Personal Respiratory Protective Devices : Efficacy of Intranasal Stent with Filters

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Abstract

Intranasal, hollow, cylindrical, medical grade and silicone stent with two outer layers face mask filters at both ends was proposed for atmospheric suspended particulate matter prevention. The personal respiratory protective device efficacy was done at the Otolaryngology Department, Ramathibodi Hospital from April 1996 to October 1997. Single pulse mode of carbon dioxide laser smoke particle was the suitable source of atmospheric suspended particulate matter. A laser plume evacuator removed laser smoke particles with 5 Millipore filters of 0.22 um pore size or 5 intranasal stent with filters attached at the inlet end. A Millipore filter got the same laser smoke particle amount that passed through each intranasal stent filter with an air flow rate of 15 l/min controlled by a rotameter. Laser smoke particle deposition in filter materials was counted under a high power optical microscope. Laser smoke particle amount in each layer of a four-layer filter of intranasal stent with 7.5, 15.0 and 30.0 l/min air flow rates is shown. The filtration efficacy of four, three and two layers of intranasal stent with a filter for laser smoke particle retention were compared. An intranasal stent with filter could be applied in a human nasal vestibule with acceptable air flow resistant during public transportation in a traffic congested area.

Key word : Intranasal, Silicone Stent, Filter, Efficacy, Suspended Particulate Matter, Laser Smoke Particle

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Intranasal, hollow, cylindrical, medical grade, silicone stent with filters at both ends has been proposed as a personal respiratory protective device. The filters are the outer layers of a face mask or surgical mask. An intranasal stent with filters device has not been used previously(1-4). Its efficacy for suspended particulate matter prevention should be evaluated in highly air-polluted conditions(5-7). Laser smoke particles are a suitable suspended particulate matter source(8,9). A laser smoke evacuator removes laser smoke particles through an intranasal stent with filters or a Millipore filter with various air flow rates. The maximum particle amount from a laser evaporative field

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was captured by a 0.22 um pore size Millipore membrane filter(10,11). Laser smoke particle amount in both filter types were examined under a high power optical microscope. Laser smoke particle amount in each filter layer of an intranasal stent with filters was used to calculate the filtration efficacy of an intranasal stent with filters for polydisperse particle in the atmosphere(12,13).

MATERIAL AND METHOD

The experiment was conducted at the Otolaryngology Department, Ramathibodi Hospital from April 1996 to October 1997. There were 5 intranasal stents with filters for each air flow rate of 7.5, 15.0 and 30.0 l/min so totally 15 intranasal stents with filters were used. The length of the intranasal stent was 1.0 cm, outer diameter was 1.3 cm and inner diameter was 1.1 cm with a cross-sectional area of 0.9507 cm^2. The filter was the outer layers of a surgical or face mask which is popular in preventing air pollution hazards in the general population. The middle layer of the face mask was not used due to its high air flow resistance. Two filter layers were sealed at each end, totally a four-layer filter, of an intranasal stent with adhesive tape for wound dressing (Fig. 1). An intranasal stent with filters was attached to a Millipore adaptor outlet which had a 3 cm in length, 1.3 inner diameter cylindrical hollow silicone stent. The filter that was close to the laser evaporative field was No 1 and that which faced the rotameter was No 4. The laser smoke particle amount in different layers of the intranasal stent with filters was compared. Each of 5 Millipore filters (GS-filter type, pore size 0.22 um, Millipore Corporation, Bedford, Massachusetts 01730, U.S.A.) was fitted inside the adapter (Fig. 2) composed of two cylindrical hollow silicones, 6 cm in length, and connected with a rotameter inlet (MFV-6, Aalborg instruments, Monsey, New York, U.S.A.,) The rotameter was calibrated with a standard flowmeter (Puratan-Bennett FT, series D, pressure compensated flowmeter, CSA Standard, U.S.A.).

The particle amount created by a single mode, 10 W, 0.2 s duration and 5 shots of a carbon dioxide laser (Model 1060, Sharplan, Laser Industries Ltd, Tel Aviv, Isarael.) was collected maximally by 0.22 um pore size 5 Millipore filters with an air flow rate of 15.0 l/min.The mean particle amount in the Millipore filter was used to calculate the filtration efficacy of the intranasal stent with various layers of filters. Each intranasal stent with filters or a Millipore filter got laser smoke particles that were confined in a 3 x 3 x 3 cm plastic box. There were 1.4 cm diameter holes at the side of the box for the laser handpiece and another 1.4 cm diameter hole at the top of the box for an intranasal stent with filters or a Millipore filter adaptor inlet (Fig. 3). A laser smoke particle evacuator (Xplume, model 100, Sharplan, Laser Industries Ltd, Tel

Fig. 1. Medical grade, silicone, hollow, cylindrical stent on the left; outer layer of face mask at the center ; intranasal stent with filters at both ends on the right.

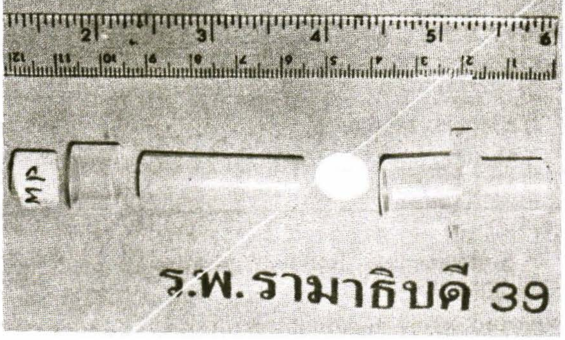

Fig. 2. Adapter for Millipore filter or intranasal stent with filters. Outer part of the adapter on the left; inner part of the adapter at the center; Millipore filter at the 2^{nd} from the left; connector for intranasal stent with filters to the adapter at the 2^{nd} from the right; intranasal stent with filters on the right

Aviv, Isarael) removed the particles during laser evaporization. The evacuator inlet was attached to a rotameter outlet. The outlet of the adapter with the Millipore filter or intranasal stent with filters at its inlet was connected with a rotameter inlet (Fig. 4). The air flow rate through the filter material was 7.5, 15.0 and 30.0 l/min and ran for 1 minute in each test.

An optical microscope (Olympus ECB, Olympus Optical Co.Ltd., 2-chrome, Hatagaza, Shibuya, Tokyo, Japan.) was used to examine particle retention in each filter material. Ten fields of particle retention in the Millipore and intranasal stent with filters were selected under a 10 x 10 optical microscope. Each field of intranasal stent filters was focused for 10 levels due to several layers of each filter layer and counted under 10 x 40. Each field of the Millipore filter was focused for 2 levels. The active surface area of the Millipore and intranasal stent with filters was 0.9507 cm^2 and each cross-sectional field under 10 x 40 microscope was 0.0013 cm^2. Total laser smoke particle amount in each filter was multiplied by 73.1308 to ten fields of particle count.

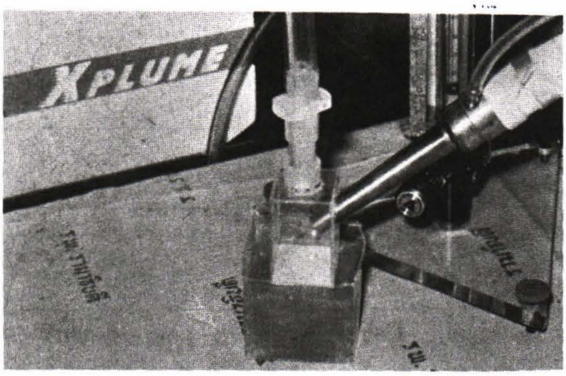

Fig. 3. Small plastic box with base for laser smoke particle confinement during laser evaporization and filter adapter connection. Laser hand-piece at the side of the box; filter adapter at the top of the box connected to a rotameter on the right and laser smoke particle evacuator on the left.

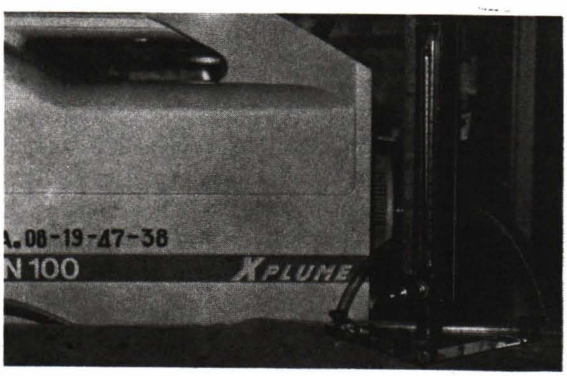

Fig. 4. Inlet of laser smoke particle evacuator on the left connected to the outlet of rotameter on the right.

RESULT

A Millipore filter is supposed to get the maximum laser smoke particle amount from a laser evaporative field with 15 l/min air flow rate. The laser smoke particle amount that passed through the Millipore filter or intranasal stent with filters was the same. The efficacy of the intranasal stent with different filter layers under various air flow rates was calculated with the mean laser smoke particle amount in the Millipore filter (Table 1). The mean and percentage of the particle amount deposition in layer No 1 to No 4 of 5 sets of intranasal stent with filters under air flow rates of 7.5, 15.0 and 30.0 l/min are shown in Table 2. The higher air flow rate created more particle penetration through the filter materrial. Mean particle retention in filter layers No 1, 2, 3 and 4 with three air flow rates was 32.5, 31.2, 20.0 and 16.3 per cent respectively. More than 80 per cent of laser smoke par-

Table 1. Laser smoke particle deposition in a Millipore filter at an air flow rate of 15.0 l/min.

Millipore filter No.	Laser smoke particle count *
1	428,547
2	440,979
3	342,984
4	362,583
5	409,094
Mean +/- S.D.	396,837.4 +/-42,360.8

* laser smoke particles were counted in 10 areas and 2 focus levels in each Millipore filter under a 10 x 40 microscope and multiplied by 73.1308 to get the total laser smoke particles

Table 2. Mean laser smoke particle amount and percentage retention in each layer of a four-layer intranasal stent at various air flow rates.

Filter layer No.	laser smoke particle amount *(%) with air flow rate (l/min) 7.5	15.0	30.0
1	107,860.4 (32.8)	89,723.8 (31.1)	91,866.4 (33.4)
2	101,513.2 (30.8)	87,124.2 (31.1)	86,607.4 (31.4)
3	68,973.6 (20.9)	60,464.6 (21.6)	47,959.0 (17.4)
4	51,085.8 (15.5)	42,679.0 (15.2)	48,939.2 (17.8)
Mean+/-S.D.	329,433.0+/-24,677.8	279,991.6+/-22,691.2	275,372.0+/-34,991.2

* laser smoke particles were counted in 10 areas and 10 focal levels in each filter layer under a 10 x 40 microscope and multiplied by 73.1308 to get the total laser smoke particle amount, 5 intranasal stents with filters for each air flow rate

Table 3. Efficacy (%) of intranasal stents with different filter layers for laser smoke particles at various air flow rates.

Filter layers in intranasal stent	Efficacy (%) at various air flow rates (l/min) 7.5	15.0	30.0	* Mean (%)
Four	83.0	70.6	69.4	74.3
Three	70.1	59.8	57.1	62.7
Two	52.8	44.6	45.0	47.4

* Compares the mean of laser smoke particle amount in a Millipore filter from Table 1 ; 5 sets of an intranasal stent with filters for each air flow rate

ticles was captured by the first three layers of the filter. The difference of particle retention in the four-layer, three-layer and two-layer filters of the intranasal stent at different air flow rates was compared (Table 2). The mean filtration efficacy of four-layer, three-layer and two-layer intranasal stents for laser smoke particles with three air flow rates was 74.3, 62.7 and 47.4 per cent (Table 3).

DISCUSSION

The intranasal stent with filters has been proposed as a personal respiratory protective device for suspended particulate matter prevention and has not been reported previously(14,15). A selection of filter layers e.g. four, three or two layers depending on the air flow resistance through the intranasal stent with filters in human nasal vestibules was tested by a standard anterior rhinomanometry(16, 17). The four-layer intranasal stent created too high a nasal airflow resistance. The three-layer intranasal stent had the same nasal airflow resistance as the two-layer intranasal stent so it should be suitable for suspended particulate matter prevention. The mean filtration efficacy of the three - layer intranasal stent was 62.7 per cent for laser smoke particles under air flow rates of 7.5, 15.0 and 30.0 l/min. The suspended particulate matter amount in some parts of Bangkok is 3-4 times above the standard level of 0.33 mg/l(18,19) and cames from vehicle exhaust, construction areas and industry waste products. The laser smoke particle amount during laser surgery could be about 0.92 mg/l which is also 3 times above the standard suspended particulate matter level for air quality in Bangkok. The average size of laser smoke particles is 0.54 um which is smaller than that of suspended particulate matter and 77 per cent of laser smoke particles is smaller than 1.1 um(8,9,20-22). In the Otolaryn-gology Department, Ramathibodi Hospital, 70 per cent of laser smoke particle size is 0.8 um with a size range of 0.5 - 27.0 um. If an intranasal stent with filters could get rid of laser smoke particles effectively, it could also filter atmospheric suspended particulate matter. An intranasal stent with filters should be a suitable personal respiratory protective device in highly air-polluted areas(23-25).

The air flow rate of 7.5 - 15.0 l/min is the human sedetary respiratory flow rate range(26). The air flow rate of 30.0 l/min is in accordance with the human moderate work load recommended by the U.S. National Institute for Occupational Safety and Health (NIOSH) and is the maximum nasal air flow rate without mouth breathing(26,27). Suspended particulate matter penetration through an intranasal stent with filters at an air flow rate above 30.0 l/min should be tried with various filter materials. The cyclidal air flow like that in humans passed through an intranasal stent with filters instead of a steady oneway air flow in this experiment should be investigated further. An intranasal stent with filters should be tested in high suspended particulate matter amounts for a longer exposure duration such as several hours during public transportation in traffic congested zones. Sophistigated instruments such as an automatic particle counter, size spectrometer, portable airborne particle counter under isokinetic conditions should be used.

SUMMARY

Intranasal stents with diffferent layers of face mask outer filters were used to collect laser smoke particles in their filter fibers. Laser smoke particles were used as a suitable source for atmospheric suspended particulate matter. The air flow rates of 7.5, 15.0 and 30.0 l/min were within the human respiratory rate range. The mean filtration efficacy of four, three and two layer intranasal stents for laser smoke particles was 74.3, 62.7 and 47.4 per cent respectively. An intranasal stent with filters was proposed for human nasal vestibule application to prevent atmospheric suspended particulate matter e.g. during public transportation in traffic congested conditions. Selection of each type of intranasal stent with filters depended on the maximum filtration efficacy, acceptable nasal air flow resistance, cost-effectiveness and human safety. Accurate particle counting instruments and other filter materials in an intranasal stent should be studied.

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เครื่องป้องกันระบบทางเดินหายใจส่วนบุคคล : ประสิทธิภาพของเครื่องถ่างในช่องจมูกพร้อมแผ่นกรองอากาศ

*ครรชิตเทพ ตั้นเผ่าพงษ์, พ.บ.**

การทดสอบประสิทธิภาพของแผ่นกรองหลายชั้นซึ่งติดที่ปลายทั้งสองของท่อซิลิโคนกลวงที่ใช้ในทางการแพทย์สำหรับใส่ในช่องจมูก เพื่อป้องกันฝุ่นในอากาศ แผ่นกรองที่ใช้ประกอบด้วยสองชั้นนอกของแผ่นกรองป้องกันฝุ่นหรือชนิดที่ใช้ในห้องผ่าตัดสำหรับปิดปากและจมูก ทำการทดลอง ณ ภาควิชาโสต นาสิก ลาริงซ์วิทยา คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี ระหว่างเดือนเมษายน พ.ศ. 2539 ถึงเดือนตุลาคม 2540 โดยใช้ฝุ่นละอองจากการเผาไหม้ของคาร์บอนไดอ็อกไซด์เลเซอร์ชนิด single mode แทนฝุ่นในอากาศซึ่งมีลักษณะใกล้เคียงกัน เครื่องดูดฝุ่นละอองเลเซอร์จะดูดฝุ่นผ่านแผ่นกรอง Millipore ที่มีขนาดรูกรอง 0.22 ไมครอนจำนวน 5 ชุด ด้วยปริมาตรการไหลของอากาศเท่ากับ 15 ลิตรต่อนาทีและควบคุมด้วย rotameter ฝุ่นที่แผ่นกรอง Millipore มีจำนวนเท่ากับฝุ่นที่ผ่านเครื่องถ่างช่องจมูกพร้อมแผ่นกรองอากาศแต่ละชุดจำนวนทั้งหมด 5 ชุด Millipore จะเก็บกักฝุ่นปริมาณสูงสุดที่ใกล้เคียงกับปริมาณฝุ่นจากแหล่งกำเนิด ทำการตรวจนับปริมาณฝุ่นที่ติดบนแผ่นกรองด้วยกล้องจุลทรรศน์กำลังขยายสูง เปรียบเทียบประสิทธิภาพการกรองของเครื่องถ่างช่องจมูกที่มีแผ่นกรองอากาศจำนวน 4, 3 หรือ 2 ชั้น ด้วยปริมาตรการไหลของอากาศเท่ากับ 7.5, 15.0 และ 30.0 ลิตรต่อนาที หลักการเลือกเครื่องถ่างช่องจมูกพร้อมแผ่นกรองอากาศเพื่อใส่ในช่องจมูกส่วน vestibule ต้องไม่ทำให้รู้สึกอึดอัด ความต้านทานการไหลของอากาศผ่านช่องจมูกต้องไม่ต่างจากค่าปกติมาก เพื่อป้องกันฝุ่นละอองขณะเดินทางโดยรถสาธารณะในสภาพรถติด

คำสำคัญ : ฝุ่น, การป้องกัน, เลเซอร์, แผ่นกรองอากาศ, ช่องจมูก

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