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Reprocessing of dental contra-angles – study of the efficacy of the washer-disinfectorTurbocid®

Summary

Background: During dental treatments with hand pieces or contra-angles and transfer instruments the effect of backflow may lead to the contamination of the air and water channels with organic debris as well as with microorganisms. Furthermore in many cases bleeding may occur during such treatments. To prevent transmission of these contaminations to the next patient adequate reprocessing of the instruments is essential.
Methods: The efficacy of a device (Turbocid®) for cleaning, disinfection and lubrication of dental transfer instruments was tested in a model test simulating practice conditions. The air and water channels of contra-angles (150 channels) were contaminated with coagulable human blood containing *E. faecium*. After drying for one hour, the items were subjected to reprocessing in the washer-disinfector Turbocid® under five different operating conditions. The relevant parameters "pressure", "duration of the respective reprocessing stages" and "media consumption" were constant.
Results: For operating condition 1 (one reprocessing cycle) the mean reduction factor for water channels was 3.5 log-steps, for air channels 2.2. For operating condition 2 (two reprocessing cycles) the mean reduction factor for both channels was 4.0. The t-test shows a significant difference for both operating conditions (water channels: $p = 0.032$; air channels: $p = 0.001$). For operating condition 3 (one cleaning stage without a disinfection stage) the mean reduction factor for water channels was 2.1 log-steps, for air channels 2.4. For operating condition 4 (four cleaning stages without a disinfection stage) the mean reduction factor for water channels was 2.2 log-steps, for air channels 2.5. For operating condition 5 (one cleaning stage and four disinfection stages) the mean reduction factor for water channels was 4.2 log-steps, for air channels 4.0. The t-test shows a significant difference for the results of operating conditions 1 and 5 ($p = 0.000$).
Concusions: Since no operating condition yielded a mean reduction of five log-steps, the sole use of the device for the reprocessing of strongly contaminated contra-angles cannot be recommended.

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Introduction

In dentistry, dental angle pieces are used for myriad treatment procedures. These are transmission instruments that transfer the rotational movement from the micromotor of the dental treatment unit to the grinding tools connected. Depending on whether the rotational movement of the micromotor is to be reduced or increased by the mechanical operations of the angle piece, a distinction is made between reducers and high-speed machines. Since the high-speed machines can reach a rotational speed of up to 200,000 revolutions per minute, there is a risk of damage to tissues because of friction-mediated heat generation. Therefore dental angle pieces are equipped with air and water channels to cool down the equipment. These are long and delicate lumens that make special demands on the decontamination process used to reprocess them.

The problem here is that the air and water channels can become contaminated with microorganisms from the oral cavity [1] while treating a patient, e.g. when treating an AIDS patient, they can become contaminated with HIV proviral DNA [2].

The main cause of internal contamination of angle pieces is the 'resuction effect'. This means that fluids such as saliva or blood from the oral cavity are sucked back into the angle piece when movement of equipment comes to a halt. The literature reports on tests such as "Model tests with E. faecium" [3] or "Reflux tests with coloured water" (Figure 1) [4] to demonstrate this resuction effect. Furthermore, with the help of the movement

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of a candle flame it has been possible to show that, in the case of turbines too, during the operating phase there are areas in the head of the angle piece under negative pressure [5].

To prevent the spread of microorganisms, and hence of infectious diseases, to the next patient, the Commission for Hospital Hygiene and Infection Prevention at the Robert Koch Institute has recommended that transmission instruments, and hence dental angle pieces too, be meticulously cleaned and disinfected both on the inside and outside after each patient [6].

The aim of the present study was to investigate the effectiveness of Turbocid®, a device designed for cleaning, disinfection and lubrication of dental transmission instruments in a practice-oriented model test. As opposed to earlier studies that used only serum to investigate the effectiveness of this apparatus [7, 8], our study used coagulable blood as a test soil, thus taking account of the fact that blood makes considerably more stringent demands on the decontamination process than does serum [9, 10].

Materials and Methods

Turbocid®

Turbocid® is a device designed for internal cleaning, internal and external disinfection and lubrication of dental hand and angle pieces (MICRO-MEGA® Dentalvertrieb GmbH & Co. KG, Neu Anspach). From a technical viewpoint, this apparatus consists of a hydropneumatic system that is controlled by means of an integrated switching circuit situated on the main board. The device features three attachments for hand or angle pieces and one for a dental turbine. A 220 V voltage source and compressed air connection with a constant compressed air supply of between 5 and 5.5 bar are needed to operate the device.

Based on the service handbook, the entire cleaning and disinfection process takes 762 seconds (12 min and 42 s); this entails internal cleaning with water (60 s), drying with compressed air at room temperature (60 s), internal disinfection (duration 96 s (exposure time 60 s)), drying with compressed air at room temperature (120 s), lubrication (96 s), external disinfection (duration 96 s (exposure time 60 s)) and drying with compressed air at room temperature (240 s).

As recommended by the manufacturer, the disinfectant Turbocidol was used (propyl alcohol, isopropyl alcohol, glyoxal; Oro Clean Chemie AG, Pfäffikon) and Micro-Mega Pflegeöl (care oil) TSU (medicinal white oil (paraffin hydrocarbon oil) as per DAB 10, isoparaffin solvent, ester oil, physiologically safe substances (additives) (TUNAP Industrie Chemie GmbH and Co. Produktions KG, Wolfratshausen).

To provide for verification of the amount of water, disinfectant solution and oil consumed, the device was modified for the tests. To that effect, openings were bored into the base leading into watertight vessels that could be sealed, cleaned and disinfected (Duran glass laboratory flasks 0.5 l with DIN thread ISO 4796 reference number 21891545 (Schott AG, Mainz)). The hole was sealed with the same gasket combination as used in the original vessels. To ensure that all tubular systems were filled with liquid, before conducting the measurements two or three cycles were run as empty loads [11]. Furthermore, the duration of the different cleaning and disinfection phases was measured.

Angle Pieces

Blue angle pieces were used for the experiments (KaVo 15 angle pieces 20 LN) with a 1:1transmission and a maximum rotational speed of 45,000 rms.

Test Organisms

Enterococcus (E.) faecium (ATCC 6057) was used as test organism. The inhibition zone test revealed that the TSU care lubricant, heparin or protamine are not endowed with either bacteriostatic or bactericidal effects against growth and propagation of *E. faecium*.

Preparation of the Test Soil

From a 24 h-culture in trypticase soybean bouillon (TSB) (Art. No. CM 129 (Oxoid, Biotechnik GmbH, Wesel)), aliquots of 100 µl were re-inoculated and after 48 h incubated on tryptone soybean agar (TSA) (Art. No. CM 131 (Oxoid Biotechnik GmbH, Wesel)) (36 ± 1 °C for 72 h). The TSA plates were rinsed off with physiologic saline, centrifuged and washed twice in NaCl solution.

To prepare the blood-bacterial suspension, using a syringe filled with 0.5 ml heparin (Braun I.U. 25,000/5 ml (B. Braun Melsungen AG, Melsungen) 2 ml fresh venous blood was taken on the test day, mixed with 1 ml bacterial suspension and shortly before contamination the blood anticoagulation effects were negated by adding 2.5 ml protamine (Protamine ICN 1.000 I.U./ml (Solco GmbH, Grenzach-Wyhlen)).

Contamination of the Test Objects

Using an endodontic cannula, aliquots of 0.1 ml of the blood-bacterial suspension were applied directly to the spray-air/spray-water channels and then the instruments were left for an hour at room temperature.

Recovery of the Test Organism

To determine the recovery rate the air and water channels of 14 angle pieces were contaminated. On completion of the drying time the angle pieces – without pre-

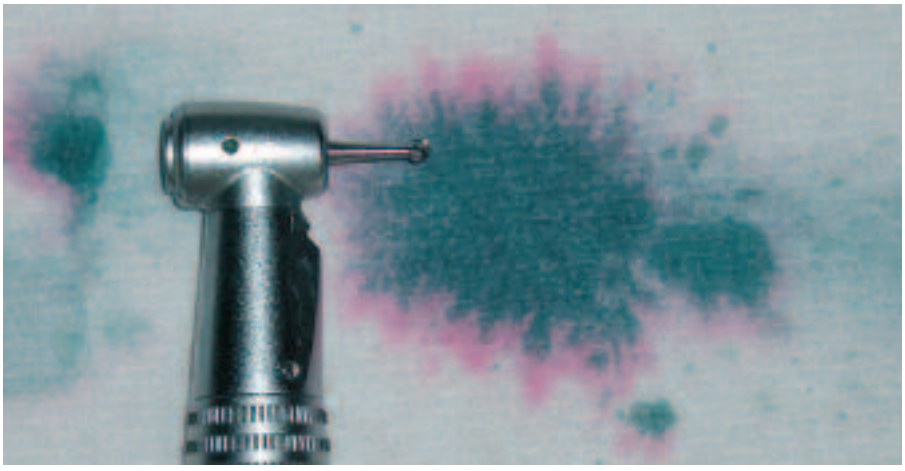

Figure 1: Resuction effect after treatment.

vious reprocessing – were dismantled, each air and water channel was rinsed with 5 ml neutraliser combination (3 % Tween 80, 3 % saponin, 0.1 % histidine, 0.1% cysteine) and the number of colony-forming units (cfu) was counted on Kanamycin aesculin azide agar (KAAA) (Art. No. 5222 (Merck, Darmstadt)) (36 h, 36 ± 1 °C).

Experimental Sequence

The angle pieces were subjected to the following decontamination processes in the Turbocid® device:

1. once to the cleaning and once to the disinfection cycle;
2. twice to the cleaning and disinfection cycle in succession;
3. once to the cleaning cycle;
4. four times in succession only to the cleaning cycle;
5. once to the cleaning and four times to the disinfection cycle.

For each decontamination process, a total of 14 angle pieces were connected to the three attachments provided; all four positions were activated.

Measurement of Residual Contamination

The angle pieces were dismantled, the air and water channels removed and rinsed with 5 ml neutraliser combination (Figure 2), prepared with the eluate dilution series and using duplicate tests =(Spiralometer) incubated on KAAA (36 h, 36 ± 1 °C). Plates with fewer than 5 cfus were not evaluated.

Calculation of Results

The reduction factor was calculated using the following formula:

$RF = \log_{10}cfu_o - \log_{10}cfu_m$

RF: Reduction factor in decadic logarithm levels

log10 cfu_o: decadic logarithm of cfu without reprocessing

log10 cfu_m : decadic logarithm of cfu with reprocessing

Statistical Evaluation

Statistical evaluation was carried out with the user program SPSS for Windows. Since the results followed the normal distribution, the t-test was used. Box plot diagrams were used for graphic illustration.

Results

Operating Parameters

The duration of the various reprocessing phases was verified a total of seven times. No fluctuations were seen, but the exposure time for external disinfection was only 51 s throughout instead of the 60 s specified in the operating instructions. When all four adapters were in use during operation of the device, the entire water consumption was relatively constant for six measurements (36.6 g; standard deviation (StA) 0.3), Turbocidol (30.5 g; StA 0.4) and Micro-Mega care lubricant TSU (0.2 g; StA 0.1).

On comparing the consumption for each of the four connections, hardly any fluctuations were noted in six measurements. For the cleaning phase between 8.4 g and 8.5 g water (StA 0.1 and 0,2) was consumed for each connector. During the internal disinfection an average of between 3.7 g and 3.8 g (StA 0.1) was consumed as well as between 1.4 g and 1.5 g (StA 0.1) during external disinfection.

Microbiology Results

With a baseline concentration of the blood-bacterial suspension of 3.5×10^{10} cfu/ml, the geometric mean of microbial recovery from the water channels was 4.6×10^7 cfu/ml and 3.5×10^7 cfu /ml from the air channels. Following that, there was no sign of optical contamination of any of the fluids recovered after reprocessing.

Figure 2: Recovery with an endodontic cannula by direct rinsing of the dismantled air and water channels.

For Operating Instruction 1 the angle pieces were subjected once to the usual decontamination process. From the control angle piece, which had not been reprocessed, it was possible to recover 3.7×10^7 cfu/ /ml from the water channel and 5.3×10^6 cfu/ml from the air channel (Figure 3, Table 1). An average reduction factor of 3.5 was obtained for the 14 water channels, with 4.5 being the highest value and 2.5 the lowest. For the air channels a reduction factor of 2.2 was obtained, with 3.9 being the highest value and 1.3 the lowest.

For Operating Instruction 2 the angle pieces were subjected twice to the usual decontamination process. From the control angle piece, which had not been reprocessed, it was possible to recover 5.9×10^7 cfu/ /ml from the water channel and 2.2×10^7 cfu/ml from the air channel (Figure 3, Table 1). An average reduction factor of 4.0 was obtained for the 14 water channels, with 4.8 being the highest value and 3.6 the lowest. For the 14 air channels a reduction factor of 4.1 was obtained, with 4.5 being the highest value and 3.1 the lowest.

For Operating Instruction 3 the angle pieces were subjected only to the cleaning phase. From the control angle piece, which had not been reprocessed, it was possible to recover 7.7×10^7 cfu/ /ml from the water channel and 2.0×10^7 cfu/ml from the air channel (Figure 3, Table 1).

After measuring residual contamination, an average reduction factor of 2.1 was obtained for the 14 water channels, with 2.5 being the highest value and 1.9 the lowest. For the 14 air channels a reduction factor of 2.4 was obtained, with 2.3 being the highest value and 1.1 the lowest.

For Operating Instruction 4 the angle pieces were subjected four times in succession to the cleaning phase. From the control angle piece, which had not been reprocessed, it was possible to recover 7.7×10^7 cfu/ /ml from the water channel and 2.0×10^7 cfu/ml from the air channel (Figure 3, Table 1). An average reduction factor of 2.2 was obtained for the 14 water channels, with 2.8 being the highest value and 2.3 the lowest. For the 14 air channels an average reduction factor of 2.5 was obtained, with 2.6 being the highest value and 1.3 the lowest.

For Operating Instruction 5 the angle pieces were subjected once to the clean-

Table 1: Colony forming units (cfus) / ml of the baseline concentrations of controls and after Operating Instructions 1-5 as well as a list of reduction factors (RF) for the water (n = 70) and air channels (n = 70).

Operating Instruction	Baseline concentration (cfu/mL)	Control (cfu/mL)	After decontamination (cfu/mL)	(n)	RF	Control (cfu/ml)	After decontamination (cfu/ml)	(n)	RF
		Water channel				Air channel			
1	$1{,}4 \times 10^{10}$	$3{,}7 \times 10^{7}$	$1{,}1 \times 10^{4}$	14	3,5	$5{,}3 \times 10^{6}$	$3{,}7 \times 10^{4}$	14	2,2
2	$3{,}4 \times 10^{10}$	$5{,}9 \times 10^{7}$	$5{,}6 \times 10^{3}$	14	4,0	$2{,}2 \times 10^{7}$	$1{,}9 \times 10^{4}$	14	4,1
3	$8{,}6 \times 10^{10}$	$7{,}7 \times 10^{7}$	$6{,}0 \times 10^{5}$	14	2,1	$2{,}0 \times 10^{7}$	$9{,}7 \times 10^{4}$	14	2,4
4	$1{,}4 \times 10^{10}$	$7{,}7 \times 10^{7}$	$4{,}8 \times 10^{5}$	14	2,2	$2{,}0 \times 10^{7}$	$6{,}8 \times 10^{4}$	14	2,5
5	$1{,}7 \times 10^{10}$	$3{,}7 \times 10^{7}$	$2{,}6 \times 10^{3}$	14	4,2	$5{,}3 \times 10^{7}$	$5{,}5 \times 10^{4}$	14	4,0

ing phase and four times to the disinfection phase. From the control angle piece, which had not been reprocessed, it was possible to recover a bacterial concentration of 3.7×10^{7} cfu/ /ml from the water channel and 5.3×10^{6} cfu/ml from the air channel (Figure 3, Table 1). An average reduction factor of 4.2 was obtained for the water channels, with 5.0 being the highest value and 3.4 the lowest. For the air channels a reduction factor of 4.0 was obtained, with 4.3 being the highest value and 3.6 the lowest.

Using the t-test a significant difference was noted between the results obtained for Operating Instructions 1 and 2. A p-value of 0.032 was obtained for the water channels and a p-value of 0.001 for the air channels. No significant difference was seen between the results for Operating instructions 3 and 4. A p-value of 0.191 was obtained for the water channels and a p-value of 0.450. However, the difference between the results for operating instructions 1 and 5 were significant. A p-value of 0.000 was obtained for the water channels and a p-value of 0.000.

Discussion

In tests conducted under everyday use conditions, the test objects harbouring contamination from such an environment, such as for example the hand and angle pieces used for treatment, are very heterogeneous in terms of the type and quantity of contamination, bacterial flora and contaminated surface. The requirement that the test results be independent of any particular place, time or person cannot be met in everyday practice [12]. But, on the other hand, the test model must as far as possible reflect the actual use conditions [13]. For that reason, this present study aimed at verification of the internal cleaning and disinfection had recourse to the model test as used in practice. Studies have shown that not all transmission instruments are equally amenable to reprocessing [7, 14, 15]. The KaVo angle piece 20 LN used is easy to dismantle.

The bacterial concentration of the contamination solution is based on the bacterial concentration of the oral cavity. However, the bacterial concentration of the oral cavity is not constant but rather depends on myriad factors such as the time of day, oral hygiene and the time since the last meal [16]. Depending on the author, the values ranged between 10^{5} cfu/ml [17] and 10^{10} cfu/ml saliva [18]. Just as the data available on the concentration of cfu/ml saliva vary, so the test soil concentrations cited in the literature differ: Neugeboren et al., Guggenheim et al. or Matsuyama et al. use a concentration of 10^{8} cfu/ml [7, 19, 20]. Borneff-Lipp used a concentration of 10^{9} cfu/process challenge device and Andersen et al. conducted experiments with a concentration of 10^{10} cfu/ml [14, 15].

Since a reduction of between 2 to 4 orders of magnitude can be expected from cleaning and of over 5 orders of magnitude from disinfection, the present study – so as to still be able to detect microorganisms – used a concentration of between 8.6×10^{9} and 3.4×10^{10} cfu/ml.

Once it had been established that the protein load in contamination solutions had implications for the cleaning and disinfection outcome, studies were conducted that more or less simulated the protein load in an everyday practice model test.

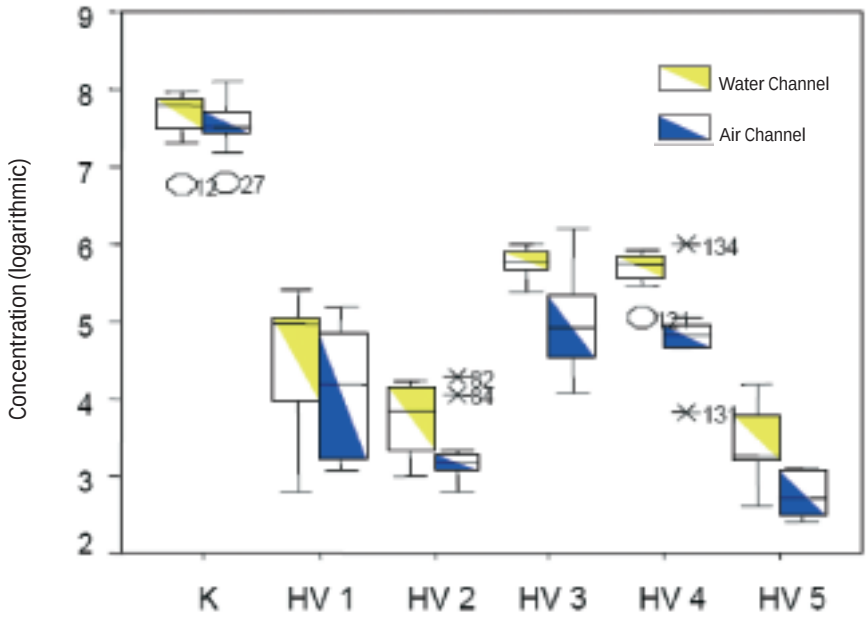

*Figure 3: Bacterial concentrations recovered for Operating Instructions (HV) 1 to 5 from the air (n=70) and water channels (n=70) as well as from the controls (n=10), shown as logarithm of cfu/ml in box plot diagram. 0: outliers, * extreme values.*

Guggenheim et al. [7] and Bößmann [8] added 5 % horse serum [7, 8]. Gräf et al. increased the serum concentration up to 20 % [21]. However, investigations by Chan-Myers and Chu showed that blood was considerably more difficult to remove than serum [10]. In the dentistry setting angle pieces are used for a large number of therapeutic procedures involving the opening of a blood vessel, thus possibly causing bleeding and, in turn, increasing the probability that angle pieces will become contaminated with blood. Furthermore, the presence of blood exerts a demonstrable influence on cleaning and disinfection [9, 22]. Sanchez and MacDonald studied in 1995 the effectiveness of different methods for reprocessing dental instruments and concluded that none of the methods studied – including those processes using ultrasound or enzymatic detergents – was able to completely remove blood residues [23]. Spicher investigated in 1997/98 how blood affected the microbicidal efficacy of various disinfectants. He concluded that the activity of disinfectants containing ammonium compounds, chloramine T or glutardialdehyde was most adversely affected by the addition of blood, whereas in the case of formaldehyde, saponated cresol solution and ethanol the disinfectant efficacy was hardly affected by the addition of blood [24]. Hence in the present study, human blood was also used.

For Operating Instructions 1, after reprocessing only an average reduction factor of 3.5 was obtained for the water channels and of 2.2 for the air channels. These results differ from the findings of Guggenheim et al. or of Bößmann [7, 8]. If one considers the results obtained by Bößmann or Guggenheim et al., the Turbocid® device yielded a reduction of around 5 in the presence of a 5 % serum concentration. For the tests presented here using human blood as contamination, a reduction factor of only 3.5 was obtained for the water channels and of 2.2 for the air channels. However, this reflects somewhat the magnitude of influence exerted by blood, as borne out in the experiments by Hachmann, Spicher or Jülich et al. [9, 12, 22]. The studies by Bößmann and Rüdebusch also revealed that disinfection with chemical substances and processes can be assured only by, in some cases, drastically prolonging the exposure time to more than an hour and that aldehyde-free disinfectants had drawbacks if the test organisms were embedded in substances such as blood [25].

For Operating Instruction 2 a higher average reduction factor of around 4 was obtained after twofold reprocessing. As such, a significant difference is seen between single and twofold reprocessing both for the water channels ($p = 0.032$) and air channels ($p = 0.001$). However, on the whole the reduction factor is low. One reason that it was not possible to achieve adequate bacterial reduction even with twofold reprocessing maybe because of the fixing effects of alcohol [26] and glyoxal. For Operating Instruction 3 (cleaning once without disinfection) and 4 (cleaning four times without disinfection) only cleaning was studied. The average reduction factors were between 2.1 and 2.5. For Operating Instruction 5 (cleaning once and disinfection four times) only an average reduction factor of around 4 was achieved. These results differ significantly both for the water and air channels ($p = 0.000$) from those of Operating Instruction 1.

Statistical evaluation has shown that twofold reprocessing or single cleaning followed by four cycles of disinfection bestowed significantly better decontamination results. A surprising finding was that fourfold cleaning did not yield any discernibly higher reduction factor than that obtained for a single cleaning cycle.

The present study used test soils that contained in addition to microorganisms coagulable blood. Since the presence of blood can influence the decontamination process [9, 10, 12, 22], the findings of our study are not comparable with those of studies that used only microbial and serum test soils. To date, there is no publication that has investigated the effectiveness of the Turbocid® device in decontaminating dental angle pieces using as test soil a blood-bacterial suspension. However, using the ortho-phthaldialdehyde (OPA) method, Schönherr showed in his studies that there were differences in the cleaning performance of two washer-disinfectors of different manufacture. To that effect, a total of 60 dental angle pieces were contaminated with coagulable blood and after leaving to dry for one hour, 30 angle pieces were reprocessed in the Lifetime (KaVo, Biberach) and 30 in the Sirona-Hygienecenter (Siemens AG, Bensheim) washer-disinfectors. Using the modified OPA method, it was possible to demonstrate that residual contamination of the air and water channels was significantly lower ($p=0.00$) in the air and water channels of the angle pieces reprocessed in the Lifetime machine [27].

By using a microbiological test soil it is possible to obtain a reduction factor comparable with the reduction factor achieved in other studies. The results of the present study demonstrate that coagulable blood is difficult to remove and that blood residues remaining after cleaning adversely affect the disinfection outcome and reduction factors obtained. Whereas Guggenheim et al. or Bößmann noted a reduction factor of more than 5 [7, 8], only a reduction factor of less than 5 was obtained in the present study.

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Conflict of Interest

The authors declare that there is no conflict of interest as understood by the International Committee of Medical Journal Editors.

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