

Scanning Electron Microscopic Evaluation of Dimensional Wear, Surface Roughness and Working-Edge Morphology of Periodontal Gracey Curettes after Repeated Clinical Use

Dr. Sabatani A¹, Dr. T. Sri Shivasankari, MDS, PhD², Dr. Paavai Ilango, MDS, PhD³, Dr. W R Gnanasagar, MDS⁴, Dr. Ayswarya V Vummidi, MDS⁵

Post graduate, Department Of Periodontology And Oral Implantology, Priyadarshini Dental College And Hospital, Tiruvallur, Tamilnadu¹, Professor and Head, Department Of Periodontology And Oral Implantology, Priyadarshini Dental College And Hospital, Tiruvallur, Tamilnadu², The Tamilnadu Dr. Mgr University, Guindy, Tamilnadu, Reader, Department Of Periodontology And Oral Implantology, Priyadarshini Dental College And Hospital, Tiruvallur, Tamilnadu⁴, Reader, Department Of Periodontology And Oral Implantology, Priyadarshini Dental College And Hospital, Tiruvallur, Tamilnadu⁵

Corresponding author: Dr. T. Sri Shivasankari, MDS, PhD, drsivasankariperio@gmail.com

ABSTRACT

Background: The efficiency of periodontal scaling and root planing is influenced by the dimensional integrity, surface smoothness and cutting-edge sharpness of curettes. Repeated clinical use may alter the morphology of the working end, but evidence based on Scanning Electron Microscopy (SEM) regarding the extent of such deterioration is limited.

Aim: To evaluate dimensional wear, surface roughness, toe morphology and cutting-edge characteristics of Gracey curettes after repeated clinical use using SEM.

Materials and Methods: An in-vitro study evaluated Gracey curettes grouped according to recorded clinical use: new instrument (0 uses) and instruments used for 100, 200, 300 and 400 uses/quadrants. SEM images were used to assess blade length, width, thickness, surface roughness, toe symmetry and cutting-edge morphology. Quantitative variables were analyzed using one-way ANOVA with post hoc comparison, and categorical variables were analyzed using the chi-square test. Statistical significance was set at $p < 0.05$.

Results: Increasing use was associated with significant dimensional reduction and increased roughness. Mean length decreased from 4.59 ± 0.25 in the new instrument to 2.69 ± 0.11 after 400 uses; width decreased from 0.90 ± 0.00 to 0.72 ± 0.04 ; thickness decreased from 0.65 ± 0.02 to 0.44 ± 0.02 ; and roughness increased from 2.17 ± 0.31 to 15.92 ± 0.49 (all $p < 0.001$). Toe symmetry also deteriorated significantly ($\chi^2 = 98.96$, $df = 8$, $p < 0.001$), with all observations becoming unacceptable after 400 uses. Cutting-edge morphology changed from sharp edges in all new instruments to irregular edges, non-functional wire edges or wide bevels after 400 uses ($\chi^2 = 138.38$, $df = 20$, $p < 0.001$).

Conclusion: Repeated clinical use progressively compromises the dimensional stability, surface integrity and cutting-edge morphology of Gracey curettes. SEM-based assessment suggests that curettes should be inspected and reshaped before extensive use, and replacement should be considered when asymmetry, wide bevel formation or non-functional wire edges are evident.

Keywords: Dental curette; Gracey curette; periodontal instrumentation; root planing; scanning electron microscopy; sharpness; surface roughness.

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INTRODUCTION

Scaling and root planning remain essential components of periodontal therapy because they are known to reduce inflammation, periodontal pocket depth, support clinical attachment gain and achieve biologically acceptable root surfaces.^{1,2} Manual curettes continue to be widely used for subgingival instrumentation. The efficiency of manual curettes depends not only on operator skill but also on the geometry and integrity of the working end, including blade dimensions, toe morphology, surface smoothness and cutting-edge quality.^{3,4}

Gracey curettes are area-specific instruments designed specifically to adapt closely to root morphology. Their offset blade and working angulation allow the lower shank are positioned

parallel to the tooth surface during subgingival scaling and root planing.⁴⁻⁶ The working edge has direct clinical relevance particularly when accessing narrow root surfaces and furcation entrances. Appropriate blade dimensions may influence accessibility such as sharp cutting edge improves tactile sensitivity, reduces operator pressure and may decrease patient discomfort and tissue trauma.⁸⁻¹²

However, prolonged clinical use can lead to progressive mechanical wear. Previous SEM-based investigations have demonstrated that curette working ends may vary by various manufacturers and that repeated instrumentation or reshaping can further alter surface and edge morphology.^{1,9,13-}

¹⁵ These changes affect the clinical performance of the instrument and emphasizes the need for regular evaluation of its working end.

The SEM based studies have provided a practical framework for examining Gracey curette working ends through measurements of blade length, blade width, blade thickness, toe morphology, surface roughness and cutting-edge morphology.¹ The present study applies this SEM-based approach to clinically determine how increasing number of uses of Gracey curettes affect working-edge morphology and to provide practical guidance regarding sharpening or replacement of instruments.

MATERIALS AND METHODS

Study design

An in-vitro, observational, analytical study was conducted to evaluate the working ends of periodontal Gracey curettes after different recorded numbers of clinical use. The study was conducted in accordance to Checklist for Reporting In-vitro Studies (CRIS) guidelines.

Sample selection and grouping

Gracey curettes were categorized according to recorded number of clinical uses/quadrants instrumented: Group I - new instrument (0 uses), Group II - 100 uses/ quadrant, Group III - 200 uses/ quadrant, Group IV - 300 uses/ quadrant and Group V - 400 uses/ quadrant. Each group contributed 15 SEM observations/measurements for quantitative analysis. Broken instruments, manufacturing defects, or incomplete usage records were excluded.

Scanning electron microscopic evaluation

The working end of each curette was evaluated under SEM as described by O'Leary TJ et al¹, frontal views were used for assessing blade length, blade width, surface roughness and toe morphology, while lateral views were used for assessing blade thickness and cutting-edge morphology.

Blade length was measured from the distal end of the blade to the top of the flat active surface. Blade width and thickness were measured at standardized points along the working end. Surface roughness was recorded from SEM-based surface assessment of the active surface. Toe morphology was assessed visually and categorized according to symmetry. Cutting-edge morphology was evaluated from high-magnification SEM images of the working edge.

Outcome variables

Quantitative outcomes included blade length, width, thickness and surface roughness. Categorical outcomes included toe morphology and cutting-edge morphology. Toe morphology was classified as symmetrical, asymmetrical or unacceptable. Cutting-edge morphology was classified as sharp edge, functional wire edge, non-functional wire edge, narrow bevel, wide bevel or irregular edge. Sharp edges were defined by a clear linear meeting of the blade face and lateral surface. Functional wire edges were defined as projections oriented

perpendicular to the edge and parallel to the scaling contact area, whereas non-functional ²

Statistical analysis

Data were entered and analyzed using SPSS 27.0 statistical software. Quantitative data were expressed as mean $\pm$ standard deviation. One-way ANOVA was used to compare quantitative variables among usage groups, followed by post hoc comparison where appropriate. Categorical variables were expressed as frequency and percentage. Chi-square test was used to find the association between categorical variables. A p value <0.05 was considered statistically significant.

RESULTS

Dimensional measurements and surface roughness

A statistically significant difference was observed among 5 groups for all quantitative parameters. Length decreased progressively from 4.59 ± 0.25 in the new instrument to 2.69 ± 0.11 after 400 uses ($F = 361.71$, $p < 0.001$). Width decreased from 0.90 ± 0.00 to 0.72 ± 0.04 ($F = 53.03$, $p < 0.001$). Thickness showed a general reduction from 0.65 ± 0.02 to 0.44 ± 0.02 ($F = 287.88$, $p < 0.001$). In contrast, surface roughness increased markedly from 2.17 ± 0.31 in the new instrument to 15.92 ± 0.49 after 400 uses ($F = 3404.82$, $p < 0.001$) (Table 1). Figure 1 illustrated the progressive reduction in length, width and thickness, together with the marked increase in surface roughness across usage groups.

Toe morphology

Toe morphology demonstrated a significant association with number of uses ($\chi^2 = 98.96$, $df = 8$, $p < 0.001$). All new instruments and 100-use instruments showed symmetrical toe morphology. At 200 uses, 46.7% of observations were asymmetrical and 53.3% remained symmetrical. At 300 uses, 66.7% were asymmetrical and 33.3% were unacceptable. After 400 uses, all observations were classified as unacceptable (Table 2). The transition from the relatively intact morphology of new instruments to visible changes in 200-use, 300-use and 400- use groups including alterations in the working end contour and cutting edge characteristics have been demonstrated in the Figure 2.

Cutting-edge characteristics

Cutting-edge morphology also showed a significant association with number of uses ($\chi^2 = 138.38$, $df = 20$, $p < 0.001$). All new instruments demonstrated sharp edges. After 100 uses, 60.0% remained sharp and 40.0% developed narrow bevels. At 200 uses, no sharp edges remained; 66.7% showed narrow bevels and 33.3% showed wide bevels. At 300 uses, functional wire edges, irregular edges and wide bevels were observed. At 400 uses, 53.3% showed irregular edges, 20.0% showed non-functional wire edges and 26.7% showed wide bevels, with no sharp or functional cutting edges remaining (Table 3).

Table 1. Dimensional parameters and surface roughness according to number of uses

Parameter	New instrument (0 uses)	100 uses	200 uses	300 uses	400 uses	F value	p value
Length	4.59 ± 0.25 ^a	3.56 ± 0.09 ^b	3.19 ± 0.10 ^c	3.18 ± 0.12 ^c	2.69 ± 0.11 ^d	361.71	<0.001
Width	0.90 ± 0.00 ^a	0.78 ± 0.04 ^b	0.74 ± 0.04 ^c	0.73 ± 0.04 ^c	0.72 ± 0.04 ^c	53.03	<0.001
Thickness	0.65 ± 0.02 ^a	0.54 ± 0.01 ^b	0.48 ± 0.01 ^d	0.51 ± 0.01 ^c	0.44 ± 0.02 ^e	287.88	<0.001
Surface roughness value	2.17 ± 0.31 ^c	6.13 ± 0.26 ^d	8.83 ± 0.27 ^c	12.95 ± 0.41 ^b	15.92 ± 0.49 ^a	340.482	<0.001

Values are expressed as mean ± standard deviation (n = 15). Different superscript letters within a row indicate significant differences among usage frequencies at $p < 0.05$. Surface roughness is presented as the recorded analytical value.

Table 2. Association between number of uses and curette toe morphology

Number of uses	Asymmetrical n (%)	Symmetrical n (%)	Unacceptable n (%)	Total (n)
New instrument	0 (0.0)	15 (100.0)	0 (0.0)	15
100 uses	0 (0.0)	15 (100.0)	0 (0.0)	15
200 uses	7 (46.7)	8 (53.3)	0 (0.0)	15
300 uses	10 (66.7)	0 (0.0)	5 (33.3)	15
400 uses	0 (0.0)	0 (0.0)	15 (100.0)	15
Total	17 (22.7)	38 (50.7)	20 (26.7)	75

Chi-square test: $\chi^2 = 98.96$, $df = 8$, $p < 0.001$.

Table 3. Association between number of uses and curette cutting-edge characteristics

Number of uses	Functional wire edge n (%)	Irregular edge n (%)	Narrow bevel n (%)	Non-functional wire edge n (%)	Sharp n (%)	Wide bevel n (%)	Total (n)
New instrument	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	15 (100.0)	0 (0.0)	15
100 uses	0 (0.0)	0 (0.0)	6 (40.0)	0 (0.0)	9 (60.0)	0 (0.0)	15
200 uses	0 (0.0)	0 (0.0)	10 (66.7)	0 (0.0)	0 (0.0)	5 (33.3)	15
300 uses	6 (40.0)	2 (13.3)	0 (0.0)	0 (0.0)	0 (0.0)	7 (46.7)	15
400 uses	0 (0.0)	8 (53.3)	0 (0.0)	3 (20.0)	0 (0.0)	4 (26.7)	15
Total	6 (8.0)	10 (13.3)	16 (21.3)	3 (4.0)	24 (32.0)	16 (21.3)	75

Chi-square test: $\chi^2 = 138.38$, $df = 20$, $p < 0.001$.

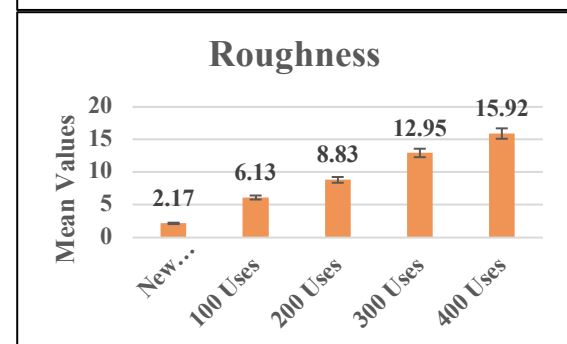
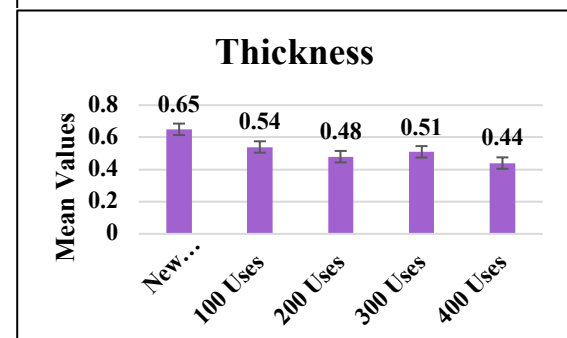
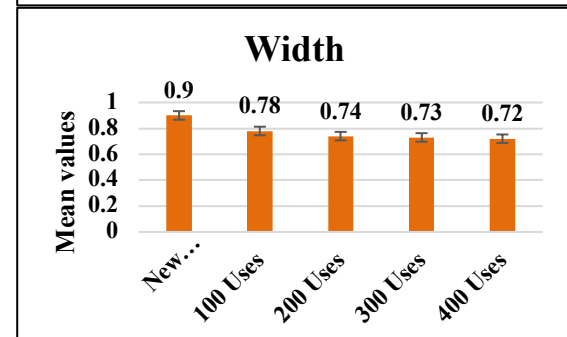
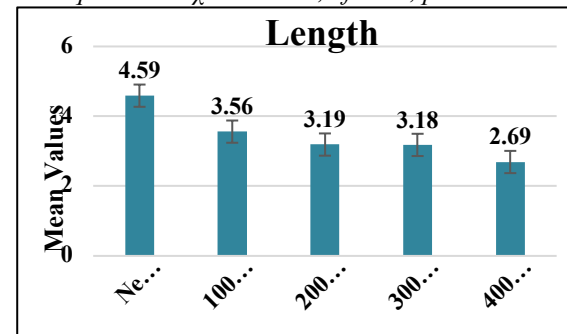


Figure 1: Bar diagrams showing changes in length (a), width (b), thickness (c) and surface roughness (d) according to number of uses.

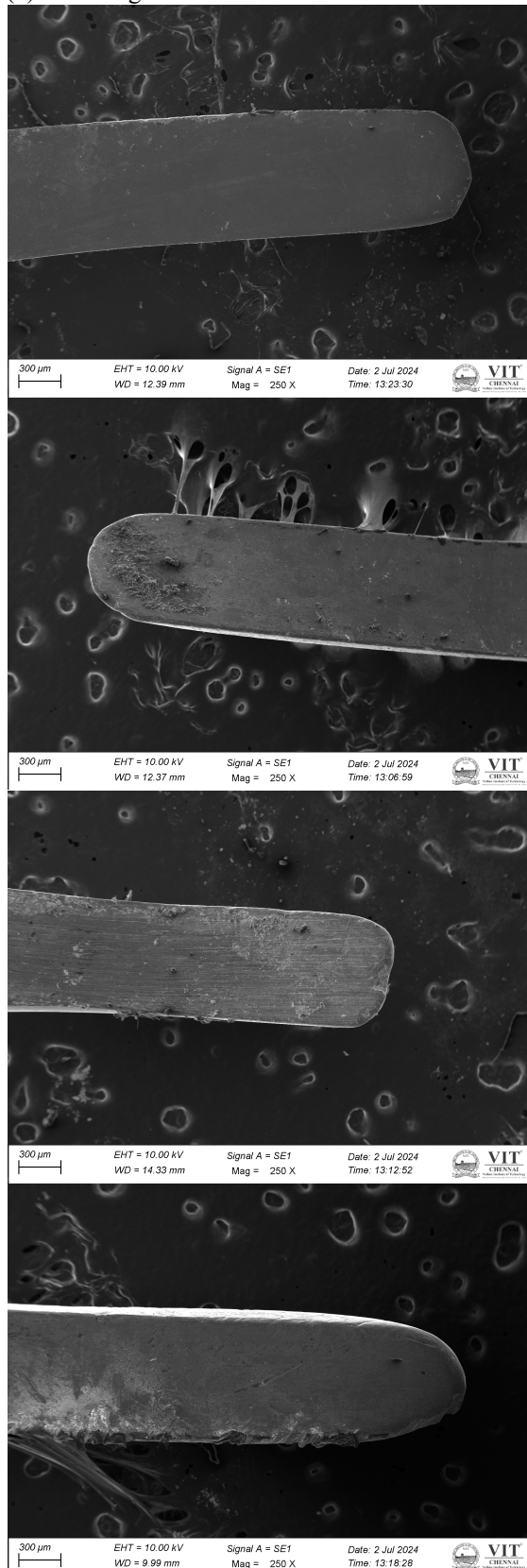


Figure 2: Representative SEM images showing progressive working-end changes of Gracey curettes

across usage groups: (a) new, (b) 200, (c) 300 and (d) 400

DISCUSSION

The present SEM-based study demonstrated progressive deterioration in the morphological dimensions of Gracey curette working ends with increasing clinical use. The length, width and thickness decreased significantly, while surface roughness increased substantially. These findings suggest cumulative material loss, surface abrasion and edge deformation during repeated instrumentation.^{9,13}

The findings have clinical significance because the efficiency of root planning is influenced by the working-end morphology of the curette. A sharp and properly contoured cutting edge allows efficient calculus removal with less lateral pressure, whereas a dull, beveled or irregular edge may reduce tactile sensitivity and increase operator effort.^{10,11} Nimmanon et al. reported that even unused standard and modified Gracey curettes from different manufacturers exhibited variations in working-end features, including blade length, toe morphology, surface roughness and cutting-edge morphology.³ These observations emphasize that instrument geometry and edge quality are important considerations in periodontal instrumentation.

The present study demonstrated that new and 100 uses per quadrant groups retained symmetrical toe morphology, whereas deterioration became evident after 200 uses/ quadrant and unacceptable toe morphology was universal after 400 uses/ quadrant. The results indicated that the repeated instrumentation may compromise the original contour of the working end. The findings suggest the importance of visual or magnified inspection as part of routine instrument maintenance.

All new instruments in the present study had sharp cutting edges, however, none of the instruments in the 200-use per quadrant group retained a sharp edge. With increasing use, the pattern shifted from sharp edges to narrow bevels, wide bevels, wire edges and irregular edges. Similar SEM-based studies have described wire-edge formation, beveling and irregularity following instrumentation or sharpening, emphasizing that both clinical use and sharpening methods can affect the functional edge.¹³⁻¹⁵

Surface roughness also increased markedly with repeated use. Increased roughness of the active surface may contribute to less controlled root instrumentation and may influence the homogeneity of the instrumented root surface. Previous SEM investigations have emphasized that surface smoothness and edge quality are important microscopic features of curette performance.^{3,9}

Although a gradual reduction in blade width may theoretically improve access to narrow areas, loss of thickness, toe symmetry and cutting-edge sharpness can compromise functional efficiency. This is

particularly relevant in furcation areas, where access is already limited and curette dimensions may exceed the width of some furcation entrances.^{12,16,17} From a practical perspective, the results indicate that reliance on unaided visual inspection may be insufficient to judge an instrument quality. A curette may appear clinically acceptable but show loss of sharpness, bevel formation or edge irregularity under SEM or magnification. Chairside inspection under magnification, regular sharpening before severe dulling, and timely replacement of instruments should therefore be emphasized in periodontal practice.

CLINICAL IMPLICATIONS

Repeatedly used curettes for scaling and root planning should not be evaluated only by gross appearance. In the current study, morphological deterioration was evident after 200 uses per quadrant and became severe by 300 to 400 uses every quadrant. Periodontal clinicians should consider routine inspection under magnification, structured sharpening protocols and replacement when instruments show asymmetry, wide bevel formation, non-functional wire edges or irregular edges. These findings support the importance of regular instrument maintenance to preserve working-end morphology and potentially improve the consistency of periodontal instrumentation.

LIMITATIONS

The study has few limitations. Instrument grouping was based on number of uses/quadrants rather than standardized instrumentation force, stroke number, root surface type or calculus load. The pressure applied by the clinician and the grade of local deposits were not standardized. The sample was limited, and the study did not directly correlate SEM findings with clinical outcomes such as calculus removal efficiency, operator fatigue, patient discomfort or root surface roughness after instrumentation. Future studies with larger samples, standardized instrumentation force, controlled root surfaces and correlation with clinical performance are recommended.

CONCLUSION

The study demonstrated that repeated clinical use resulted in significant dimensional reduction, increased surface roughness, progressive loss of toe symmetry and deterioration of cutting-edge morphology of Gracey curettes. Sharp cutting edges were lost by 200 uses every quadrant, and unacceptable morphology was prominent by 300 to 400 uses per quadrant. SEM evaluation supports the need for regular inspection, timely sharpening and replacement of curettes to maintain effective and safe periodontal instrumentation.

DECLARATIONS

Ethical approval: Not applicable for instrument-based in vitro analysis. No patient-identifiable data were used.

Informed consent: Not applicable.

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Conflicts of interest: The authors declare no conflicts of interest.

Data availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Author contributions: [Insert individual author contributions according to journal format].

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