

The effect of wear on ultrasonic scaler tip displacement amplitude

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Abstract

Aim: During clinical usage, scaler tips may become worn and reduced in length. It is unknown what effect wear has on the magnitude of scaler tip vibrations when they are utilized under typical clinical loads. The aim of this investigation was to assess the effect of simulated wear on ultrasonic scaler tip displacement amplitude, using a scanning laser vibrometer.

Materials and Methods: A Cavitron SPS (Dentsply) ultrasonic generator and three scaler insert designs (FSI-100, FSI-1000 and FSI-SLI-10S) were selected for the investigation. Tip vibration displacement amplitude was assessed unloaded and then contacting against tooth surfaces with loads of 0.5 and 1.0 N. Tips were then ground down by 1 mm and then 2 mm and scans were repeated.

Results: For all tips, load and length were found to be significant variables ($p < 0.0001$). The scaler tips showed a fall in displacement amplitude with a reduction in tip length. However, all scaler tips showed variability in the amount of oscillation that occurred. This was most pronounced with FSI-SLI-10S.

Conclusions: This investigation demonstrated that tip wear could affect the performance of dental ultrasonic scaler inserts by reducing their vibration displacement amplitude. Clinicians should be aware of this variability, which may be significant enough to affect clinical procedures.

Key words: laser vibrometer; periodontology; ultrasonic scaler

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Ultrasonic scaler systems are commonly used in dentistry for the debridement of plaque and calculus from root and tooth surfaces and have been shown to be as effective as hand instrumentation for improving periodontal health (Badersten et al. 1981, Breininger et al. 1987, Loos et al. 1987). Removal of plaque and calculus using ultrasonic scalers is primarily achieved by the mechanical chipping action of the scaler tip. A measure of the efficiency of the chipping action is the magnitude of the tip displacement amplitude (Walmsley et al. 1986, Lea et al. 2003a, b).

During normal clinical usage, scaler tips may become worn and reduced in length. It is currently unknown what effect wear has on the magnitude of scaler tip vibrations when they oscillate in air and when they contact teeth under typical clinical loading forces. It is thought that a reduction in the length

of a scaler insert tip reduces the magnitude of the scaler tip vibration. Theoretically, this may result in a reduction of scaling efficiency.

Using scanning laser vibrometry it is possible to perform a non-contacting assessment of ultrasonic scaler tip vibration (Lea et al. 2002). Previous research has investigated the effect of generator power setting (both piezoelectric and magnetostrictive systems) on loaded and unloaded scaler tip displacement amplitude (Lea et al. 2003a, b), revealing two important results. First, there is a reduction in the vibration displacement amplitude of the scaler tip when load was applied and second, there is considerable variability between tips of the same design.

The aim of this investigation was to assess the effect of tip wear on the displacement amplitude of three commonly available designs of scaler tip, using scanning laser vibrometry.

Materials and Methods

Tooth processing

Extracted molars and pre-molar teeth were collected and fixed in formalin. Prior to experimentation, they were washed in water and then partially embedded in resin (Orthoresin, Dentsply, Weybridge, Surrey, UK) such that one root aspect was left exposed to allow instrumentation. The resin block was then fixed to a mount on a Model 31 (1000 g) load cell (Sensotec, Columbus, OH, USA) connected to an E725 Microprocessor Transducer Indicator/Controller. The load cell enabled loads of 0.5 and 1.0 N to be used with an accuracy of 0.01 N.

Experimental

The generator selected for this study was the Cavitron SPS 30 kHz generator (Dentsply, York, PA, USA). The three

designs of scaler tip (five tips of each design) selected for this study (Fig. 1), were FSI-100, FSI-1000 and FSI-SLI-10S (Slimline, Dentsply, York, PA, USA).

The vibration displacement amplitudes of all tips were measured using a scanning laser vibrometer (model PSV-300-F/S High Frequency Scanning Vibrometer System, Polytec GmbH, Waldbronn, Germany), which uses the



Fig. 1. Three scaler tips used in the study from top to bottom (FSI-SLI-10S, FSI-100 and FSI-1000).



Fig. 2. An unaltered tip is placed alongside a tip that has been ground by 2 mm to simulate the effect of wear.

Table 1. Mean displacement amplitude data (measured in micrometres \pm 1 standard deviation) for unadjusted FSI-100, FSI-1000 and FSI-SLI-10S scaler inserts under loaded and unloaded conditions

Insert (design/number)	Mean tip displacement amplitude (micrometres)		
	unloaded	0.5 N load	1.0 N load
FSI-100			
Tip 1	21.93 \pm 2.33	14.19 \pm 1.02	14.37 \pm 1.47
Tip 2	22.24 \pm 1.55	18.19 \pm 0.75	13.06 \pm 1.73
Tip 3	10.37 \pm 0.86	11.53 \pm 1.65	11.31 \pm 1.94
Tip 4	19.19 \pm 2.72	11.30 \pm 1.21	13.97 \pm 1.69
Tip 5	20.20 \pm 2.46	17.38 \pm 2.38	14.48 \pm 1.65
FSI-1000			
Tip 1	22.40 \pm 2.25	16.10 \pm 1.59	19.92 \pm 0.79
Tip 2	22.22 \pm 2.79	16.67 \pm 1.54	14.21 \pm 2.47
Tip 3	21.61 \pm 2.97	17.72 \pm 1.31	18.68 \pm 2.52
Tip 4	21.58 \pm 2.33	16.70 \pm 1.79	14.07 \pm 1.22
Tip 5	29.61 \pm 2.85	17.88 \pm 2.58	15.73 \pm 1.88
FSI-SLI-10S			
Tip 1	37.82 \pm 2.49	22.77 \pm 2.99	21.22 \pm 1.37
Tip 2	28.14 \pm 2.86	26.30 \pm 1.10	19.99 \pm 1.98
Tip 3	25.18 \pm 1.34	28.31 \pm 1.60	14.81 \pm 0.51
Tip 4	29.89 \pm 1.50	23.89 \pm 1.68	20.45 \pm 1.23
Tip 5	30.87 \pm 0.98	26.67 \pm 1.48	18.41 \pm 1.08

Doppler shift of a reflected laser beam to measure vibration velocity (Lea et al. 2002) from which the displacement amplitude may be calculated.

A graduated scale was made for the SPS ultrasound generator and was positioned over the original power output display to enable accurate selection and re-location of power settings. An FSI-100 insert was selected and placed within the scaler handpiece. The scaler and handpiece were held in place via the use of a clamp, with the anterior face of the scaler tip perpendicular to the scanning laser vibrometer (SLV) camera.

The laser beam from the SLV was aligned with the camera head and a virtual measurement point was selected and superimposed over the video image of the unconstrained end of the vibrating scaler tip. This measurement point is used to guide the laser to the position on the scaler tip's surface that is to be investigated. A constant water flow rate of 20 ml/min. over the tip surface was established and was used continuously throughout this investigation for all tips.

Measurement procedure

Initially, measurements were performed with the scaler tip unloaded (i.e. oscillating in air). With the ultrasonic generator set to the half power mark, 10 scans were made over a frequency measurement range of 0–100 kHz. Each scan recorded and averaged 10 measurements and lasted approximately 5 s.

Once these scans were completed, the scaler tip was brought into contact with the resin-embedded tooth until a load of 0.5 N was established. The laser beam was re-aligned and 10 further scans performed as described above. The contact load was then increased to 1.0 N and 10 scans were repeated as described above. All data were collected and the mean tip vibration displacement amplitude under unloaded and loaded conditions calculated.

The whole procedure was repeated for each of the remaining FSI-100 inserts and then for each of the five FSI-1000 inserts and the five FSI-SLI-10S inserts. All data were collected and the average tip displacement amplitude under unloaded and loaded conditions calculated.

Scaler tip grinding

The length of the tips was reduced to represent the effect of wear. Initially a length of 1 mm was removed from the end of the tip. A digital micrometre was used to measure the 1 mm distance and this was marked with a pen to indicate the area to be removed.

The tip was held against a stone driven by a handpiece. The initial bulk removal was accomplished by holding the end of the tip against the side of the stone. Once the majority of the marker at the end of the tip had been removed the tip was ground away more slowly using the top of the stone, which allowed more grinding control and produced a rounded tip edge, more closely representing the effect of wear through usage (Fig. 2). Once a tip length of 1 mm had been removed, the process was repeated for all of the remaining tips. Figure 2 shows a normal tip compared with one reduced in length by 2 mm. Scans were then performed for the ground tips as described previously. Ten repeat measurements of tip displacement amplitude, for all tips, were performed under unloaded and loaded conditions and the mean displacement amplitudes calculated.

The tip length was then reduced by a further 1 mm (2 mm total) as described above and scans performed to determine the mean tip displacement amplitude, under loaded and unloaded conditions.

Results

Scans were performed to determine the mean displacement amplitude of scaler

Table 2. Mean displacement amplitude data (measured in micrometres \pm 1 standard deviation) for FSI-100, FSI-1000 and FSI-SLI-10S scaler inserts with 1 mm removed, under loaded and unloaded conditions

Insert (design/number)	Mean tip displacement amplitude (micrometres)		
	unloaded	0.5 N load	1.0 N load
FSI-100			
Tip 1	8.38 \pm 2.28	13.52 \pm 1.74	11.56 \pm 0.65
Tip 2	8.15 \pm 1.81	10.71 \pm 1.92	11.67 \pm 1.30
Tip 3	9.96 \pm 2.24	14.29 \pm 1.72	15.02 \pm 1.39
Tip 4	8.08 \pm 2.98	13.17 \pm 2.12	11.92 \pm 1.28
Tip 5	11.42 \pm 0.94	11.28 \pm 2.03	11.29 \pm 0.44
FSI-1000			
Tip 1	21.14 \pm 1.80	14.99 \pm 2.53	11.26 \pm 1.31
Tip 2	17.10 \pm 2.37	13.64 \pm 2.38	15.01 \pm 1.78
Tip 3	15.97 \pm 3.02	8.11 \pm 1.27	8.87 \pm 2.08
Tip 4	21.36 \pm 3.00	14.82 \pm 1.78	17.45 \pm 1.73
Tip 5	19.94 \pm 1.04	15.37 \pm 1.45	14.33 \pm 1.10
FSI-SLI-10S			
Tip 1	16.28 \pm 0.54	10.74 \pm 0.92	7.24 \pm 1.02
Tip 2	13.17 \pm 1.17	10.82 \pm 1.43	10.18 \pm 0.75
Tip 3	18.37 \pm 1.55	10.22 \pm 1.33	7.97 \pm 1.18
Tip 4	10.74 \pm 0.64	9.58 \pm 0.59	8.11 \pm 0.96
Tip 5	10.70 \pm 0.99	13.83 \pm 1.01	16.25 \pm 0.72

Table 3. Mean displacement amplitude data (measured in micrometres \pm 1 standard deviation) for FSI-100, FSI-1000 and FSI-SLI-10S scaler inserts with 2 mm removed, under loaded and unloaded conditions

Insert (design/number)	Mean tip displacement amplitude (micrometres)		
	unloaded	0.5 N load	1.0 N load
FSI-100			
Tip 1	13.78 \pm 1.64	12.17 \pm 1.24	8.91 \pm 1.01
Tip 2	12.04 \pm 2.51	8.24 \pm 1.56	8.80 \pm 0.64
Tip 3	9.41 \pm 1.24	7.90 \pm 1.06	7.26 \pm 1.17
Tip 4	10.71 \pm 2.61	10.75 \pm 1.37	8.84 \pm 1.57
Tip 5	8.69 \pm 2.19	11.59 \pm 3.98	13.10 \pm 1.52
FSI-1000			
Tip 1	13.87 \pm 1.88	12.77 \pm 1.55	9.62 \pm 0.95
Tip 2	14.48 \pm 1.70	10.53 \pm 1.75	10.13 \pm 1.30
Tip 3	13.23 \pm 1.75	12.62 \pm 2.40	13.66 \pm 0.48
Tip 4	13.02 \pm 2.48	9.12 \pm 0.99	12.02 \pm 0.64
Tip 5	11.57 \pm 2.54	10.34 \pm 2.79	9.03 \pm 1.05
FSI-SLI-10S			
Tip 1	11.31 \pm 0.80	8.30 \pm 0.78	7.63 \pm 0.59
Tip 2	10.96 \pm 0.72	11.24 \pm 0.89	11.38 \pm 0.60
Tip 3	10.34 \pm 1.29	8.40 \pm 0.53	7.24 \pm 0.74
Tip 4	9.44 \pm 0.43	8.33 \pm 0.54	9.94 \pm 0.82
Tip 5	10.49 \pm 1.22	11.77 \pm 0.37	10.58 \pm 0.36

tips under loaded and unloaded conditions. Tips were initially scanned in their new and unused state (Table 1). Data were then gathered for tip displacement amplitude following 1 mm of wear (Table 2) and 2 mm of wear (Table 3). The effect of tip length on vibration displacement amplitude is demonstrated in Fig. 3, which shows the change in mean maximum vibration displacement amplitude for FSI-SLI-10S Tip 1 under each load condition.

Statistical analysis

Data were analysed using SPSS v12.0. The significance of variation in tip-displacement amplitude, for different tip lengths under various load conditions, was tested using univariate analysis of variance (general linear model) and using multiple post hoc comparisons (Tukey's test) at a significance level of $p < 0.05$, with the dependent variable being displacement amplitude.

For all tips, load and length were found to be significant variables ($p < 0.0001$). The effect of tip length on scaler tip vibration displacement amplitude was then assessed by comparison with the data obtained for the full length, unworn scaler tip under the same operating conditions (Table 4a-c).

General tip comparisons

FSI-100 tips

For all load and tip length conditions, the vibration displacement amplitude of tip 3 was significantly different from all other tips ($p < 0.0001$). There were no significant differences between tips 1 and 2 ($p > 0.13$), tips 1 and 5 ($p > 0.99$), tips 2 and 4 ($p > 0.21$) and tips 2 and 5 ($p = 0.07$). All other tips were significantly different to each other ($p < 0.0001$).

FSI-1000 tips

General tip comparisons. For all load and tip length conditions there were no significant differences between the vibration displacement amplitudes of tips 1 and 4 ($p > 0.95$), tips 1 and 5 ($p > 0.96$), tips 2 and 3 ($p > 0.67$), tips 2 and 4 ($p = 0.14$) and tips 4 and 5 ($p > 0.64$). All other tips were significantly different to each other ($p < 0.02$).

FSI-SLI-10S tips

General tip comparisons. For all load and tip length conditions, all tips' vibration displacement amplitudes were significantly different to each other ($p < 0.002$) except for tips 1 and 2 ($p > 0.96$) and tips 3 and 4 ($p > 0.97$).

Discussion

All three styles of tips showed differences in performance between tips of the same design. Under unloaded conditions, the FSI-100 tips showed a high degree of variability with tip 3 demonstrating approximately 50% of the vibration displacement amplitude of the other four tips (Table 1). The FSI-SLI-10S design showed the greatest degree of variability with most tips oscillating significantly differently to each other for all load and tip length conditions. This research confirms previous work that has shown that there are differences in the oscillation of scaling tips both in the unloaded and loaded situation (Lea

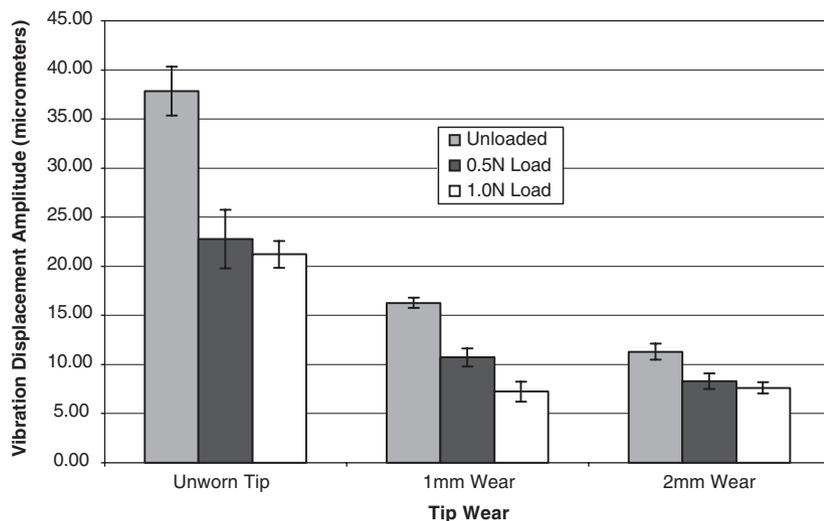


Fig. 3. Graph demonstrating the effect of wear on scaler tip vibration displacement amplitude (tip 1) under loaded and unloaded conditions.

et al. 2003a, b, Trenter et al. 2003). This occurs whether they are based on the solid probe design (Lea et al. 2003a, b) or the thin design of scaling tip (Trenter et al. 2003).

The primary cleaning mechanism of dental ultrasonic scalers is the mechanical chipping action of the scaler tip when contacted against the tooth surface. It has previously been assumed that the magnitude of the scaler tip vibration displacement amplitude may therefore be used as a convenient measure of the efficiency of the instrument (Walmsley et al. 1986, Lea et al. 2003a, b).

This investigation has demonstrated that a reduction of tip length (through wear) may significantly affect the magnitude of tip displacement amplitude. Such a reduction in the vibration dis-

Table 4. Effect of tip length on scaler tip vibration displacement amplitude (a) (unloaded), (b) (0.5 N load) and (c) (1.0 N load) assessed by comparison with data obtained for full length, unworn scaler tip under the same operating conditions

(a)		
Tip design	Unloaded data	
	1 mm wear	2 mm wear
FSI-100	All tips significantly different ($p < 0.0001$) from when they were new and unadjusted, except tip 3, which showed no significant difference ($p > 0.83$)	All tips significantly different from when they were new and unadjusted ($p < 0.0001$) except tip 3, which showed no significant difference ($p > 0.36$)
FSI-1000	All tips significantly different ($p < 0.0001$) from when they were new and unadjusted except tips 1 ($p > 0.34$) and 4 ($p > 0.98$), which showed no significant difference	All tips significantly different from when they were new and unadjusted ($p < 0.0001$)
FSI-SLI-10S	All tips significantly different from when they were new and unadjusted ($p < 0.0001$)	All tips significantly different from when they were new and unadjusted ($p < 0.0001$)
(b)		
Tip design	0.5 N Load data	
	1 mm wear	2 mm wear
FSI-100	All tips significantly different ($p < 0.04$) from when they were new and unadjusted, except tip 1, which showed no significant difference ($p > 0.52$)	All tips significantly different ($p < 0.007$) from when they were new and unadjusted except tip 4, which showed no significant difference ($p > 0.72$)
FSI-1000	All tips significantly different ($p < 0.04$) from when they were new and unadjusted except tips 1 ($p > 0.41$) and 5 ($p = 0.06$), which showed no significant difference	All tips significantly different from when they were new and unadjusted ($p < 0.002$)
FSI-SLI-10S	All tips significantly different from when they were new and unadjusted ($p < 0.0001$)	All tips significantly different from when they were new and unadjusted ($p < 0.0001$)
(c)		
Tip design	1.0 N Load data	
	1 mm wear	2 mm wear
FSI-100	All tips significantly different ($p < 0.02$) from when they were new and unadjusted except tip 2 ($p > 0.06$), which showed no significant difference	All tips significantly different ($p < 0.0001$) from when they were new and unadjusted except tip 5 ($p > 0.06$)
FSI-1000	All tips significantly different ($p < 0.0001$) from when they were new and unadjusted except tips 2 ($p > 0.62$) and 5 ($p > 0.08$), which showed no significant difference	All tips significantly different from when they were new and unadjusted ($p < 0.004$)
FSI-SLI-10S	All tips significantly different from when they were new and unadjusted ($p < 0.0001$)	All tips significantly different from when they were new and unadjusted ($p < 0.0001$)

placement amplitude of the ultrasonic scaler tip may produce a clinically noticeable difference in scaling performance. If the clinician observed such an effect it is possible that they might increase the power setting of the ultrasound generator in an attempt to improve the scaler efficiency. However, previous research has shown that increasing the power setting of the ultrasound generator does not always correspond to an increase in scaler tip displacement amplitude (Lea et al. 2003a, b) and so therefore this may not be a suitable solution to the problem.

Conclusions

This investigation has demonstrated that tip ‘‘wear’’ can affect the performance of dental ultrasonic scaler inserts by reducing their vibration displacement amplitude. Clinicians who retain their inserts for years may find their instrument tips become reduced in length through wear, potentially leading to a

detrimental change in the performance of the scaling system.

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References

- Badersten, A., Nilveus, R. & Egelberg, J. (1981) Effect of non-surgical periodontal therapy. 1. Moderately advanced periodontitis. *Journal of Clinical Periodontology* **8**, 57–72.
- Breining, D. R., O’Leary, T. J. & Blumenshine, R. V. H. (1987) Comparative effectiveness of ultrasonic and hand scaling for the removal of subgingival plaque and calculus. *Journal of Periodontology* **58**, 9–18.
- Lea, S. C., Landini, G. & Walmsley, A. D. (2002) Vibration patterns of ultrasonic scalers with scanning laser vibrometry. *Journal of Dentistry* **30**, 147–151.
- Lea, S. C., Landini, G. & Walmsley, A. D. (2003a) The displacement amplitude of ultra-

sonic scaler inserts. *Journal of Clinical Periodontology* **30**, 505–510.

Lea, S. C., Landini, G. & Walmsley, A. D. (2003b) Ultrasonic scaler tip performance under various load conditions. *Journal of Clinical Periodontology* **30**, 876–881.

Loos, B., Kiger, R. & Egelberg, J. (1987) An evaluation of basic periodontal therapy using sonic and ultrasonic scalers. *Journal of Clinical Periodontology* **14**, 29–33.

Trenter, S. C., Landini, G. & Walmsley, A. D. (2003) The effect of loading on the vibration characteristics of thin magnetostrictive ultrasonic scaler inserts. *Journal of Periodontology* **74**, 1308–1315.

Walmsley, A. D., Laird, W. R. E. & Williams, A. R. (1986) Displacement amplitude as a measure of the acoustic output of ultrasonic scalers. *Dental Materials* **2**, 97–100.

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Clinical Relevance

Scientific rationale for study: Ultrasonic scaler tip vibration displacement amplitude may be used as a measure of instrument efficacy. Tip wear may lead to a reduction in scaler efficiency though the effect is currently unevaluated.

Principal findings: Tip wear significantly affects the magnitude of vibration displacement amplitude. The tips investigated showed significant differences in performance between tips of the same design under loaded and unloaded conditions.

Practical implications: Wear may affect the performance of dental ultrasonic scalers by reducing their vibration displacement amplitude. Clinicians who retain inserts for years may find wear leads to a detrimental change in scaler performance.

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