the risks of difficulty in reaching the working length, an inadequate apical seal, and material extrusion from a clinical perspective.

Limitations

The methodological design of this study has several limitations. First, the Woodpecker R1 Plus gauge operates on a go/no-go calibration principle rather than continuous digital measurement; consequently, raw diameter values (mean ± SD, median, IQR, min-max) could not be derived from the collected data. Future studies employing digital calipers, profilometers, or micro-CT should permit continuous measurement and quantitative reporting of dimensional deviations. Second, restricting the examination to only ISO #30/.06 gutta-percha limits the generalizability to other sizes and taper values. Third, although the use of an endodontic gauge offers a clinically practical method, it may not capture micron-level deviations detectable with advanced techniques such as digital micrometers, optical microscopy, or micro-CT. Fourth, conducting the study under in vitro conditions excluded environmental factors, such as temperature and humidity, that may affect cone dimensions during clinical use. Fifth, the evaluation of materials from only four manufacturers limits the generalizability of the results to other products on the market. From a statistical standpoint, the present study employed pairwise comparisons with Bonferroni correction rather than a multivariable approach such as log-linear analysis. While log-linear models allow the simultaneous estimation of brand-by-region interaction effects, the primary aim of this study was to characterize dimensional distribution patterns within each brand and region independently. The chosen approach is consistent with the methods used in comparable gutta-percha standardization studies in the literature (3, 5, 6). Future studies examining gutta-percha of different sizes and taper values will contribute to a more comprehensive evaluation of manufacturer-related variations. Supporting the findings obtained with the endodontic gauge using micro-CT or digital imaging techniques may allow for a more detailed presentation of production-related dimensional differences. Furthermore, research using different sealer types and obturation techniques in simulation models that reflect clinical conditions will provide an opportunity to evaluate the effects of these variations on treatment success more directly.

Conclusion

Within the limitations of this in vitro study, dimensional variability was observed among the ISO #30/.06 gutta-percha cones from different manufacturers. ProTaper Ultimate and MetaBiomed exhibited the highest compatibility with nominal ISO dimensions across all measurement levels. EndoArt showed a consistently high proportion of undersized cones across all regions, which may compromise the tug-back sensation and apical seal. Diadent exhibited a notably high rate of oversized cones at the D15 level (66.7%), which may impede insertion to the working length. These dimensional discrepancies may affect cone-canal adaptation, particularly in single-cone obturation techniques. Therefore, pre-obturation verification of the gutta-percha cone dimensions using an endodontic gauge is recommended to optimize apical adaptation and minimize the risk of obturation errors.

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