

Effectiveness of Disposable (Single-use) Tips for Dental Air-water Syringes

ABSTRACT

Background: Single-use dental syringe (SUS) tips eliminate cross-infection risks. Many dental materials are moisture sensitive; therefore bonding could be affected by remaining moisture from SUS tips. *Methods:* An air-water syringe was calibrated to 50 PSI and the air pressure measured. SUS tips were then attached and pressure re-measured. Seven tips were tested; moisture content and spray pattern were investigated. Ethical approval was granted. Twenty third molar teeth were sectioned, stored in phosphate buffered saline and randomly allocated into groups with a SUS tip. They were mounted in acrylic and polished. Specimens were dried with a tip under standardised conditions, treated using a 3-step etch-prime-bond technique, then had a post bonded perpendicular to the dentine surface. The force to detach them was measured. Data were analysed using one-way analysis of variance (ANOVA) and Chi-squared tests. *Results:* The difference in output pressure between groups proved significant ($p < 0.001$). Tensile force at failure was significantly different between groups ($p = 0.19$). *Conclusions:* The pressure output of the syringe and bond strength are influenced by the SUS tip.

INTRODUCTION

The dental profession requires that non-disposable equipment be decontaminated and sterilised after use, making it safe for the next patient. Reusable metal air-water syringe tips cannot be reliably sterilised and single-use syringe (SUS) tips eliminate this risk.^{1,2,3}

The designs of SUS tips are diverse and may influence their effectiveness. Most SUS tips have separate channels for air and water, which helps to eliminate crossover. Plastic tips have a degree of flexibility, which allows some to be bent to reach all areas of the mouth. The degree to which this is possible differs, as do the manufacturer's recommendations on bending; several are supplied with a preformed bend. This distortion could also affect the pressure and amount of air and/or water expressed at the tip.⁴

It is essential to have separation of air and water, as many dental materials are moisture sensitive.^{5,6} When separate channels are not used, condensation may occur. Adhesion to dentine relies on a dry and uniform surface and adequate and consistent moisture control using an appropriate drying method. The following experiment will consider 'dry-bonding,' as excess surface water can cause dilution of bonding primer, while air-drying provides a risk of over-drying and collagen collapse.^{6,7} However, studies show that water-based primers can to a certain extent rehydrate the collagen network.^{8,9} The collagen network will not, however, return completely to its former state. A non-collapsed collagen network is essential for the formation of a good hybrid layer.⁸

Keywords

Dentine
Bond Strength
Moisture
Single-use Syringe Tip

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Received: 28.01.15
Accepted: 14.08.15

doi: 10.1922/EJPRD_1440Edwards05

For this reason, the spray pattern and distribution of air and water within the pattern become important. Spray pattern can be affected by other tip characteristics including length, material, tip angle, fabrication method and the need for an adapter. If air streams from SUS tips are not uniform and circular, the operator may unknowingly over-dry or under-dry a specific area of dentine.^{6,8} The tooth becomes at risk of collagen collapse and the patient of dentine sensitivity. A calibrated and consistent air-pressure is therefore required and favours the formation of a uniform hybrid layer.^{8,9}

This study aims to evaluate the effectiveness of SUS tips, firstly by assessing the connection of the tips with the air-water syringe body through pressure changes. Secondly, to investigate moisture content in the air spray. Finally, to investigate if differences in air streams between the tips affect dentine drying and the potential to reduce bond strength.

MATERIALS AND METHODS

Pressure analysis

An air-water syringe was set up and calibrated to 50 PSI. Seven SUS tips were tested (Table 1) attached to a DCI (DCI, Newport, Oregon, USA) triplex syringe. The pressure of the air expressed with no tip attached was measured with a pressure gauge. The SUS tips were then attached (with adapter if applicable) and pressure re-measured with the gauge and a piece of hose with hose clamps creating an airtight seal around the end of the SUS tip.

Moisture content analysis

A solution of cobalt chloride dissolved in 95% ethanol was dispensed into dry test tubes. Water was dispensed from the SUS tips for 10 seconds and discarded. Air was then expressed for 3 seconds into the solution. Moisture contamination was

represented by a colour change from blue (anhydrous) to pink (hydrous).

Spray Pattern Analysis

The pressure of the air-water syringe body (input) was calibrated at 50 PSI and a jig was used to hold each syringe in position. The position was standardised with the end of each SUS tip being a set distance/angle of 5 cm and 90 degrees (perpendicular) to a paper target. Each SUS tip was attached facing a sheet of A4 size blotting paper. Air only was dispensed for ten seconds followed by air and water for a further 3 seconds. Images were captured using a camera (Canon SX110 IS) and tripod at a set distance of 40 cm and angled parallel to the paper. Images were captured two seconds after spray ceased using the built-in timer. The experimental images were then compared against the theoretical patterns postulated by a mathematical model considering area, perimeter and circularity using ImageJ software.¹⁰

Effect on adhesion to dentine surfaces

Ethical approval for the use of human teeth was granted. Twenty unrestored, caries-free, third molars were sectioned first mesio-distally then bucco-lingually into quarters to produce 70 specimens, which were stored in phosphate buffered saline and randomly allocated into seven groups of ten specimens and randomly assigned to a SUS tip. They were mounted in cold cure acrylic with the coronal dentine exposed and polished to 240 µm. Specimens were treated using a 3-step etch, prime, bond technique according to manufacturer's instructions (Adper™ Scotchbond™ Multi-Purpose Adhesive System, 3M ESPE, Minnesota, USA). 1. Etching: Apply etchant (phosphoric or maleic) to dentine, wait 15 seconds, rinse for 15 seconds then dry for 5 seconds. 2. Priming: Apply multi-purpose primer to etched dentine and dry gently for 5 seconds. 3. Adhesive application: Apply multi-purpose adhesive to the primed dentine and light cure for 10 seconds.

Table 1. Tukey post-hoc analysis of ANOVA - results of mean pressure output.

Type of SUS tip	V	Type of SUS tip	Std. Error	Mean Pressure Difference (psi)
Pro Tip Plus* (Astek Innovations, Cheshire, UK)		Crystal Tips (Crystal Tip, California, USA)	0.855	-8.5+
Pro Tip Plus*		Riskontrol* (Acteon, Merignac, France)	0.855	-8.4+
Pro Tip Plus*		Safe Tips EZ (Kerr Total Care, California, USA)	0.855	-7.4+
Pro Tip Plus*		Sani-Tip* (Dentsply, Pennsylvania, USA)	0.855	-8.5+
Pro Tip Plus*		Seal Tight* (Kerr Total Care, California, USA)	0.855	-8.5+
Pro Tip Plus*		FASTips (Dentsply, Pennsylvania, USA)	0.855	-8.5+

*Required an adapter +Significant difference (p < 0.05)

The prepared dentine then had a glass fibre-reinforced composite root canal post 1.2 mm diameter (Rebilda® Post, Voco, Cuxhaven, Germany) bonded perpendicular to the dentine surface using one increment of resin cement (Permabond, Permabond Engineering Adhesives Ltd, Winchester, UK) using a cement applicator and a custom jig, which provided even continued force for 1 minute. Specimens were connected to a microtensile-testing machine, the acrylic block was held in a vice grip and the post connected through a brass tube connector. The angle of post attachment to the dentine surface was verified each time to ensure it was a 90° angle. The arrangement was then attached and subjected to a tensile load at a crosshead speed of 0.5 mm/second until failure. The same operator carried out all tests. Data were analysed using a one-way ANOVA and Chi-squared test using SPSS version 21 (IBM, New York, USA).

A scanning electron microscope (JEOL 6700F FE-SEM, JEOL Ltd., Tokyo, Japan) was used at x100 – x1000 to determine the type of failure (adhesive or cohesive). The samples were coated with gold palladium in an Emitech K575X Peltier-cooled high resolution sputter coater (EM Technologies Ltd, Kent, England). The accelerating voltage used was 5kV, with 30µm aperture and a secondary electron detector.

RESULTS

Where the data were approximately normally distributed within groups, one-way ANOVAs were used to assess overall differences with post-hoc tests used for pairwise comparisons. Where data were not approximately normally distributed within groups, Kruskal-Wallis and Dunn's tests were used in the same way.

Output pressure data did not exhibit a normal distribution and was analysed using the Kruskal-Wallis test with the grouping variable 'type of disposable tip'. The data was statistically significant ($p < 0.001$), meaning that at least one of the samples was significantly different from the others. A Dunn's test

revealed that Pro Tip Plus showed a lower output in pressure to all other tips tested.

Two of the 70 samples tested positive to moisture. Both involved Seal Tight tips. Using a Chi-squared test this was determined to be not significant ($p = 0.055$).

Analysis of the area of combined air/water spray produced by the tips (Figure 1) showed there was a statistically significant difference between tips as determined by one-way ANOVA ($p < 0.001$). Further post-hoc analysis showed that the tips were significantly different (Table 2).

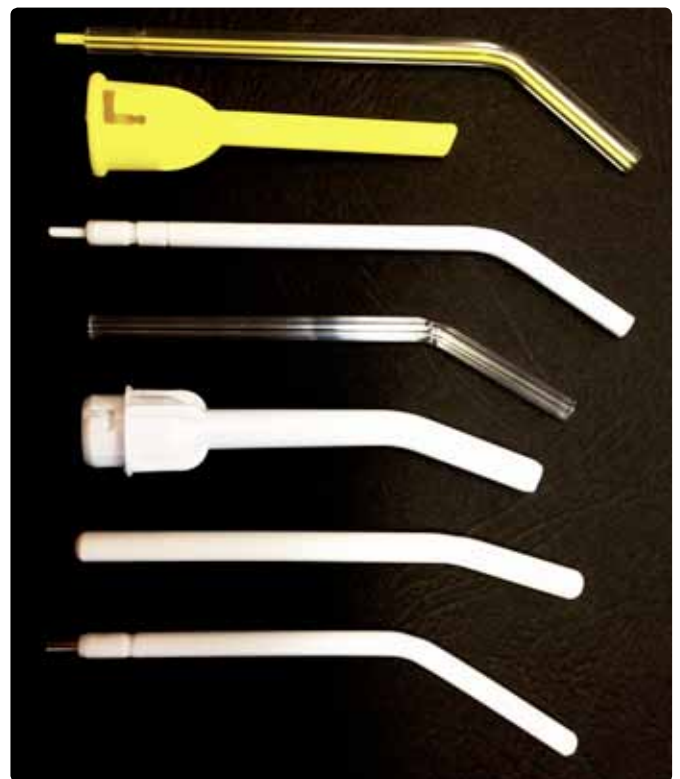


Figure 1: Example of combined air/water spray pattern.

Table 2. Mean values and standard deviation for area, perimeter and circularity.

	Mean Area (cm)	SD Area	Mean Perimeter (cm)	SD Perimeter	Mean Circularity	SD Circularity
Crystal Tips	31.41	1.94	22.12	0.83	0.81	0.04
Riskontrol	31.12	2.40	22.05	1.09	0.80	0.04
Safe tips EZ	35.44	5.99	24.34	3.36	0.76	0.11
Sani-Tip	30.14	2.22	21.91	0.94	0.79	0.06
Pro Tip Plus	33.27	5.24	22.87	1.91	0.82	0.04
Seal Tight	28.00	1.51	21.25	0.82	0.78	0.04
FASTips	25.30	2.44	20.57	1.04	0.75	0.08

Considering perimeter, there was a statistically significant difference between SUS tips as determined by one-way ANOVA ($p < 0.001$). The perimeter produced by Safe Tips EZ was significantly larger than the perimeter produced by all tips except Pro Tip Plus (Table 2). Circularity differences between the tips were not statistically significant ($p = 0.123$).

The force at failure between SUS tip types proved significantly different ($p = 0.019$), (Figure 2)

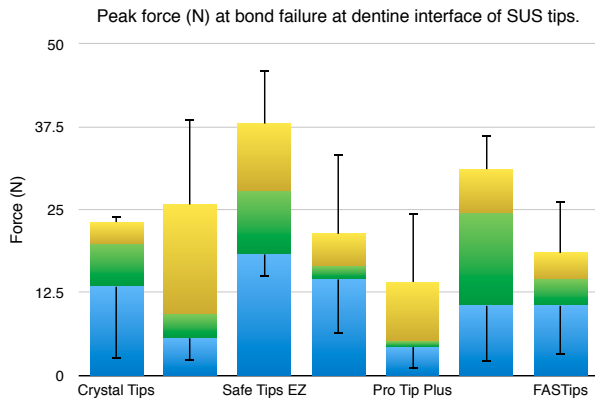


Figure 2: Peak force (N) at bond failure at dentine interface of single-use tips

SEM analysis showed that the majority of samples exhibited cohesive failure (failure within one of the substrates) or within the adhesive itself. A significant amount of fractured dentine was observed and broken post material seen (Figure 3).

DISCUSSION

To help avoid post-operative sensitivity it is important that the pressure output of the SUS tips is predictable. There were significant differences between Pro Tip Plus and the other SUS tips, with Pro Tip Plus having a lower output pressure. This may affect dentine bonding through inadequately drying the collagen network. The DCI triplex syringe system was used to test all samples. It is possible that the adapter was a confounding factor, as tips without adapters did not feature significant drops in pressure.

All values (perimeter, area and circularity) obtained during analysis of the spray patterns are influenced by one another. Area (A) is related to perimeter (P) through the equation . Therefore it can be seen that each is influenced by the other, but not by circularity. Circularity (C) is represented by a more complex equation , influenced by both area and perimeter.

The perimeter produced by the SUS tips is important clinically as it relates to the amount of dentine in the 'drying field.' It is desirable that prepared dentine is dried evenly, and it is impractical to judge whether all surfaces have been equally exposed to the air stream for drying. The perimeter values found in this study (range 18.2 to 30.3 cm) are large enough to not affect most clinical cavity preparations. The study by Lau and co-workers found that the SUS tips they tested produced a perimeter of a similar size.¹¹

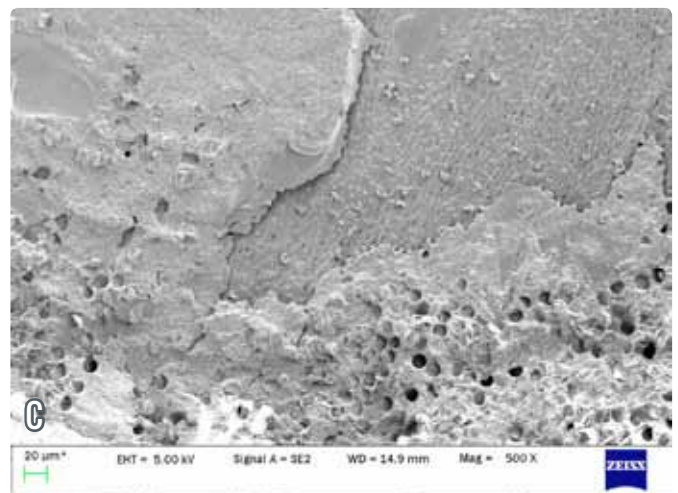
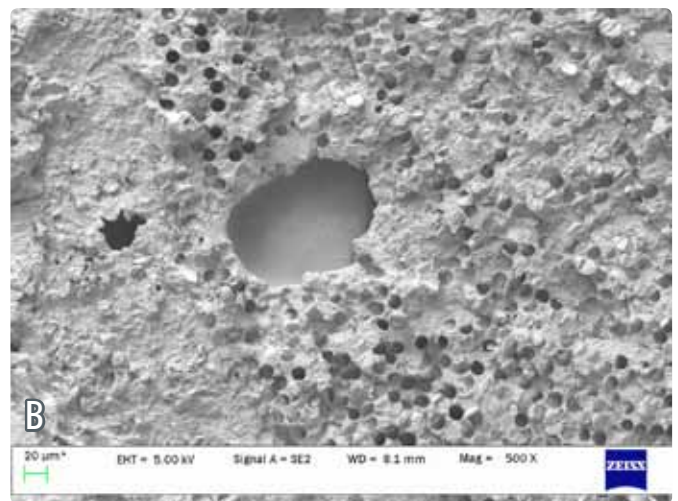
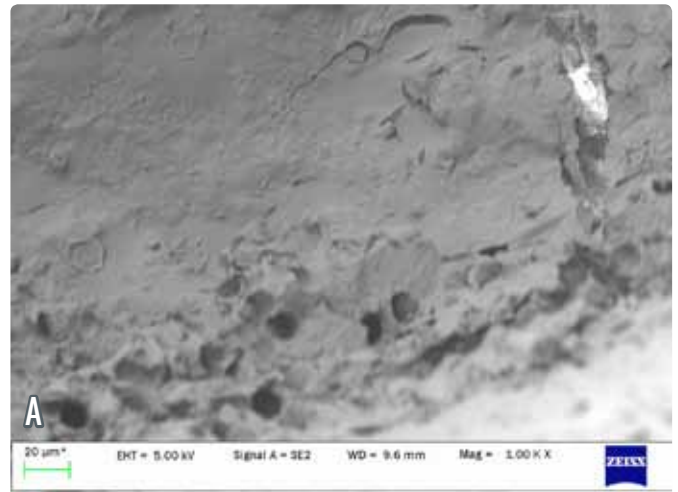


Figure 3:

- a: F=2.49 N adhesive failure
- b: F=38.75 N cohesive failure (Evidence of break down of post fibres)
- c: F=33.54 N adhesive and cohesive failure (Evidence of break down of post fibres)

The spray pattern area produced by the Pro Tip Plus was significantly larger than Seal Tight and FASTips. The range of areas was 22.0 cm to 44.5 cm. With the spray covering a large area, there is a risk of significant aerosol production, as well as contamination of other working fields.

Circularity changes with the angle of application, but this was fixed in the study. None of the tips produced a pattern that was perfectly circular, and there was no significant difference between the tips.

An adequately dry surface is essential for good 'dry-bonding.' As none of the moisture results were statistically significant, contamination was probably not a significant factor in dentine adhesion in this study.

Pressure, spray pattern and moisture may all influence adhesion to dentine. When testing tensile strength it is important to ensure that the force is purely tensile and the post is at 90 degrees to the exposed dentine surface.

The micro-tensile results confirm that bond strength is influenced by the SUS tip used.

This may be due to the effects of output pressure. For example Seal Tight tips, which maintained a PSI of 50, had a peak failure force of 20.95N. Whereas Pro Tip Plus, which had a significantly lower PSI of 41.5 and a peak failure force of 9.33N. Bond strength may also be influenced by spray pattern, however, as circularity, area and pressure are influenced by one another it is difficult to pinpoint which has the greatest influence. Results could be attributed to natural variations in dentine, minimised by the randomisation of the specimens.

An effective bond is highly important in dentistry,¹² and the tip chosen has the potential to influence clinical bonding of moisture sensitive materials. The tip related to the greatest bond strength was Safe Tips EZ, with the lowest values produced by Pro Tip Plus. The results obtained are similar to those obtained by Lau and colleagues¹¹ using similar methodology.

CONCLUSIONS

Single use syringe tips eliminate cross-infection risks. The pressure output is influenced by the tip used, and moisture contamination is not a significant problem. The perimeter and area of the spray produced by the SUS tips is significantly dif-

Table 3. Statistically significant difference in peak force at failure between SUS tips

Type of SUS tip	V	Type of SUS tip	Mean force difference (N)
Riskontrol		Safe Tips EZ	-13.68*
Safe Tips EZ		Pro Tip Plus	16.14*
Safe Tips EZ		FASTips	10.90*
Pro Tip Plus		Seal Tight	-11.62*

*Difference is statistically significant (p<0.05)

ferent but the circularity is not. There is a difference between SUS tips with regards to bond strength to dentine, indicating differences in their drying performance.

ACKNOWLEDGEMENTS

We wish to thank Acteon (France) for funding this research. Professor Murray Thomson (University of Otago) completed the statistical analyses. Voco (Germany) supplied the root canal posts, and single-use tips were donated at no cost by the manufacturers.

Allan Gamble (University of Otago, Department of Health Sciences) is thanked for his help in moisture evaluation and Ms. Liz Girvan (Otago Centre for Electron Microscopy) for SEM imaging.

The authors appreciate the facilities provided by the Sir John Walsh Research Institute, Faculty of Dentistry and the Department of Applied Sciences, University of Otago, Dunedin, New Zealand

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