

In vitro study of anti-suck-back ability by themselves on new high-speed air turbine handpieces

Toshiko OZAWA, Masako NAKANO and Takashi ARAI

Department of Periodontics and Endodontics, Tsurumi University School of Dental Medicine, 2-1-3 Tsurumi, Tsurumi-ku, Yokohama 230-8501 Japan

Corresponding author, Toshiko Ozawa; E-mail: ozawa-t@tsurumi-u.ac.jp

The anti-suck-back ability of five new high-speed air turbine handpiece models was evaluated in this study. First, suck-back pressure with water displacement within a glass tube was measured. Next, under three different conditions, how many on-off times it takes before fluorescent stains became visible on a piece of gauze at the exhaust vent was counted and the presence of fluorescent stains on the exhaust vents itself was examined. As a result, the water height for each part of one handpiece, the TWINPOWER TURBINE PAR-4HX-O, was below 0 mm. Except for under full emersion, this model, the TWINPOWER TURBINE PAR-4HX-O, did not have any visible fluorescence penetration to the exhaust vent even after 500 on-off switches under fume/mist conditions. Conversely, the other handpieces (Ti-Max X700L, T1 CONTROL, SYNEA TA-98CLED, GENTLE silence LUX 8000B) showed suck-back. In conclusion, the first mentioned new turbine handpiece, the TWINPOWER TURBINE PAR-4HX-O, had a possibility of no suck-back by itself. However, full immersion of the whole head of the handpiece which is not completely sealed must be avoided to prevent liquid intake.

Keywords: Suck-back, Air turbine handpiece, Cross infection

INTRODUCTION

High-speed air turbine handpieces rotate by capturing air called “drive air” in the impeller inside the head of the handpiece. When the turbine handpiece stops rotating, the supply of drive air is cut off. If drive air is not supplied to the impeller, it will still continue to rotate inertially for a few seconds before stopping. During this inertial rotation, the impeller works like an exhaust fan and will draw in outside air through the exhaust tubing into the turbine handpiece as well as into the treatment unit¹⁻⁴. This is known as the suck-back phenomenon^{2,4}.

Suck-back causes the intake of saliva and blood from the oral cavity as well as cut shavings, which contaminates not only the turbine handpiece, but also the coupling, tubing and the treatment unit. Cross infection can occur even if the turbine handpiece is changed for each patient¹⁻¹⁰.

Therefore, some companies have been developing handpieces that incorporate a non-return valve, labyrinth seals, and other components in an attempt to minimize suck-back. However these products are limited to only reducing suck-back rather than eliminating it completely. Furthermore, these devices require additional built-in suck-back prevention equipment on the treatment units¹¹⁻¹⁵. If there is a possibility of no suck-back, meaning no suction is produced by inertial rotation of the turbine handpiece, it will be a valuable option in preventing patient cross infection through the handpiece.

The purpose of this study was to evaluate the anti-suck-back effect of five new high-speed air turbine handpieces.

MATERIALS AND METHODS

Five new handpiece models (A: Ti-Max X700L, NSK, Tochigi, Japan, B: T1 CONTROL, Sirona, Bensheim, Germany, C: SYNEA TA-98CLED, W&H, Bürmoos, Austria, D: GENTLE silence LUX 8000B, KAVO, Biberach, Germany, E: TWINPOWER TURBINE PAR-4HX-O, MORITA, Kyoto, Japan) produced by five different independent companies were investigated (Table 1). Experiments were performed using a special device to precisely control the handpieces' rotation and air pressure instead of an actual treatment unit. To maintain consistency in our results, the same air pressure of 0.25 MPa at the handpiece connection for each handpiece was used whereas generally, 0.2-0.3 MPa air pressure would be used.

Measuring suck-back pressure

In order to measure the suck-back pressure of the whole handpiece head, the turbine handpiece was rotated within a special sealed flask which had an extra glass tube extending from its side and the end was submerged in another beaker full of water dyed with blue ink (Figure 1). Also, to measure the suck-back pressure of the front and back faces of the handpiece, each face was covered with a sealed plastic tube which was connected to the special sealed flask individually (Figure 2). After shutting off the compressed air supply and waiting for the rotation to stop, how much blue water had been drawn into the glass tube by was confirmed by measuring the maximum water height/level on the video image that was recorded. The average height in millimeters through five experiments for each part of the five

Table 1 Evaluated handpiece models

Sample ID	Manufacturer	Handpiece name
A	NSK, Tochigi, Japan	Ti-Max X700L
B	Sirona, Bensheim, Germany	T1 CONTROL
C	W&H, Bürmoos, Austria	SYNEA TA-98CLED
D	KAVO, Biberach, Germany	GENTLE silence LUX8000B
E	MORITA, Kyoto, Japan	TWINPOWER TURBINE PAR-4HX-O



Fig. 1 Complete test setup: Measuring suck-back pressure of the whole handpiece head.

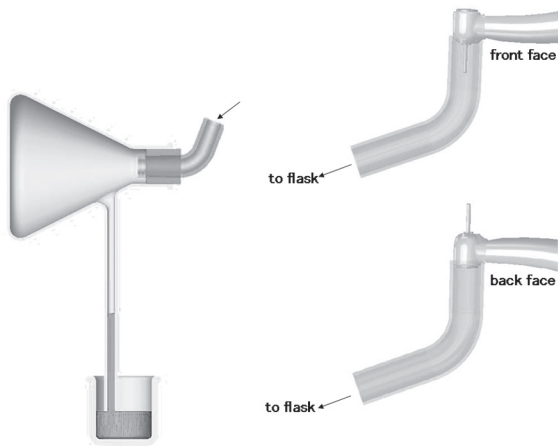


Fig. 2 Face test setup: Measuring suck-back pressure of each face of the handpiece.

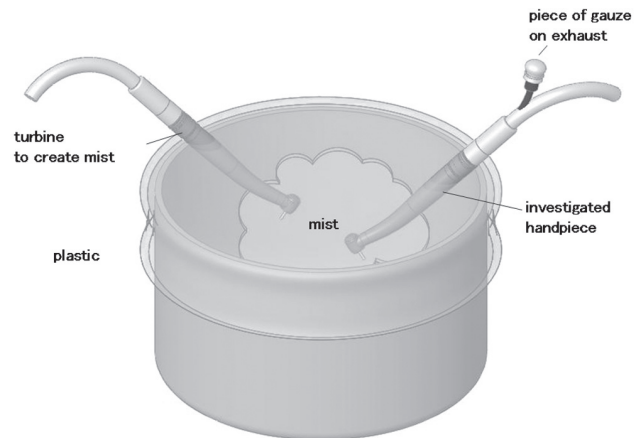


Fig. 3 Test setup to verify suck-back: Mist condition.

handpieces was calculated and recorded. For the water height test of the whole handpiece head, ANOVA and Tukey's test ($p < 0.01$) were used to determine the significance of the difference for each of the five handpieces.

Verification of suck-back

We prepared three conditions to simulate an oral cavity. The turbine handpiece was placed and rotated in it under each condition as explained below. A finely woven piece of gauze was fixed onto the end of the exhaust tube of the handpiece to catch fluorescent stains by the suck-back phenomenon. A fluorescent liquid (PUSR-80 1% dilution in water, Mitsubishi Pencil Co. Ltd., Tokyo, Japan) was used in the experiment to enhance the visibility of the suck-back phenomenon.

The three conditions:

(1) Mist condition

A fluorescent mist (mist: 60 mL/min) was created by another turbine handpiece (PAR-4HE-O, Morita, Kyoto, Japan) set 10 cm away from the investigated turbine handpiece head in a beaker sealed with a sheet of plastic wrapping (Figure 3).

(2) Fume condition

The investigated handpiece was placed in an opened flask. On the short tube of the flask, an ultrasonic

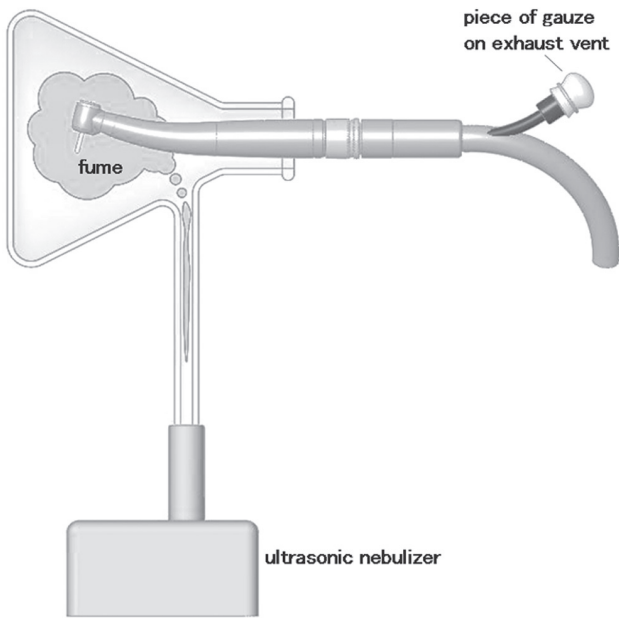


Fig. 4 Test setup to verify suck-back: Fume condition.

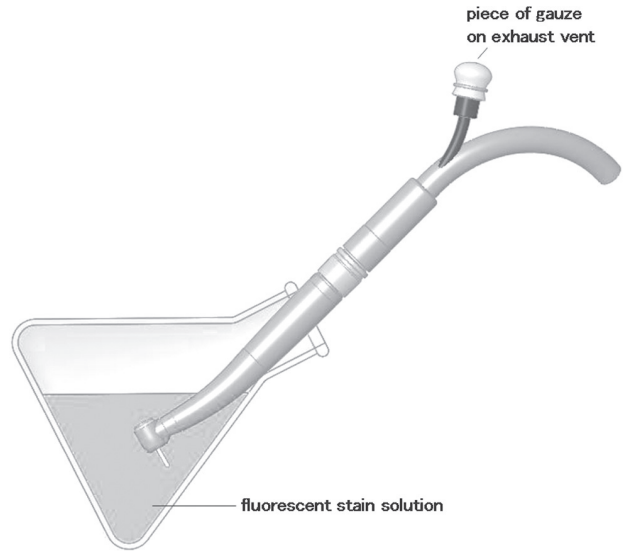
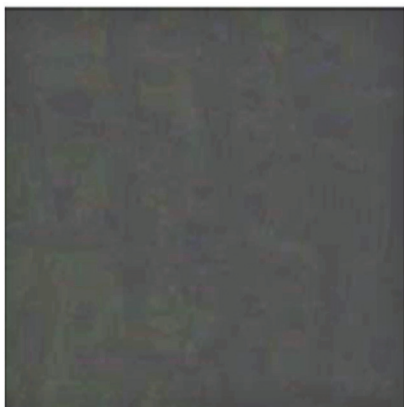


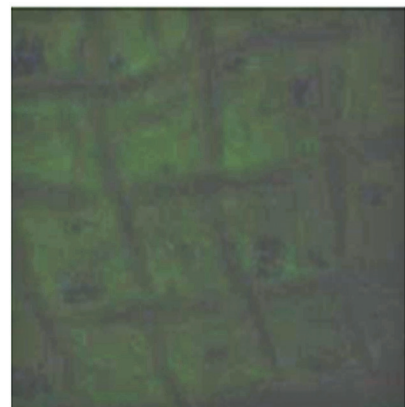
Fig. 5 Test setup to verify suck-back: Full immersion test setup.



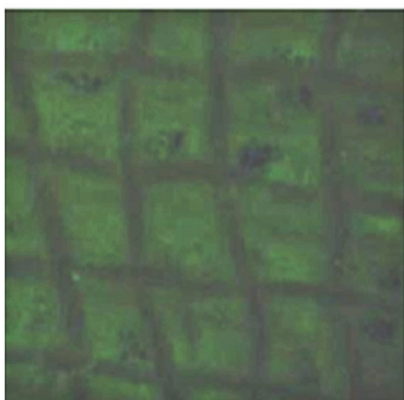
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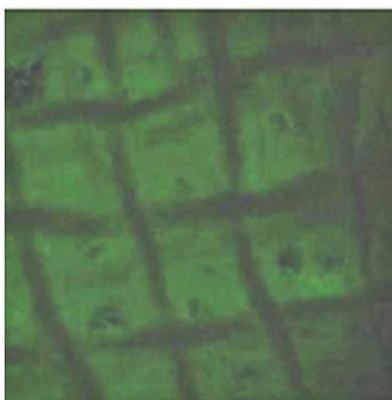
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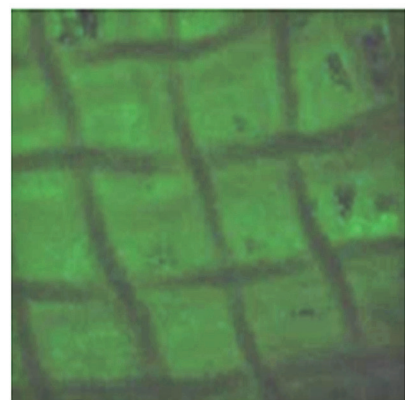
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Score 6

Fig. 6 Scoring of the presence or absence of visible fluorescent staining.

nebulizer (UN-132, A&D, Tokyo, Japan) was attached to create and deliver a fluorescent fume (fumes: 1 mL/min) into it (Figure 4).

(3) Full immersion

The entire head of the handpiece was fully immersed in a fluorescent stain solution in a flask (Figure 5).

We carried out a cycle of a two second rotation with a five second stop repeatedly 1, 3, 5, 10, 30, 40, 50, 100, 200, 300, 400, and 500 times until fluorescent staining on the gauze became visible when observed through a fluorescent microscope under each test condition. Photographs of all the gauze specimens were taken by a fluorescent microscope (VB7010, Keyence, Osaka, Japan) and recorded. We organized the photographs based on six ranks to evaluate the presence or absence of visible fluorescent staining (Figure 6). Five investigators scored according to this ranking for each image. When a resultant photo scores a 3 or higher as determined by four out of five investigators, we considered it to be suck-back positive.

Furthermore, the component of the exhaust vent on the coupling, as well as on the handpiece head, were examined through a fluorescent microscope for the presence of fluorescent staining after the above experiments were carried out.

RESULTS

Measuring suck-back pressure

The water height for each part of handpiece E was less than 0 as was the level for the back face of handpiece B. The water height of the whole head of handpiece E was significantly lower than the others' ($p < 0.01$) and the whole head of handpiece A had the highest water height. When the whole head of each handpiece was

compared with one another, there were significant differences ($p < 0.01$) except between handpieces B and D where there was no significant difference (Table 2).

Verification of suck-back

The number of on-off switches possible before fluorescent staining became visible was 20 to 200 times with the four models (A to D) under fume and mist conditions. Handpiece E did not have any visible fluorescent staining even after 500 on-off switches under both fume and mist conditions. However, under full immersion and with just one on-off switch, all models showed suck-back (Table 3).

Fluorescent staining was observed on the exhaust vents of four handpieces (A to D). The fluorescent stain penetrated to the exhaust vent components on the coupling as well as to the handpiece head. However, fluorescent staining could not be confirmed on handpiece E even after 500 times of repeated starting and stopping (Figure 7).

DISCUSSIONS

Sterilization/disinfection of both the internal and external parts of all handpieces should be mandatory^{4,7,16-17}. However, even if the dentist uses a freshly disinfected handpiece for each patient, there is still a possibility of cross-infection due to suck-back, as the coupling itself could be contaminated from previous treatments. Furthermore, there is a possibility of a microbial contamination occurring in the dental unit waterlines during the suck-back of liquids from the patient's oral cavity in high speed handpieces⁸⁻¹⁰.

Although the suck-back phenomenon is due to a combination of intake pressure, inertial rotation time,

Table 2 Maximum negative pressure of turbine handpieces measured as the maximum water height

Handpiece model	Maximum water height		
	whole head	Mean (SD) mm, $n=5$	
		front face	back face
A	426.0 (5.5)	358.0 (4.5)	219.0 (1.2)
B	31.4 (0.5)*	34.6 (0.5)	<0
C	56.2 (1.3)	11.6 (0.5)	30.0 (0.7)
D	35.8 (0.4)*	29.8 (0.7)	14.6 (0.5)
E	<0	<0	<0

* no significant difference ($p > 0.01$)

Table 3 The number of on-off switches possible before visible fluorescence

Handpiece model	Number of on-off (times)		
	full immersion	mist	fume
A	1	20	20
B	1	200	50
C	1	200	20
D	1	100	30
E	1	>500	>500

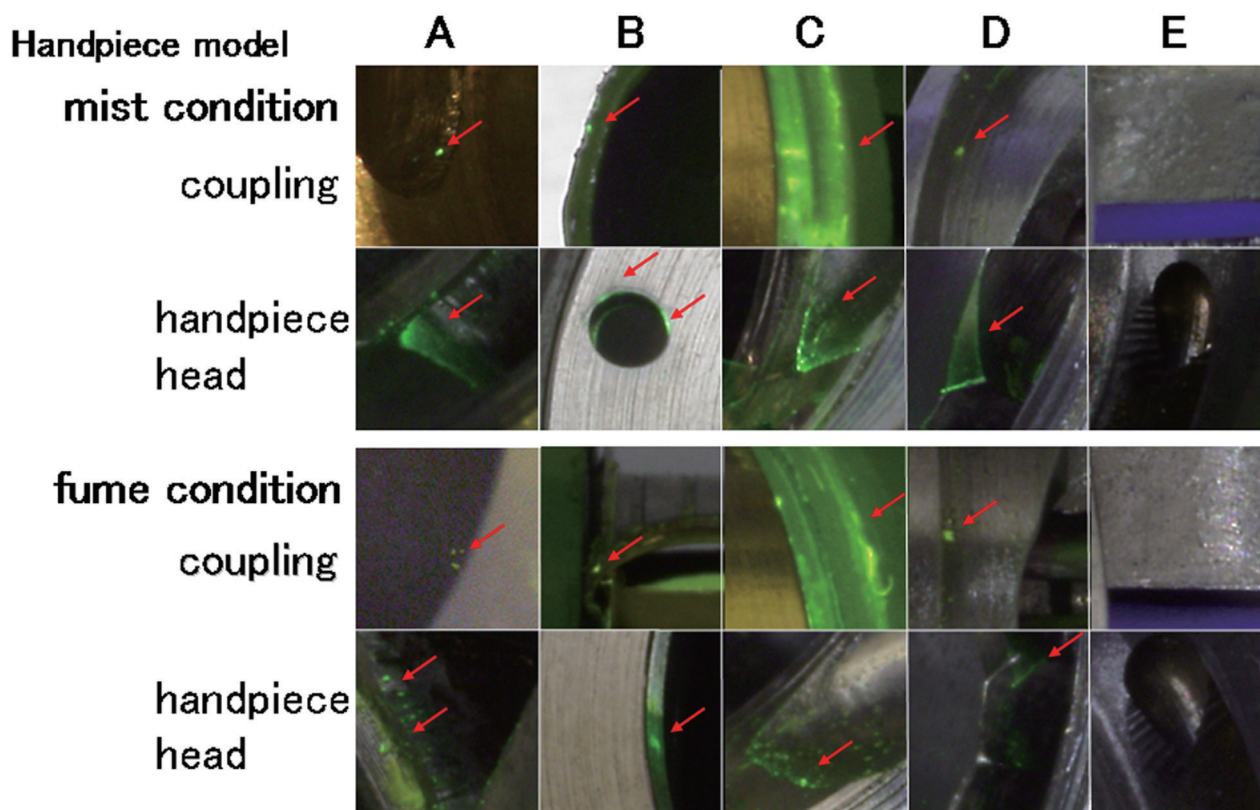


Fig. 7 Presence of fluorescent penetrant on exhaust vent components of coupling and handpiece heads (arrows) (Superimposed fluorescent microscope observation images onto general images).

and other factors, it is evident that the turbine handpiece exerts a strong suction force due to suck-back as seen from the height of the intake water.

In this study, we used the water height to easily detect whether any pressure differential resulted from the suck-back phenomenon. The amount of suck-back depends on the flow resistance at the front and back of the head, and there was some exhaust flow exhibited for all tested handpieces except for handpiece E. This handpiece displayed no suck-back at all in this study. Handpiece E, which had been specifically developed for no suck-back, showed an intake pressure less than 0 for all locations examined. The results show that the handpiece did not produce negative pressure (suction) inside the head due to inertial rotation and the negative change in water height shows that air was actually forced out through the head. For handpiece B, there was a slight pressure produced at the back of the head that caused some air to flow out. Thus, the suck-back for the whole handpiece was slightly less than that of the front of the head only. The pressure at the back of the head for handpiece B was probably produced by a turbine handpiece structure similar to that of handpiece E. Handpiece C has an anti-suck-back structure at the front of the head, although it does not perform very well. This is probably the reason why the suction at the front of the head is less than at the

back.

Under mist and fume conditions that simulated the conditions of the clinical oral cavity, there was no suck-back for handpiece E. Two tests for mist and fumes were performed in order to determine if there would be any difference in the results for particulates of varying size. Note that fume particulates (10 μm) are smaller than mist particulates (10 to 50 μm) and therefore entered the exhaust air line more easily and were detected sooner for handpieces A through D. In actuality, mist, fume and complete immersion conditions are possible in general clinical situations. Handpiece E showed no suck-back by itself under fume and mist conditions even after switching on-off 500 times which should far exceed the number of times this would be performed clinically.

The results demonstrated that a handpiece model can by itself achieve no suck-back, even when the treatment unit does not have any additional suck-back prevention apparatuses. Handpiece E is able to invert the air flow that causes suck-back in other handpieces by using the pocket diffusers within its head when the rotor of the handpiece is rotating inertially. The inverted flow expels air propelled by the turbine blade from of the handpiece head. Whereas other handpieces are only able to reduce suck-back by using labyrinth seals, stop valves, or other means.

However, liquid intake was observed immediately on all handpiece models under full immersion. As the head is not completely sealed, some fluorescent liquid can seep inside and will then be expelled through the exhaust line. The drive air itself drew the liquid into the device under this condition. This is to be expected and is beyond the definition of the suck-back phenomena as it is not the result of suction inside the exhaust lines produced by inertial rotation. Therefore, we must be careful not to immerse the whole handpiece head in saliva or blood clinically in order to prevent cross infection.

CONCLUSIONS

We concluded that handpiece E had a possibility of no suck-back by itself. It will be highly beneficial as an additional option in preventing patient cross infection through the handpieces. However, we still must avoid full immersion of the whole handpiece head in order to prevent liquid intake.

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