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Effectiveness Evaluation of Different Suction Systems

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SUMMARY

Microorganisms of the patient's oral cavity and his/her blood and saliva may cause different air-borne and blood-borne infectious diseases among odontologists and their assistants who work with patients.

Quantitative analysis and spatial distribution analysis of the environmental spread of oral liquid and cooling liquid mixture were performed during this study. Effectiveness of suction systems of four types was evaluated: without suction, using a small-size suction pump alone, using a small-size and large-size suction pumps, using a small-size suction pump together with an experimental extra-oral aspirator. Quantitative changes of the water aerosol, which enters the environment during the preparation of teeth, were determined in respect of the used suction systems. The small-size pump system together with an experimental extra-oral suction system eliminated best the aerosol formed during the preparation.

Keywords: Infection transmission, aerosol, suction systems

INTRODUCTION

The modern odontological care is not possible to imagine without teeth preparation using burs turned by air turbine and without cooling by means of compressed air and water. The cost of this progress is increased risk to transmit air-borne and blood-borne infectious diseases to medical staff, which works in the odontologic clinic [1,2,3]. Although most patients have no health complaints and no visible disease symptoms are observed as well, many different pathogenic microorganisms are located in oral cavities of patients. The money saved on individual protection will never serve as substitute for treatment expenses and lost health. The protection is indispensable because many patients do not disclose their health status or evaluate it inadequately. Symptoms expressed during the incubation or during the course of latent infection, which could indicate certain forms of disease, may be absent. Soft tissues of the oral cavity are injured often during odontological interventions. The mixture of blood and saliva may result in blood induced infectious diseases [4]. The aim of this study is to perform quantitative analysis and spatial distribution analysis of environmental spread of oral and cooling fluids mixture and to evaluate the effectiveness of different suction systems.

MATERIAL AND METHODS

An even plane surface is formed 25 cm below a phantom and seven microscopy slides of 75x25 mm are put at every 10cm.

The following distances are formed from the phantom oral cavity (H) till the diagnostic slides in this way:

27 cm
32 cm
39 cm
47 cm
56 cm
65 cm
74 cm

The upper anterior phantom teeth are ground 5 minutes with a cylinder bur H&M (881), diameter 012 using the turbo-tip НТБ-250-М4 (Russia) and cooling by means of a cooling mixture at the rate of 45 ml/min. The physiological salt solution used as a cooling mixture is coloured with red gouache (25 g gouache per 1 L of solution) with aim to facilitate data analysis. Four test series with different suction systems are carried out, each including 10 tests:

1. First series (A): without suction.
2. Second series (B): using a small-size suction pump.
3. Third series (C): using a small-size and large-size suction pumps.
4. Fourth series (D): using a small-size suction pump together with an experimental extra-oral aspirator.

The analysis of experimental slides is performed.

<u>Equipment</u>

Video-camera

In close cooperation with leading world firms, the company Photometrics, USA (www.photomet.com) established in 1978 has developed and produced a professional high-resolution cooled video camera CoolSnap Pro for scientific research.

<u>Software</u>

The professional software Image-Pro Plus and im-

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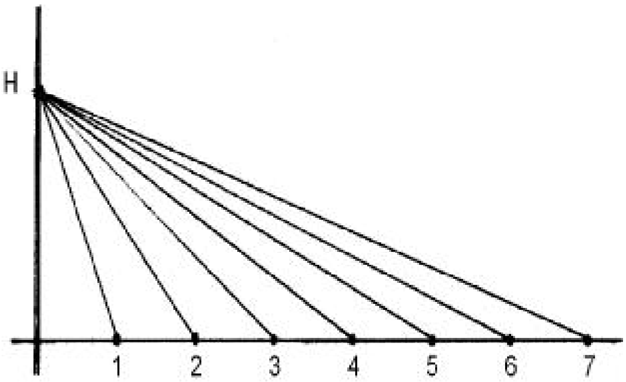


Fig. 1. Placement scheme of experimental glass slides

Fig. 2. Experimental extra-oral aspirator.

age data base IQbase, which functions in its specific environment, provided by the company Media Cybernetics, USA (www.mediacy.com) founded in 1981 is used for image based analysis, image processing, measurement of objects in view, statistical analysis and formation of the image data base.

Measurement methodology

Water droplets coloured with red gouache settle together with gouache particles on microscope slides. A LED (light emitting diode), green 1 Watt power diode, is used to increase the contrast in the microscope. Images of droplets and particles present on the microscope slides, which are seen using the microscope, are entered by means of the video camera CoolSnap Pro into a personal computer.

Ten evenly distributed areas are selected on each microscope slide, images of which are fixed by video camera and saved in the memory. The area of one slip makes 10 mm^2 of the microscopy slide. Ten slips are recorded for every slide. The total analysed slide area makes total of 100 mm^2 in every test series. Every slip of video camera constitutes of 1,392x1,040 image elements. Grey-scale information of 12 bit is recorded in every image element.

The software Image-Pro Plus v. 5.1 for image analysis processes them according to the developed algorythm:

Initial image processing. Unevenness of the background eliminated by removing the background of a slip from the image.

Formation of the droplet mask. The background and all outside objects present in the slip, which are not related with a form of droplets, are removed fully from every slip.

Separation of droplets. The logical image product of a droplet slip mask and slip forms a new slip, in which only objects having a form of a droplet are observed against a white background.

Count of droplets and measurement of their parameters. Measurement of the average diameter of every droplet and measurement of the area occupied on the microscope slide are performed and statistical parameters of the average diameter of droplets are counted. Minimal and maximal diameters of measured droplets, the range of diameter variation, average diameters, standard deviation of diameter, the total diameters and the number of droplets on the surface of experimental slides are found.

Analysed droplets are sorted by their average diameter.

RESULTS

Statistical means of all performed tests are presented in the tables Tables 1-4.

Based on average findings of the study when no

Table 1. Data of the first test series (A): without suction

	Total area, mm^2	Min. diameter, µm	Max. diameter, µm	Average particle size, µm	Total in µm	Number
A1	14.85	26	626	109	79013	726
A2	11.86	26	853	94	65898	703
A3	5.25	27	1038	89	40463	454
A4	2.85	26	223	80	18372	230
A5	3.09	26	224	73	9759	134
A6	2.59	26	143	59	4221	71
A7	3.17	25	123	60	2814	47

Table 2. Data of the second test series (B): using the small-size suction pump

	Total area, mm^2	Min. diameter, µm	Max. diameter, µm	Average particle size, µm	Total in µm	Number
B1	10.02	26	357	94	94942	1005
B2	5.49	26	414	84	65616	782
B3	2.67	26	223	86	33380	389
B4	0.824	26	161	73	12182	167
B5	0.343	27	139	73	5013	69
B6	0.137	27	129	64	2162	34
B7	0.083	27	144	55	1330	24

Table 3. Data of the third test series (C): using a small-size and large-size suction pumps

	Total area, mm^2	Min. diameter, µm	Max. diameter, µm	Average particle size, µm	Total in µm	Number
C1	5.028	6	1494	85	20037	237
C2	1.503	16	330	67	13971	207
C3	0.936	17	328	66	10317	157
C4	0.56	17	204	54	7967	147
C5	0.482	16	214	40	7558	189
C6	0.301	16	144	43	5489	128
C7	0.159	17	141	38	3283	87

Table 4. Data of the fourth test series (D): using a small-size suction pump together with an experimental extra-oral aspirator

	Total area, mm^2	Min. diameter, µm	Max. diameter, µm	Average particle size, µm	Total in µm	Number
D1	0.989	16	702	55	5099	93
D2	1.145	15	197	33	3183	97
D3	0.0684	16	108	27	2111	77
D4	0.047	16	135	27	1450	54
D5	0.031	17	43	25	1303	53
D6	0.0295	15	42	23	1343	59
D7	0.0236	16	38	22	1131	52

suction system had been used (Table 1), the area coverage with an aerosol-form fluid from the phantom oral cavity per 100 mm^2 decreased five times at the investigated distance of 27 cm (A1) to 74 cm (A7), from 14.85 mm^2 to 3.17 mm^2. The biggest change occurred within the limits A2 and A4. That was between 32 cm and 47 cm. Also the biggest change in the number of particles occurred at this distance. When referring to changes of the maximal diameter of particles it was observed that largest droplets flied only within the limits A1-A4 with contamination of a widest surface area. The maximal diameter of particles decreased 5 times at the distance A1-A7 and the average diameter diminished 1.8 times at the distance A1-A7. The number of particles and their diameter decreased with increase of a distance.

Based on average findings of the study when only a small-size pump was used (Table 2), the area coverage with an aerosol-form fluid from the phantom oral cavity per 100 mm^2 decreased 121 times at the investigated distance of 27 cm (B1) to 74 cm (B7), from 10.02 mm^2 to 0.083 mm^2. The biggest change occurred within the limits B1 and B4. That was between 27 cm and 47 cm. Also the biggest change in the number of particles occurred at this distance. Changes of the maximal diameter of particles occurred evenly throughout the whole investigated distance. High dispersion of particle size was not observed. The maximal diameter of particles decreased 2.5 times at the distance B1-B7 and the average diameter decreased 1.7 times at the distance B1-B7. The number of particles and their diameter decreased with increase of a distance.

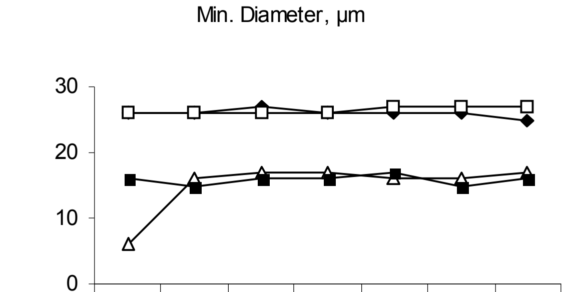
Based on average findings of the study when a small-size pump and large-size suction pump were used together (Table 3), the area coverage with an aerosol-form fluid from the phantom oral cavity per 100 mm^2 decreased 32 times at the investigated distance of 27 cm to 74 cm (C7), from 5.028 mm^2 to 0.159 mm^2. The biggest change occurred within the limits C1 and C4. That was between 27 cm and 47 cm. Changes of the maximal diameter of particles occurred evenly throughout the whole investigated distance except at the distance C1 because of frequently found occasional low-energy large-diameter drops. High dispersion of particle size was not observed. The average diameter of particles decreased 2.2 times at the distance C1-C7. The number of particles and their diameter decreased while the distance increased.

According to the presented average results of the study when a small-size suction pump was used together with an experimental extra-oral aspirator (Table 4), the surface area coverage with an aerosol-form fluid from the phantom oral cavity per 100 mm^2 decreased 42 times at the investigated distance of 27cm (D1) to 74 cm (D7), from 0.989 mm^2 to 0.0236 mm^2. The biggest change occurred within the limits B1 and B4. That was between 27 cm and 47 cm. Also the biggest change of the number of particles occurred at this distance. Change of the maximal diameter of particles occurred evenly throughout the whole investigated distance except at the distance D1 because of frequently found occasional low-energy blarge-diameter drops. High dispersion of particle size was not observed. The average diameter of particles decreased 2.5 times at the distance D1-D7. The number of particles and their diameter decreased with increase of a distance.

The following was detected during effectiveness evaluation of different suction systems in regard of decreasing environmental surface contamination with aerosol (Figures 3 - 7).

Based on the findings of the study when double aerosol suction systems (groups C and D) were used (Figure 3), minimal diameters of droplets were by 10 µm smaller compared with the investigated group (A and B) without use of any suction system or with use of a small-size suction pump alone. The minimal droplet diameter remained even throughout the whole investigated distance (from 27 cm to 74 cm). Namely this diameter corresponds the fog aerosol, which may float in the air freely for several hours, to settle on different surfaces and penetrate into airways of medical staff and patients. The smallest minimal diameter of droplets was obtained in the group C1 (distance of 27 cm) using a small-size and large-size suction pumps. It is possible to state thus that this system is the most effective in collecting smallest aerosol particles.

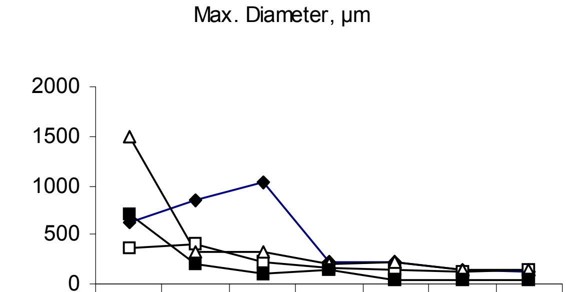
Referring to the findings of the study, we may con-



	1	2	3	4	5	6	7
A	26	26	27	26	26	26	25
B	26	26	26	26	27	27	27
C	6	16	17	17	16	16	17
D	16	15	16	16	17	15	16

Distance

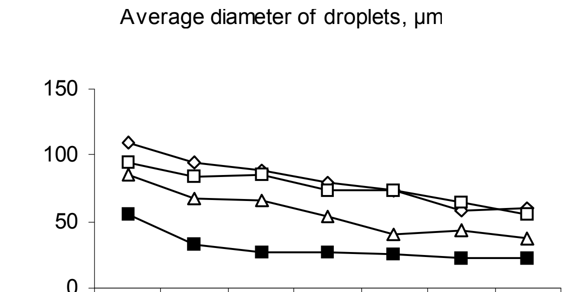
Fig. 3. Changes of the minimal diameter of droplets among the investigated groups A, B, C and D in µm



	1	2	3	4	5	6	7
A	626	853	1038	223	224	143	123
B	357	414	223	161	139	129	144
C	1494	330	328	204	214	144	141
D	702	197	108	135	43	42	38

Distance

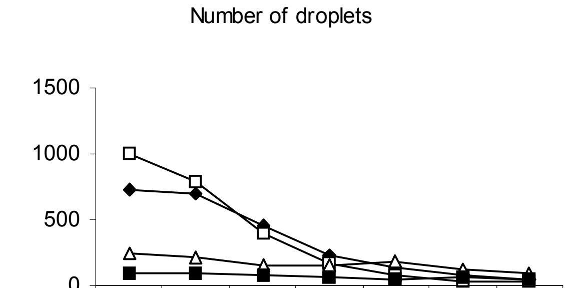
Fig. 4. Changes of the maximal diameter of droplets among the investigated groups A, B, C, D in µm



	1	2	3	4	5	6	7
A	109	94	89	80	73	59	60
B	94	84	86	73	73	64	55
C	85	67	66	54	40	43	38
D	55	33	27	27	25	23	22

Distance

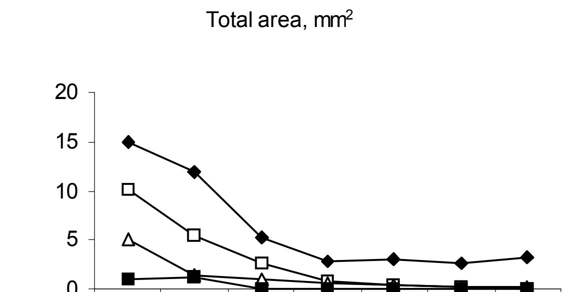
Fig. 5. Changes of average diameter of droplets among the investigated groups A, B, C, D in µm.



	1	2	3	4	5	6	7
A	726	703	454	230	134	71	47
B	1005	782	389	167	69	34	24
C	237	207	157	147	189	128	87
D	93	97	77	54	53	59	52

Distance

Fig. 6. Changes in number of droplets among the investigated groups A, B, C and D.



	1	2	3	4	5	6	7
A	14,85	11,86	5,25	2,85	3,09	2,59	3,17
B	10,02	5,49	2,67	0,824	0,343	0,137	0,083
C	5,028	1,503	0,936	0,56	0,482	0,301	0,159
D	0,989	1,145	0,068	0,047	0,031	0,03	0,024

Distance

Fig. 7. Changes in the total area of droplets between the investigated groups A, B, C, D.

clude that occasional fluid splashing with droplets of maximal diameter occurs if no one suction system is used (Figure 4). The highest pick is at the distance 3 (39 cm). The maximal diameter diminishes between distances 3 and 4 (39 to 47 cm). Droplets also increase until the distance 2 (32cm) and fall evenly in the investigated group B. The highest decrease of big droplets is observed between distances 1 and 2 (27-32 cm) in the investigated groups C and D. The maximal diameter of droplets becomes similar (mean of 181µm) in all experimental groups at the distance 4 (47cm) and evenly diminishes throughout the investigated distance. The spread of large-size particles is the highest when no one suction system is used or a small-size pump is used alone. The large-size pump collects small droplets effectively, but it is unable to gather the largest water droplets, however the distance flown by them is the lowest because of their weight. Occasional non-controllable droplets result in a comparatively great statistical diameter of particles in the investigated group C. They are collected successfully by means of an experimental extra-oral pump. The best result is achieved using a small-size pump together with an extra-oral pump.

The average diameter of droplets (Figure 5) of the group D is as twice as low when comparing the groups A and D at the distance 1 (27 cm); that permits to conclude that the proposed extra-oral suction method is the most effective. If to compare the same groups at the distance 7 (74 cm), this ratio is even more impressive - the average droplet diameter is as thrice as low. The average particle diameter at the distance of 27 cm is 109 μm for the group A and 55 μm for the group D. And 60 μm were for the group A and 22 μm for the group D at the distance of 74 cm. Data varied between groups A, B and C, D when a large-size pump was used. Similarly proportionate decrease of the particle size iss observed throughout the whole investigated distance when comparing tests C and D. However the average particle size is the lowest already at the distance 1 (27 cm) by performing tests D and it decreases throughout the whole investigated distance.

If to compare by a number of particles in the investigated area (Figure 6), this number is significantly lower in the tests C and D. The difference between the maximal value at the distance 1 (27 cm) in the test B and the minimal value at the distance 1 in the test D is above 10 times. The results on effectiveness of suction systems are better for the tests C and D in comparison with A and B. The difference between the maximal value of the test A at the distance 4 (47 cm) and minimal value of the test D at the distance 4 decreases and remains higher than 4 times. The suction system D is the most effective.

The comparison of the investigated 100 mm^2 area coverage with droplets (Figure 7) shows that the lowest coverage is observed evidently in the investigated group D: from 0.9% at the distance 1 (27 cm) to 0.02% at the distance 7 (74 cm). In case of the investigated group A, 14.85% and 3,17% respectively. The critical range is between distances 3 and 4 (39-47cm) for the groups A and B. Insignificant changes prevail at longer distances. According to the findings of the study, the most effective system is the suction system applied in the investigated group D.

DISCUSSION

During the preparation of hard dental tissues, the drill driven by air turbine sprays the mixture of compressed air and water of approximately 2 atmospheres into the oral cavity and it leaves the cavity in the form of aerosol.

The aerosol includes particles of tooth tissues and droplets of bood and saliva of various sizes. The size of droplets determines the rate of their spread in the environment and the distance of distribution on surfaces. Formed during the work of high-speed rotating devices, a fine aerosol composed of moisture droplets and fine hard particles, which are smaller than 50 μm diameter most often, may stay suspended in the air for many hours. When inhaled such aerosol may reach the finest parts of lungs. Aerosol particles of 10-15 μm settle in the upper airways; and those of 0.5-5 μm settle in the lower airways and may cause viral respiratory diseases [5,6]. Water droplets are much larger (over 50 μm) than aerosol particles and they may transfer not only a higher amount of pathogens, but blood particles as well. Fine water droplets sprayed during the work of odontologist are usually found at the distance of 2 meters around the workplace [7]. Aerosol particles and also water droplets may contain agents causing infection because the diameter of bacteria does not exceed 10 μm and viruses are still smaller.

The infected aerosol settles first on hands, face, hairs and cloths of the doctor who works in close proximity of a patient and covers surrounding surfaces [8]. In this way, the medical workers become disseminator of asymptomatic infections, even beyond their workplace. Microorganisms spread via airborne way are dangerous not only for those who work directly with patients, but also for other persons. The surfaces contaminated with aerosol and mucous membranes of the oral cavity (primary), hands of medical staff and instruments (secondary) may serve as a primary and secondary ways of the spread of infection. The staff who contacts with such primary surface (aerosol, saliva, blood) may pass the contagion to odontological tip and other instruments having a direct contact. Despite performed surface disinfections, it is not possible to do that in every single case or some surfaces, e.g. door or drawer handles, are not cleaned. The infection may be transmitted so from one surface to another [9].

CONCLUSIONS

1. The smallest water particles fixed in the study were found evenly distributed throughout the whole investigated distance. These particles were larger (26 μm) when ineffective suction systems were used. The diameter of the smallest fixed particles (16 μm) decreased with increase of suction effectiveness.
2. The concentration of the largest water particles detected in the study increased in closer proximity of the source of contamination with increase of suction effectiveness.
3. A standard small-size pump could not ensure good collection of water particles. Auxiliary suction systems increased the effectiveness. Based on the number of found water particles and the total area covered with water particles, it is possible to state that an experimental extra-oral suction system was more effective compared to the traditional complementary suction system of increased suction capacity (turbo-pump).

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