# Three-dimensional optical assessment of experimental iatrogenic mechanical damage to canine dental enamel caused by a sonic scaler

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**ABSTRACT**: Removal of dental calculus deposits is one of the basic parts of professional dental cleaning. Despite the popularity of power-driven scalers, several risks are associated with their use, mechanical damage of the enamel surface being one of the most important. The present study evaluated enamel damage caused by a sonic scaler in different work patterns to quantify the damage and allow a clear comparison. Seventy-five canine teeth were carefully extracted from twenty-three dogs. The scaler was used on a clean surface with several combinations of time (five to twenty seconds) and parts of the scaler (point vs. side of the tip). Subsequently, damaged surface topography was mapped using three-dimensional optical microscopy. The results revealed a high variance in defect depth which was influenced by both factors. Statistical assessment confirmed highly significant ($P < 0.001$) or at least significant ($P < 0.05$) differences in data acquired for each group. As expected, the shallowest defects were produced by the scaler side in the shortest experimental period (five seconds). Point use proved to be quite damaging, as it resulted in approximately four times higher median values than the side in the same timeframe. Therefore, it is crucial to follow all safety precautions when handling a power-driven scaler even during routine treatments. Use of the side of the tip and constant movement on the tooth surface are essential to reduce the risk of enamel damage.

**Keywords**: profilometry; periodontal treatment; teeth; tartar

Dental enamel is considered the hardest substance in the mammalian body. It has a fibrous structure and contains hydroxyapatite prisms (only a marginal portion of mammal enamel is aprismatic), a small amount of water and proteins (as bonding agents). The complete tissue is more resistant than the mineral part itself. As the enamel is brittle, its inner structure allows effective absorption of external mechanical impulses. The amount of organic substances increases from the outer surface to the dentin-enamel junction (Maas and Dumont 1999). Prisms in the canine teeth of dogs were reported to form two bands with switching right-angled orientation. Near the tooth cervix these bands are almost parallel whereas in the cusp they are concentric (Hanaizumi et al. 1998).

Supragingival scaling is an important part of professional dental cleaning (Bellows 2004; Caiafa 2007), and the roughness of the post-treatment enamel surface determines the speed of accumulation of bacteria, dental plaque and calculus (Cobb 2002). Although calculus itself is not a causative agent of periodontal disease, it provides convenient space for growth and survival of a bacterial microflora (Hoffman et al. 2007). Dental scaling equipment includes hand and power-driven instruments (Robinson 2007; Holmstrom 2013a). Power-driven equipment should have an advantage over hand instrumentation, as shorter treatment times are achieved and the treatment is more effective and less exhausting (Cobb 2002; Lea and Walmsley 2009). However, other authors report that clinical outcomes of treatment with hand and power-driven scalers are comparable (Obeid et al. 2004), and some believe that the best option is to combine both methods (Lea and Walmsley 2009). The antimicrobial effects of supragingival scaling have been questioned (Schenk et al. 2000), although Thurnheer et al. (2013) proved that ultrasonic scalers are capable of biofilm detachment. Power-driven scalers are ultrasonic (magnetostrictive or piezoelectric) or sonic according to the source of oscillation (Robinson 2007; Niemiec 2013). Power-driven scalers should be used carefully because of the risks for both the patient and dentist/hygienist (Gorrel 2004; Niemiec 2013). Most studies consider magnetostrictive and piezoelectric scalers to be equal or only marginally different with respect to risks (Yousefimanesh 2012), although sonic scalers are sometimes considered to be less dangerous (Caiafa 2007). *In vitro* studies indicate that the scaler tips produce heat which could be dangerous for the vitality of the dental pulp (Lea et al. 2004). Power settings were documented to have a great influence on murine odontoblast-like cells *in vitro* (Scheven et al. 2007). Focusing on treatment safety is justified as it is difficult to follow the essential rules objectively during the treatment. Even experienced human dental hygienists tend to misinterpret their workload retrospectively. Namely, the number of patients and length of ultrasonic scaler use are overestimated (Akeson et al. 2001).

## MATERIAL AND METHODS

**Inclusion in the study**. Sample teeth for the study were collected from November 2010 to December 2013. The dog's canine tooth (×04 in the modified Triadan system) was chosen as the model tooth. Sampling was performed in otherwise healthy dogs undergoing routine periodontal treatment during the sampling period. There was no breed, sex, age, or weight limitation. However, there were four main inclusion criteria: (1) The dog had not undergone periodontal treatment within the preceding year, and the clients did not perform dental homecare. (2) The sampled canine tooth was scored as PDI 4 (periodontal disease index – based on the classification of Caiafa 2007) and therefore extraction was the only indicated treatment. (3) The tooth itself had no visible damage or discoloration involving its hard tissues, especially the enamel. (4) There was an exposed area in the apical third of the vestibular enamel surface of at least 3 mm in diameter OR the calculus deposit was so severe that it could be removed with calculus forceps to expose such an area of vestibular enamel surface without scratching it.

**Sampling, experimental damage, storage**. The teeth were carefully extracted, and excessive calculus was removed in one piece with calculus forceps if necessary. The vestibular enamel surface was wiped with a soft cloth. The experimental damage procedure was performed on the tooth mounted in a modelling clay; when it was not feasible to damage the enamel at the time of extraction, the tooth was preserved in 10% formaldehyde solution and processed within seven days. Experimental iatrogenic enamel damage was carried out using a sonic power-driven scaler (group designation S) for 5, 10 and 20 s (groups accordingly designated with the number) using the point (groups "x") or side of the tip of the instrument (groups "-"). Accordingly, the groups were designated as Sx5, Sx10, Sx20, S-10, and S-20.

**Quantification of damage**. After experimental damage, the teeth were preserved in 10% formaldehyde solution until the measurements were performed. Prior to measurement, the tooth was washed with clear tap water and air-dried. It was mounted in a modelling clay and measured three times. The peak defect depth was software-assessed as the difference between the edge and bottom of the defect in each measurement.

**Instrumentation, software, statistics**. A sonic scaler KaVo SONICflex quick 2008 L with standard No. 6 scaling tip and elliptical tip movement pattern (KaVo Dental GmbH, Biberach/Riß, Germany) was used to produce the experimental defects. The device was set to half power and water supply. The tip's point or side was placed at a right angle to the tooth surface in the apical third of the vestibular crown enamel, touching it without any pressure applied (Figures 1 and 2. The topography of surface defects was measured using a 3D optical microscope (Contour GT-X by Bruker, AZ, USA). A vertical scanning interferometry method was used coupled with 5× magnification lens, 1.0× converter and white light filter. This option resulted in a measurement area of 1.24 mm × 0.93 mm with height accuracy < 0.75 % and level of noise of 5 nm. Software processing of the surface profile was performed with Vision64 (Bruker, AZ, USA). This was set to detect reflections on the enamel surface at 4% threshold, compensate cylinder deformation of the scanned object and bridge 15 pixels when computing the surface profile; only teeth with more than 80% of measurable surface were included in the

Figure 1. Scaler tip's point placed to the enamel surface

Figure 2. Scaler tip's side placed to the enamel surface

study. Statistical significance was assessed using the Mann-Whitney test. SPSS Statistics Standard (IBM Software, NY, USA) and Excel 2013 (Microsoft Corporation, WA, USA) software were used.

## RESULTS

The canine teeth of twenty-three dogs (nine female, one spayed female, and 13 male) aged (mean ± SD) 10.8 ± 2.5 years were sampled for this study. The sampled animals comprised five mongrels, three Dachshunds and Yorkshire terriers, two American Cocker Spaniels, English Cocker Spaniels and Schnauzers and one Chihuahua, Cavalier King Charles Spaniel, Chinese Crested, Maltese, Pug, and Standard Poodle each. Seventy-five teeth from these 23 dogs met the inclusion criteria (one tooth – one dog, two teeth – five dogs, three teeth – four dogs, and four teeth – 13 dogs). Teeth were randomly assigned to groups of 15 teeth (multiple teeth from a single dog were all assigned to the same group).

The median and the range of defect depth for each group are shown in Table 1. The point produced highly significantly ($P < 0.001$) deeper defects than

Table 1. Enamel defect depths in treatment groups (all values in micrometers)

| Treatment | Median | Range |
|---|---|---|
| S-5 | 10.03 | 7.49–23.23 |
| S-10 | 24.63 | 4.21–27.12 |
| Sx5 | 44.11 | 15.85–76.22 |
| Sx10 | 108.93 | 29.17–170.81 |
| Sx20 | 133.35 | 43.77–273.68 |

the tip side. In addition, the longer the duration of action, the deeper the defect. The difference between Sx10 and Sx20 groups was significant ($P < 0.011$), and the difference between all other groups was highly significant ($P < 0.001$).

## DISCUSSION

Although scaling is an essential part of professional dental cleaning, the adverse effects of power-driven scalers on the enamel surface are rarely described in peer-reviewed veterinary journals (Brine et al. 2000; Fichtel et al. 2008). Even in human dentistry, the number of recent articles on this topic does not correlate with the frequency of performance of this procedure. It is well-known that the use of such instruments carries the risk of mechanical and thermal damage. However, comments on their use are usually limited to general advice such as using the side of the scaler, moving it continually, staying on one tooth no longer than 15 s, and applying no or minimal pressure (Caiafa 2007; Holmstrom 2013b; McMahon 2013; Niemiec 2013). The clinical significance of power-driven scaler use is accentuated by the fact that professional treatment is valued much more than thorough homecare by human patients (Needleman et al. 2005).

This study was designed with the aim of adhering to real-life conditions. No ethical committee approval was necessary as the dogs underwent routine clinical procedures and extraction was the only indicated method of therapy for the sampled teeth. Clients sign informed consent routinely before any dental treatment. No surface modifications of sampled teeth (like sandpaper polishing) were done except for soft cloth wiping and the experimental damage. In these respects our study is very similar to the only veterinary study performed on quantitative scaler effects on the canine tooth enamel (Brine et al. 2000). In similar human studies, the preparation of samples often includes different methods of storage, cutting, grinding, polishing and even freezing (Kuhar et al. 1997; Eisenburger and Addy 2002; Las Casas et al. 2008; Yu et al. 2009) prior to the actual experimental procedures in order to render surfaces as smooth as possible. It could be suggested that the flat, polished enamel surface would be beneficial for precise measurements; on the other hand, such surface preparations remove up to several hundred micrometres of enamel. This considerably alters the superficial layer of enamel, which is believed to be very resistant to mechanical insults and chemical permeability (Kuhar et al. 1997), although Las Casas et al. (2008) suggested that the surface irregularities become less obvious when the medium enamel layer (with irregular prism orientation) is reached. When this layer is incomplete or absent, the values can be considered only relatively comparable to data from studies with the same sample preparation, and some authors admit that their preparation methods can alter the interpretability of results (Yu et al. 2009). This could easily become problematic, as there is no unified preparation procedure among the numerous studies on enamel hardness and resistance to mechanical and chemical wear and damage (Bartlett 2005; Lea and Walmsley 2009).

For the same reason the experimental damage procedures were performed manually, without constructing a special scaler holder. A single veterinary surgeon performing daily at least one professional dental cleaning, carried out all experimental procedures to ensure consistency, which is typical for this type of study (Lee et al. 1995). The values naturally vary to some degree; we must take into account the fact that the teeth were not of the same size and maturity and although the surface had to be intact, it was not possible to prove consistent enamel thickness and composition in all teeth. Xie et al. (2008) suggested that hypomineralised human enamel has significantly worse mechanical resistance than sound enamel. Brine et al. (2000) made precautions to objectify the effect of four different power scalers (a load cell, a balanced arm holding the sample and ceramic blocks as a control group). It was notable that in their preliminary trial with experienced dentists, the load of the scaler tip ranged between 60 and 80 g. This suggests that even human-applied load is quite consistent. Moreover, the results indicated that even with highly different loads, enamel samples treated with a sonic scaler showed only slight variations in surface roughness. It is worth noting that special arrangements with the aim of standardising the results affect the clinical character of the study and move it closer to laboratory measurements. Too many special arrangements may make it difficult for clinical practitioners to interpret the conclusions (Eisenburger and Addy 2002).

Three-dimensional optical microscopy was chosen to measure the defect depth. This is a non-contact, non-destructive method, and the device used has a vertical resolution highly exceeding the needs of the study. Three-dimensional surface mapping is fast and easy. In comparison to stylus profilometry used by Brine et al. (2000), the optical method does not risk damage to the sample surface (Passos et al. 2013), which could provide higher reliability for repeated measurements. It was also possible to measure the absolute depth of the defects, which is an advantage over the electron microscopy used in the study of Fichtel et al. (2008). Lee et al. (1995) used both methods and observed that despite the differences in the appearance of surface samples with various treatments observed using an electron microscope, profilometry allowed reliable quantitative assessment of significance.

Our results show that there is an excessive risk of severe damage to enamel when the point of the scaler's tip is used. This was a predictable result; the quantification of such damage is much more important – it was found that the median damage caused by the point after 5 s and 10 s was more than four times higher that that caused when the tip's side was used for the same length of time. Considering the normal thickness of enamel (up to 0.6 mm according to Gracis 2007) and the peak depths achieved in this study, prolonged action of a power-driven scaler can penetrate a considerable part of the enamel layer. Even the shortest experimental time was naturally much longer than a dentist should apply at one particular area of the crown surface during the actual procedure, and Brine et al. (2000) showed that with comparable instrumentation, using the side of the scaler in a constant movement results in acceptable changes in surface roughness (22.0–23.8 kiloangstroms with deviation 7.5–7.7 kiloangstroms with a sonic scaler under a load of 50–500 g). The authors' experience, however, shows that improper use of power-driven dental equipment in veterinary practice is quite frequent.

## CONCLUSION

Even with variable samples and manually operated equipment, the results showed highly significant differences in the enamel surface defect depth. The sonic scaler, although considered quite safe, can be a very damaging tool when used improperly. Use of the point must be avoided under all circumstances – even the shortest time was enough to damage enamel severely and there are certainly more factors which should be considered (i. e. time or movement of the scaler). Further studies could clarify whether there are significant differences in enamel thickness and composition in different breeds and ages. The influence of other types of scaler units, tip designs, hand instruments, and polishing on the enamel surface should also provide clinicians with useful information on professional dental cleaning safety.

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## REFERENCES

Akeson I, Balogh I, Skerfving S (2001): Self-reported and measured time of vibration exposure at ultrasonic scaling in dental hygienists. Applied Ergonomics 32, 47–51.

Bartlett D (2005): The implication of laboratory research on tooth wear and erosion. Oral Diseases 11, 3–6.

Bellows J (2004): Periodontal equipment, materials, and techniques. In: Bellows J (ed.): Small Animal Dental Equipment, Materials and Techniques: A Primer. 1st ed. Blackwell Publishing, Oxford. 115–175.

Brine EJ, Marretta SM, Pijanowski GJ, Siegel AM (2000): Comparison of the effects of four different power scalers on enamel tooth surface in the dog. Journal of Veterinary Dentistry 17, 17–21.

Caiafa A (2007): Canine infectious, inflammatory and immune-mediated oral conditions. In: Tutt C, Deeprose J, Crossley D (eds.): BSAVA Manual of Canine and Feline Dentistry. 3rd ed. BSAVA, Gloucester, UK. 96–125.

Cobb CM (2002): Clinical significance of non-surgical periodontal therapy: an evidence-based perspective of scaling and root planing. Journal of Clinical Periodontology 29, 6–16.

Eisenburger M, Addy M (2002): Erosion and attrition of human enamel in vitro. Part I: Interaction effects. Journal of Dentistry 30, 341–347.

Fichtel T, Crha M, Langerova E, Biberauer G, Vlasin M (2008): Observations on the effects of scaling and polishing methods on enamel. Journal of Veterinary Dentistry 25, 231–235.

Gorrel C (2004): Periodontal Disease. In: Gorrel C (ed.): Veterinary Dentistry for the General Practitioner. 1st ed. Elsevier, Philadelphia. 87–110.

Gracis M (2007): Orodental anatomy and physiology. In: Tutt C, Deeprose J, Crossley D (eds.): BSAVA Manual of Canine and Feline Dentistry. 3rd ed. BSAVA, Gloucester, UK. 1–21.

Hanaizumi Y, Kawano Y, Ohshima H, Hoshino M, Takeuchi K, Maeda T (1998): Three-dimensional direction and interrelationship of prisms in cuspal and cervical enamel of dog tooth. The Anatomical Record 252, 355–368.

Hoffman SL, Kressin DJ, Verstraete FJM (2007): Myths and misconceptions in veterinary dentistry. Journal of American Veterinary Medical Association 231, 1818–1824.

Holmstrom SE (2013a): Dental instruments and equipment. In: Holmstrom SE (ed.): Veterinary Dentistry: A Team Approach. 2nd ed. Elsevier, St. Louis, Mo. 78–116.

Holmstrom SE (2013b): The Complete Prophy. In: Holmstrom SE (ed.): Veterinary Dentistry: A Team Approach. 2nd ed. Elsevier, St. Louis, Mo. 167–193.

Kuhar M, Cevc P, Schara M, Funduk N (1997): Enhanced permeability of acid-etched or ground dental enamel. The Journal of Prosthetic Dentistry 77, 578–582.

Las Casas AB, Bastos FS, Godoy GCD, Buono VTL (2008): Enamel wear and surface roughness characterization using 3D profilometry. Tribology International 41, 1232–1236.

Lea SC, Landini G, Walmsley AD (2004): Thermal imaging of ultrasonic scaler tips during tooth instrumentation. Journal of Clinical Periodontology 31, 370–375.

Lea SC, Walmsley AD (2009): Mechano-physical and biophysical properties of power-driven scalers: driving the future of powered instrument design and evaluation. Periodontology 2000 51, 63–78.

Lee S, Lai Y, Morgano SM (1995): Effects of ultrasonic scaling and periodontal curettage on surface roughness of porcelain. The Journal of Prosthetic Dentistry 73, 227–232.

Maas MC, Dumont ER (1999): Built to last: the structure, function, and evolution of primate dental enamel. Evolutionary Anthropology: Issues, News, and Reviews 8, 133–152.

McMahon J (2013): The Dental Cleaning. In: Perrone JR (ed.): Small Animal Dental Procedures for Veterinary Technicians and Nurses. 1st ed. Wiley-Blackwell. 59–86.

Needleman I, Suvan J, Moles DR, Pimlott J (2005): A systematic review of professional mechanical plaque removal for prevention of periodontal diseases. Journal of Clinical Periodontology 32, 229–282.

Niemiec BA (2013): The complete dental cleaning. In: Niemiec BA (ed.): Veterinary Periodontology, 1st ed. John Wiley & Sons, Ames. 129–153.

Obeid PR, D'Hoore W, Bercy P (2004): Comparative clinical responses related to the use of various periodontal instrumentation. Journal of Clinical Periodontology 31, 193–199.

Passos VF, Melo MAS, Vasconcellos AA, Rodrigues LKA, Santiago SL (2013): Comparison of methods for quantifying dental wear caused by erosion and abrasion. Microscopy Research and Technique 76, 178–183.

Robinson J (2007): Dental instrumentation and equipment. In: Tutt C, Deeprose J, Crossley D (eds.): BSAVA Manual of Canine and Feline Dentistry. 3rd ed. BSAVA, Gloucester, UK. 67–76.

Schenk G, Flemmig TF, Lob S, Ruckdeschel G, Hickel R (2000): Lack of antimicrobial effect on periodontopathic bacteria by ultrasonic and sonic scalers in vitro. Journal of Clinical Periodontology 27, 116–119.

Scheven BA, Millard JL, Cooper PR, Lea SC, Walmsley AD, Smith AJ (2007): Short-term in vitro effectsof low frequency ultrasound on odontoblast-like cells. Ultrasound in Medicine and Biology 33, 1475–1482.

Thurnheer T, Rohrer E, Belibasakis GN, Attin T, Schmidlin PR (2013): Static biofilm removal around ultrasonic tips in vitro. Clinical Oral Investigations, DOI 10.1007/s00784-013-1157-2.

Xie Z, Swain M, Munroe P, Hoffman M (2008): On the critical parameters that regulate the deformation behaviour of tooth enamel. Biomaterials 29, 2697–2703.

Yousefimanesh H, Robati M, Kadkhodazadekh M, Molla R (2012): A comparison of magnetostrictive and piezoelectric ultrasonic scaling devices: an in vitro study. Journal of Periodontal and Implant Science 42, 243–247.

Yu H, Wegehaupt FJ, Wiegand A, Roos M, Attin T, Buchalla W (2009): Erosion and abrasion of tooth-colored restorative materials and human enamel. Journal of Dentistry 37, 913–922.

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