Hats Off: A Study of Different Operating Room Headgear Assessed by Environmental Quality Indicators

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BACKGROUND: The effectiveness of operating room headgear in preventing airborne contamination has been called into question. We hypothesized that bouffant style hats would be as effective in preventing bacterial and particulate contamination in the operating room compared with disposable or cloth skull caps, and bouffant style hats would have similar permeability, particle penetration, and porosity compared with skull caps.

STUDY DESIGN: Disposable bouffant and skull cap hats and newly laundered cloth skull caps were tested. A mock surgical procedure was used in a dynamic operating room environment. Airborne particulate and microbial contaminants were sampled. Hat fabric was tested for permeability, particle transmission, and pore sizes.

RESULTS: No significant differences were observed between disposable bouffant and disposable skull caps with regard to particle or actively sampled microbial contamination. However, when compared with disposable skull caps, disposable bouffant hats did have significantly higher microbial shed at the sterile field, as measured by passive settle plate analysis ($p < 0.05$). When compared with cloth skull caps, disposable bouffants yielded higher levels of 0.5 μm and 1.0 μm particles and significantly higher microbial shed detected with passive analysis. Fabric assessment determined that disposable bouffant hats had larger average and maximum pore sizes compared with cloth skull caps, and were significantly more permeable than either disposable or cloth skull caps.

CONCLUSIONS: Disposable bouffant hats had greater permeability, penetration, and greater microbial shed, as assessed by passive microbial analysis compared with disposable skull caps. When compared with cloth skull caps, disposable bouffants yielded greater permeability, greater particulate contamination, and greater passive microbial shed. Disposable style bouffant hats should not be considered superior to skull caps in preventing airborne contamination in the operating room. (J Am Coll Surg 2017;225:573−581. © 2017 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Hospital-acquired infections cost nearly $10 billion annually, with surgical site infections comprising nearly one-third of that cost.[1] Therefore, finding ways to reduce surgical site infections is of utmost importance, both for patient care and for optimal resource use within hospital systems. In this regard, controlling airborne contamination and reducing microbial shed from personnel in the operating room may help reduce surgical site infections. Several organizations, including the

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Joint Commission, the CDC, and the Association of periOperative Registered Nurses, publish guidelines to govern operating room practices.[2] One such area of focus has been on surgical attire, which attempts to create a functional barrier between the care team and the patient. Only the use of specific articles of surgical clothing, such as sterile gloves and impervious surgical gowns, have actually been shown to reduce surgical site infections.[2] In fact, the most beneficial factor in the modern operating room has been the development of appropriate and effective ventilation strategies, which help to cleanse the air and reduce bacterial load.[3,4]

Surgical scrubs have become standard in the operating room since the middle of the 20th century.[5] There have been multiple studies that have looked at the type of fabric used for the scrubs, and whether the cuffs and ankles should be tucked.[6] Over the last several decades, the type of surgical headgear worn by the surgeon and other operating room personnel have been called into question. A study in 1991 suggested that wearing any type of head gear in the operating room did not decrease bacterial counts. However, the use of proper ventilation techniques drastically reduced these counts.[4] Authors concluded that nonscrubbed individuals did not need to wear head gear because proper ventilation likely counteracted any bacterial shedding. Ten years later, however, a conflicting study showed a 2- to 5-fold increase in bacterial contamination at random sites throughout the room when headgear was not worn, and a 60-fold increase in contamination in the wound bed.[7] This study prompted operating room leaders to investigate hats more closely.

The 2016 edition of the Association of periOperative Registered Nurses Procedure Manual suggested that all operating room personnel wear disposable bouffant type hats.[8] Cited studies have suggested that the hair is a potential vehicle for bacterial dispersal, and that it can carry various core and transient bacteria including, but not limited to, *Staphlococcus, Streptococcus,* and *Corynebacterium*.[5,9] However, there has been no definitive evidence that links bacteria in the hair to surgical site infections. Additional studies suggested that more bacteria could be found in the ears of surgical staff as compared with the forehead or eyebrows.[10] Therefore, the intent of the bouffant hat was to "cover the head, hair, ears, and facial hair."[8]

The debate on hats further came into question in September 2016, when *The Boston Globe* published an article citing discord between members of the American College of Surgeons and the Association of periOperative Registered Nurses.[11] In this article, surgeons did not believe that they should be mandated to wear a bouffant type hat because there was no evidence to suggest that these hats were superior, nor did they feel that they represent the symbolic nature of the surgeon. Given that there were very few scientific studies supporting optimal headgear in the operating room, we set out to investigate the degree of airborne contaminants with different head covers in an operating room environment, using a previously validated test of Environmental Quality Indicators.[12] We hypothesized that bouffant style hats would be as effective in preventing bacterial and particulate contamination in the operating room compared with disposable or cloth skull caps, and bouffant style hats would have similar permeability, particle penetration, and porosity compared with skull caps.

METHODS

Location

One operating room from each of 2 different hospital systems were chosen for experimentation. Both were associated with academic medical schools. Both had High Efficiency Particulate Air Filter air supplies to the rooms and were 638 and 554 square feet, respectively. Studies took place from February to April 2017.

Personnel and mock surgical procedure

The study team consisted of a surgeon, a microbiologist, 2 engineers specializing in heating, ventilation, and air conditioning, and an industrial air hygienist. These 5 people, in addition to a scrub nurse and medical student from each individual facility, performed 1-hour-long mock surgical experimental procedures, as previously validated and described.[11] Study personnel wore standard hospital issued clean scrubs, masks, and shoe covers.

In order to provide consistent execution of the procedure and to ensure unbiased repeatability, a detailed timed process was developed and displayed on the computer monitors within the operating room. This "script" defined the physical actions for each of the research team members to perform in 4-minute increments during the procedure to simulate actual operating room conditions. The script simulated the actual steps undertaken by operating room staff and included gowning and gloving, passing instruments, personnel entering and leaving the room, and use of electrocautery on an uncooked steak to generate particulate tissue matter.

Hats

Disposable bouffant and skull cap headgear from each of the 2 institutions were used for experimentation. Cloth skull caps were provided by the surgeon leading the procedure and were laundered in hot water with detergent at home the evening before the study. Disposable bouffant style caps were worn with all hair and ears within the garment (Fig. 1A). Disposable and cloth skull caps were worn similarly, with the ears exposed and a small amount of hair protruding at the sides and base (Figs. 1B, C).

Figure 1. Styles of hats. All hats were worn in the manner that they were intended. (A) Bouffant hats covered all hair and were worn over the ears. (B) Disposable skull and (C) cloth skull hats were worn with some hair and the ears exposed. (Reprinted with permission from Troy A Markel, MD, FACS.)

Hats were changed and alternated between each experiment so that all participants were wearing the same style of hat for each separate experiment. Each hat was evaluated twice at each institution for a total of 4 1-hour-long experiments for each hat (4 hours of experimentation for bouffant, 4 hours for disposable skull caps, and 4 hours for cloth skull cap). Similar hats then underwent permeability and porosity testing.

Environmental quality indicators

Assessment of airborne contamination and Environmental Quality Indicators was performed as previously described.[12] Air velocity measurements at key locations in the rooms were measured using a calibrated air velocity meter (Model 9565; TSI Velocicalc). The velocities were measured every 2 minutes during the 1-hour mock procedure at the operating room table (sterile field-SF, n = 108 data points per hat type) and at the back instrument table (back table-BT, n = 108 data points per hat type) and recorded in feet per minute.

Particle contamination was measured using a Climet Model CJ-750T 75 LPM counter. We used ISO 14644 standards, which required measuring the number of particles at 9 grid points throughout the room based on the size of the space (Fig. 2). This resulted in 3 complete passes through the 9-point grid during the 1-hour long mock procedure. The particle sizes recorded were 0.3, 0.5, 1.0, and 5.0 microns in particles per cubic meter (particles/M^3, n = 108 data points for each particle size per hat type).

Microbial contamination was measured by active assessment and by passive settle plate assessment. For active assessment, Bioscience viable surface air samplers (SAS180) were placed at both the sterile operating field and at the back instrument table to detect microbial contaminants (Fig. 2). Air samplers acquired 1,000 L of ambient air over a 5.5-minute period, and Petri plates with blood agar medium were used in the samplers to collect the microbes. The plates were changed in regular cycles to collect microbial data during the entire mock procedure (n = 96 agar plates assessed at sterile field and back table for each hat type). Passive settle plate assessment was achieved by placing 4 blood agar settle plates around the sterile field and allowing them to collect microbes and debris that dropped throughout the 1-hour mock procedures (Fig. 2; n = 16 agar plates assessed at sterile field for each hat type). The viable microbial samples were sent under chain of custody to a third-party microbiology laboratory for qualitative and quantitative analysis of bacteria. Bacterial genus were identified and quantified as colony forming units per cubic meter (CFU/M^3). Settle plates were analyzed by the team's microbiologist and quantified as colony forming units per plate (CFU/plate).

Hat permeability, penetration, porosity, thickness, and fiber imaging

For hat fiber analysis, 3 samples of each type of hat from each institution were analyzed (n = 6 samples per hat type). Because the disposable skull cap was composed of

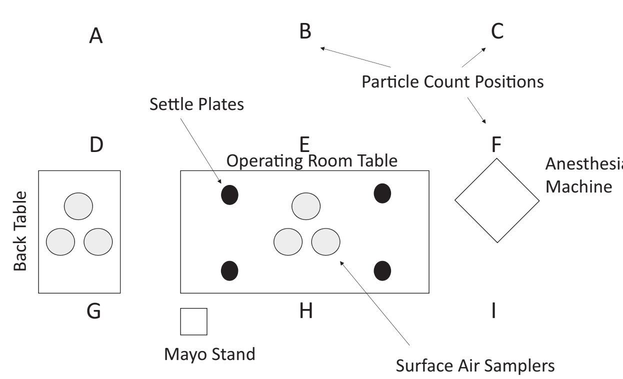

Figure 2. Room layout for measurement of environmental quality indicators. Representative layout of operating room table and back table along with key assay equipment. A-I points, placement of particle counter for 9-point assessment according to ISO 14644 standards.

a more porous appearing "crown" and a less porous appearing paper side, the materials from these hats were separated and assessed separately.

Hat permeability was analyzed using a TEXTEST model FX3300-II air permeability tester (TEXTEST Instruments). The TEXTEST uses a circular clamping mechanism that automatically creates a vacuum when the sample is clamped down, causing the air pressure to be different on 1 side of the sample. Air then flows from the side of higher pressure, through the sample to an area of lower pressure, creating the rate of flow, and determining the air permeability of the sample. The volume of air flow, in cubic feet per minute (CFM), at a resistance of 125 Pa, was then assessed for 6 samples of each hat type.

A TSI Automated Filter Tester 8130 (TSI Incorporated) was used to determine the penetration of a mono-dispersed, 0.3-micron sodium chloride aerosol. The aerosol particles were generated from a 15% by mass salt water solution. Penetration was tested at a 32-L per minute air flow, which is commonly used for standard air filtration tests.[13] Samples with an area of 100 cm^2 from each hat type were tested. Penetration was determined by 2 laser photometers measuring the aerosol concentration levels both upstream and downstream from the material. The resulting penetration value was a ratio of the 2 aerosol concentration measurements and represents the amount of particle that was transmitted through the hat. Values greater than 100% suggest that the hat shed material into the airstream.

Hat thickness was assessed with the use of an Ames gauge (B Ames Inc). The samples rested flat on a platform, while a circular pressure plate was lowered to rest on the surface of the sample. The pressure was manually maintained on the sample while a measurement of the distance between the platform and the pressure plate was calculated to the nearest 0.01 mm.

Pore size analysis was performed using a PMI Capillary Flow Porometer (model CFP1100-A, Porous Materials Inc). Samples of each hat (n = 6/group) were cut into approximately 2-inch squares and placed into the sample chamber. Each sample was fully hydrated with Galwick wetting solution (15.9 dynes/cm surface tension) before the chamber was sealed. Gas pressure was used to overcome the capillary action of the wetting fluid within the sample's pores under increasing pressure until all of the pores were empty and the sample was dry. The flow rate and pressure were used to calculate the diameter of the pores within the samples.

A Phenom ProX (Phenom-World BV) model desktop scanning electron microscope was used to image the fibers from each group of hats. A Cressington 108 Sputter Coater (Cressington Scientific Instruments) was used to coat the samples with a thin layer of gold to gain better image resolution.

Statistics

All statistical analysis was done using GraphPad Prism 7 (GraphPad Software). Data were assessed for normalcy by the Shapiro-Wilk and the KS normality tests and reported as mean with standard error of the mean (parametric) or median with interquartile range (nonparametric). Parametric data were compared with 1-way ANOVA and post hoc Tukey's multiple comparisons test. Nonparametric data were compared with the Kruskal-Wallis test followed by post hoc Mann-Whitney comparison with Bonferroni correction. Values of $p < 0.05$ were considered statistically significant.

RESULTS

Particle shedding

Significant differences in airborne particles were observed in 0.5-μm and 1.0-μm particles based on the style of headgear worn. Post hoc analysis demonstrated that airborne particle contamination was significantly higher for disposable bouffant hats as compared with cloth hats at particle sizes of 0.5 μm ($p = 0.012$) and 1.0 μm ($p = 0.001$). There were no significant differences in other airborne particle sizes for these 2 hat types. In addition, there were no statistical differences in airborne particle counts when disposable skull caps and cloth hats were compared, or when disposable bouffants and disposable skull caps were compared (Table 1).

Microbial shedding

Active microbial air sampling did not detect any differences in microbial shedding between any type of hat. Interestingly though, the amount of airborne microbes detected at the back instrument table was consistently and significantly higher than at the sterile field (Fig. 3A). This observation negatively correlated with air velocity within the room, which demonstrated that velocities at the back table were significantly lower than at the sterile field (Fig. 3B).

Passive settle plate microbial assessment did demonstrate a significant difference between hats (Fig. 4A). Bouffant hats yielded significantly higher levels of microbes (3, interquartile range [IQR] = 5) as compared with either disposable skull caps (1, IQR = 1) or cloth skull caps (1, IQR = 3; Fig. 4B). There was no difference in debris contamination (ie visible particulate matter, fiber contamination) between hat types (Fig. 4C). In

Table 1. Particle Counts with Different Operating Room Headgear

	Bouffant		Disposable skull		Cloth skull		KW
Particle size, pass	**Median**	**IQR**	**Median**	**IQR**	**Median**	**IQR**	**p Value**
0.3 μm							
First pass	48,775	33,181	46,795	20,193	50,544	27,546	0.67
Second pass	8,042,979	21,012,507	6,438,947	21,265,162	6,203,989	18,812,866	0.91
Third pass	6,445,975	22,055,148	2,837,841	21,623,512	100,358	18,188,184	0.38
0.5 μm							
First pass	28,563	19,603	28,743	12,593	28,123	14,824	0.25
Second pass	776,787	866,690	538,342	2,059,248	325,052	530,541	0.03*
Third pass	782,718	2,120,548	497,369	1,291,634	219,365	849,377	0.05
1.0 μm							
First pass	14,523	9,043	13,957	6,618	13,100	7,147	0.24
Second pass	111,759	87,866	98,426	214,466	108,877	157,530	0.98
Third pass	129,648	238,011	83,749	144,434	54,706	111,927	0.03*
5.0 μm							
First pass	1,430	1,052	1,537	758	1,393	900	0.48
Second pass	1,620	1,248	1,560	738	1,713	761	0.63
Third pass	1,633	753	1,663	931	1,447	632	0.1

*Significant.
IQR, interquartile range; KW, Kruskal-Wallis.

addition, no human hairs were identified on any of the settle plates during experimentation.

Permeability, penetration, and thickness

Bouffant hats and the disposable skull cap crowns had significantly higher permeability than the disposable skull cap sides or cloth skull caps (Fig. 5A). Three of the bouffant hats tested had permeability that was so high that it was not measureable by the machine. These 3 hats were arbitrarily given the highest value of measurable bouffants. Therefore, bouffants had a median permeability of 444.0 cubic feet per minute (CFM) (IQR 82.5 CFM). The disposable skull crown had a median permeability of 385.5 CFM (IQR 34.3 CFM), while the sides had a median permeability of 144.8 CFM (IQR 226.4 CFM). Cloth skull had the lowest median permeability, at 64.7 CFM (IQR 47.6 CFM).

Penetration of particulate matter was higher for bouffant hats (101.9% ± 1.1%) compared with either the disposable skull crown (94.6 ± 1.8%, $p < 0.05$) or the disposable skull sides (92.0 ± 0.6%, $p < 0.05$). Penetration of particulate matter was also higher for cloth skull

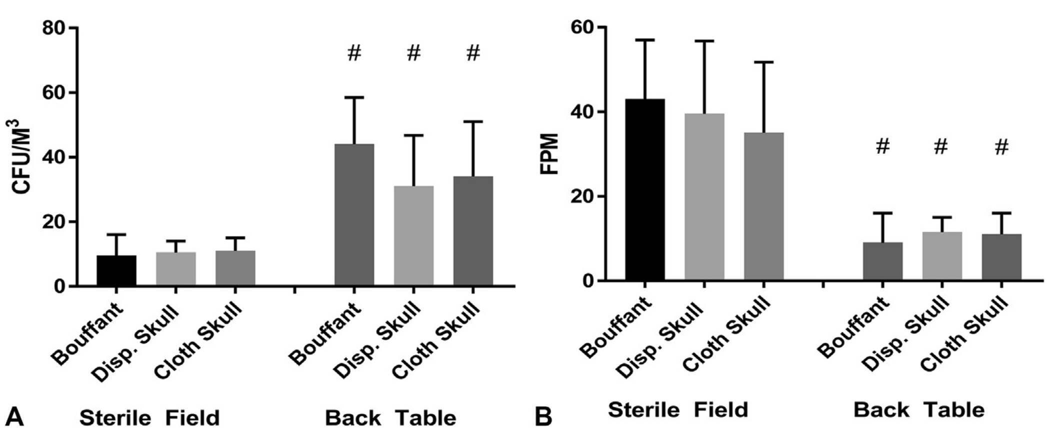

Figure 3. Active microbial assessment. (A) No differences were seen in airborne microbes at the sterile field or at the back table with regard to the type of hat worn. However, there was significantly higher microbial contamination at the back instrument table for all hat types when compared with the sterile operating field. (B) Air velocity at the sterile field was consistently higher in all conditions as compared with the back table. ($^{\#}p < 0.05$ vs respective sterile field value). CFU/M^3, colony-forming units per cubic meter; Disp., disposable; FPM, feet per minute.

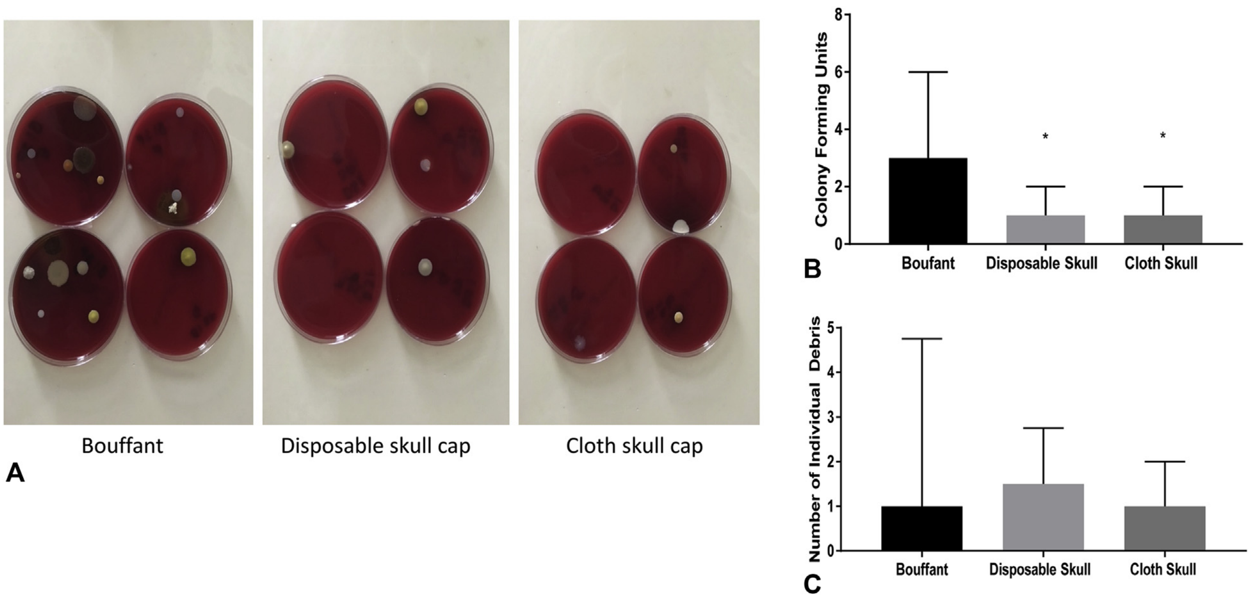

Figure 4. Passive microbial assessment. (A) Representative settle plates for bouffant, disposable skull, and cloth skull hats. (B) Higher numbers of colony-forming units were observed when bouffant style hats were worn compared to disposable skull or cloth hats. No significant difference was seen between disposable skull or cloth skull caps. (C) The level of debris detected was similar for each hat type.

hats (100.1 ± 0.84%) compared with either the disposable skull crown or the disposable skull sides ($p < 0.05$; Fig. 5B).

Cloth hats were significantly thicker than bouffants or the crowns and sides of disposable skull caps (Fig. 5C). There were no significant differences in hat thickness between bouffants and the crowns and sides of disposable skull caps.

Porosity

Pore sizes were compared by maximum pore size, average pore size, and minimum pore size. There was no statistical difference between hats in minimum pore size (Fig. 6A). However, the average pore sizes (Fig. 6B) and the maximum pore sizes (Fig. 6C) in bouffant hats were significantly higher than those seen in cloth skull caps ($p < 0.05$). Bouffant hats had average and maximum pore sizes of 89.4 ± 30.68 μm and

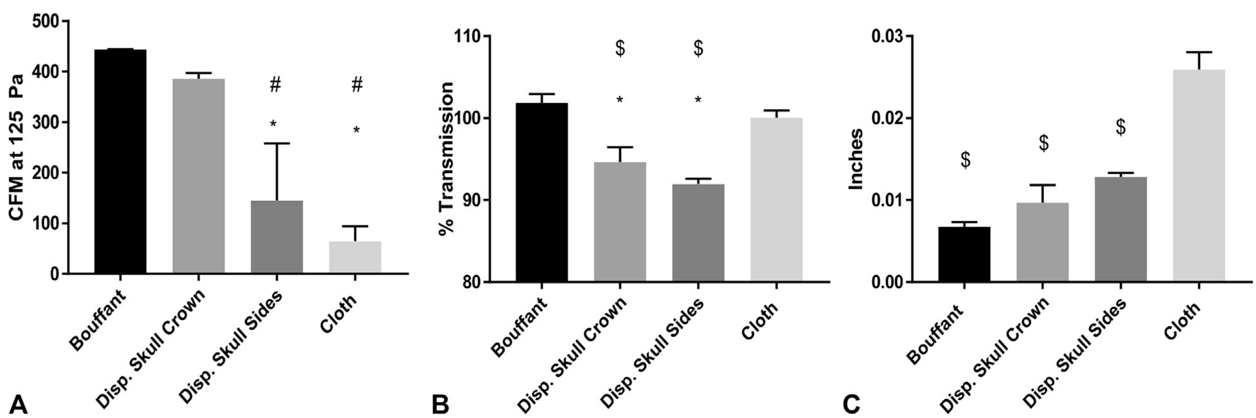

Figure 5. Hat permeability, penetration, and thickness. (A) The permeability of bouffant style hats was significantly higher than either the sides of the disposable skull cap or the cloth skull cap. The permeability of the crown of the disposable skull cap was also significantly higher than the sides of the disposable or cloth skull caps. No significant difference was seen in permeability between bouffants and the crown of skull caps. (B) Penetration of the bouffant hats and cloth skull caps was significantly higher than the disposable skull crown or sides. (C) Cloth skull hats were significantly thicker than bouffants or disposable skull cap sides or crowns. (*$p < 0.05$ vs bouffant hats, $^{\#}p < 0.05$ vs disposable skull cap crown, $^{\$}p < 0.05$ vs cloth skull cap). CFM, colony-forming units; Disp., disposable; Pa, Pascal.

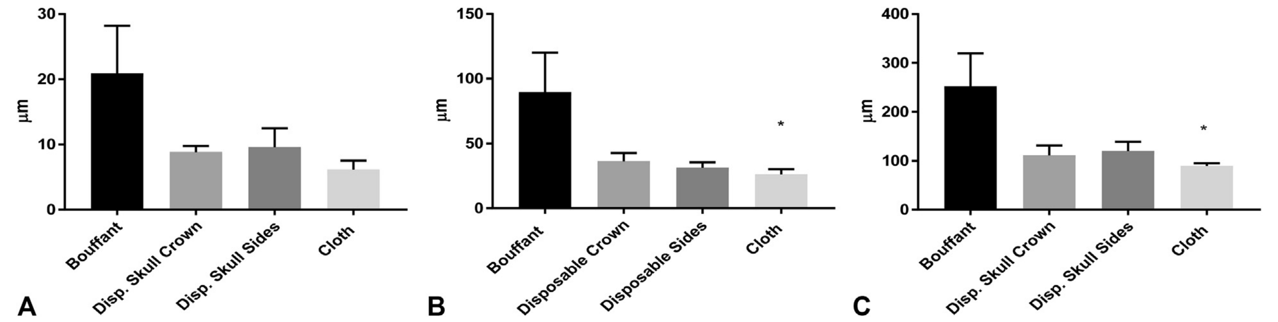

Figure 6. Hat pore size. No differences were seen between hats in terms of (A) minimum pore size. Bouffant hats did maintain significantly larger (B) average and (C) maximum pore sizes compared to cloth hats. No significant differences were seen in pore sizes between other groups ($p < 0.05$ vs bouffant). Disp., disposable.

251.8 ± 67.9 µm; those in the disposable skull cap crowns were 36.2 ± 6.6 µm and 111.0 ± 20.4 µm, disposable skull cap sides were 31.3 ± 4.1 µm and 119.8 ± 18.2 µm, and cloth skull caps were 26.1 ± 4.1 µm and 89.5 ± 5.7 µm. Representative scanning electron microscopy images of hat materials are depicted in Figure 7.

DISCUSSION

Many policies that have been implemented in the operating room environment have been done so without rigorous scientific study. Most recently, the sterility of the surgical skull cap has been called into question, mostly because it exposes the hair around the nape of the neck and the sides of the head in addition to the ears. Some experts believe that a bouffant style hat is superior because these hats can be worn over the ears and hair, which are known sources of bacterial contaminants.[5,10] Here we report that bouffant hats are more permeable, have higher penetration of particles through the material, maintain a larger maximum pore size, and allow greater particle and microbial shed compared with certain types of skull caps.

The shedding of 0.5- and 1.0-µm particles was higher for bouffant hats as compared with cloth style skull

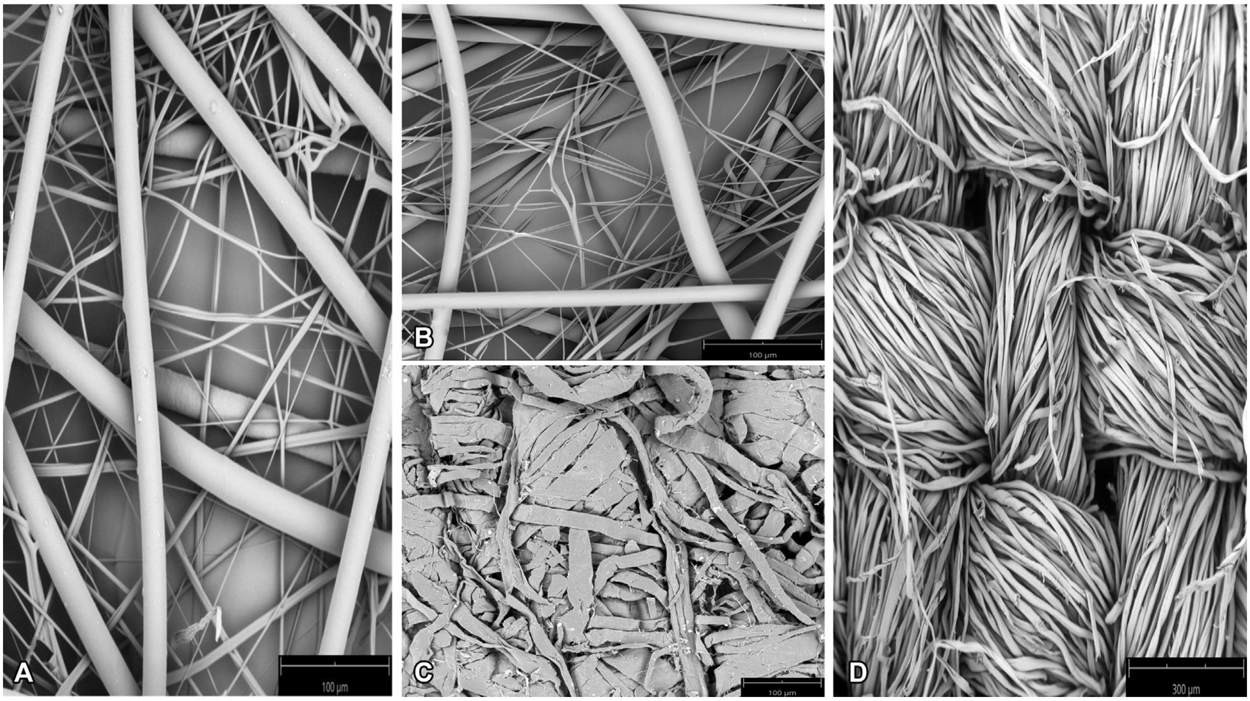

Figure 7. Electron microscopy. (A) Bouffant hats were visually identified with electron microscopy as having fairly porous material. (B) The crown of disposable skull caps also was made of a visually porous material. (C) The sides of the skull caps were visually less porous, as were (D) the cloth skull caps.

caps. No difference was seen in particulate airborne contamination between bouffant hats and disposable skull caps. This lack of difference may be due to the crown of the disposable skull caps being very similar to bouffant hats in terms of material composition. Therefore, particulate contamination may have been similar between these 2 hat types. It is interesting that only the 0.5- and 1.0-μm particles showed significant differences between cloth skull caps and bouffants. We observed a large variability in particle assessment throughout this study, and in our previous studies. We attributed this high variability to the use of electrocautery during the experiment. Electrocautery on a piece of steak, as is also seen on human flesh, generates a large amount of particles, and therefore the variation in numbers can be quite high.

Active assessment of airborne microbes yielded no significant differences between hat types at the sterile field or at the back instrument table. However, passive assessment with settle plates did reveal a significant decrease in microbial shed and deposition with the use of either a disposable skull cap or a cloth skull cap. The passive microbial assessment data are in line with other data in this study, which suggest that bouffant hats have higher porosity and permeability, and therefore, may contribute to higher levels of bacterial shed. The settle plates were set around the sterile field and were allowed to sit in place for the entire 1-hour mock surgical procedure. The Petri dishes in the active air samplers acquired 1,000 L of ambient air over 5.5 minutes and were changed regularly. Therefore, it is possible that having the settle plates out for the entire hour allowed for a better assessment of the ambient bacterial load.

The average and maximum pore sizes were observed to be larger in bouffant hats as compared with cloth skull hats. The median maximum pore size for bouffant hats was 247.9 μm and for cloth skull caps was 92.56 μm. It is generally thought that the average diameter of a single bacteria is between 0.2 and 0.3 μm, with lengths up to and slightly in excess of 1.0 μm.[14] In addition, the average diameter of a human hair ranges from 20 to 180 μm.[15] Therefore, the maximum pore diameters of both hats could allow bacteria and smaller diameter hair particles to escape, irrespective of the type of hat worn. The effects of pore size were seen in correlating with permeability and particle transmission. Bouffant style hats consistently had higher permeability. In fact, the bouffant hats at 1 institution were so porous that they were not able to effectively be measured by the permeability assessment machine.

Porosity also likely relates to higher transmission of particulate matter through the hat material. In this study, we saw that transmission of a small particle through bouffant hats was significantly higher than the crown or sides of disposable skull caps. We also saw that cloth skull caps had high particle penetration. Although not different from bouffants, cloth skull caps did have a higher transmission of particles than the crown or sides of disposable skull caps. Both bouffant hats and cloth hats had transmission numbers greater than 100%. This means that there were more particles noted on the downstream side of the tested material than on the incoming side. The explanation for this is that the fiber material actually added particles into the air stream during the assessment. This would suggest that bouffant hats and cloth hats may actually shed material during normal use in the operating room.

Another interesting finding was the consistent observation of higher microbial load at the back instrument table compared with the sterile field. This phenomenon likely relates to decreased air velocity over the back table as compared with the sterile field due to the placement of the diffusers in the ceiling and the air flow over the table. Despite these different conditions, the type of hat had no effect on microbial shed at these 2 sites with active assessment. These data are in line with previous studies that suggested that the location of the grilles providing ventilation, rather than the hat itself, make the most difference in terms of airborne contamination in the operating room.[4]

Limiting infectious complications in an operating room environment is of utmost importance. In this study, we observed that disposable bouffant hats had higher microbial shed compared with disposable skull caps, as assessed by passive settle plate analysis. In addition, bouffant hats had similar permeability and pore sizes, but higher particle penetration compared with disposable skull caps. Therefore, we concluded that disposable bouffant hats are not superior to disposable skull caps in terms of limiting airborne contamination in an operating room environment.

When assessing cloth skull caps, there appeared to be no differences in terms of microbial or particulate shed compared with disposable skull caps. Cloth skull caps had a lower permeability compared with the crown of a disposable hat, but no difference compared to the material that made up the sides. Furthermore, cloth skull caps had a higher transmission of particles through the material compared to disposable skull caps, suggesting that some of the cloth may shed with active wear. When comparing cloth skull caps to disposable bouffant hats, the cloth skull caps had lower particulate shed, and lower settle plate shed. In addition, cloth skull caps had a lower permeability, lower average and maximum pore sizes, and similar penetration compared with bouffants. These data might suggest that cloth skull caps are superior to disposable bouffant hats.

Limitations

There were several limitations in this study that should be noted. First, our experiments were performed during a mock procedure rather than during real operations with patients. Due to health privacy laws and ethical considerations, we were not able to perform these experiments during patient operations. However, the conditions of the mock procedure were very similar to those of a real operation, and therefore, the data are likely able to be extrapolated. In this regard, we believe that this study represents the best scientific attempt to assess operating room headgear in a dynamic, microbial loaded operating room.

An additional limiting factor to this study was that it was not blinded or randomized. The study personnel wearing the hats were also performing data acquisition as part of their scripted mock procedure. Therefore, they could not be blinded by the hat type. Study bias could therefore be a criticism, but we felt that careful adherence to the scripted mock procedure would eliminate that bias.

We also realize that there are likely numerous brands of disposable skull, cloth, and bouffant style hats on the market that are made of different materials. Some of these may be perform better than others in alleviating microbial and particulate airborne contamination. Comparing specific brands of hats was beyond the scope of this study and could be considered for additional studies. Furthermore, it is unclear how the laundering process of the cloth hats affected the outcomes. Given that the disposable hats were clean, we believed that testing a clean cloth hat would be prudent. However, it is common knowledge that surgeons don't always launder their cloth hats daily, and therefore, a dirtier, unwashed hat could possibly lead to different penetration, transmission, and airborne contaminant results.

CONCLUSIONS

The topic of operating room headgear has been very controversial, and the quality of data used to support operating room policy surrounding this topic is marginal. In this study, we observed that bouffant style hats had high permeability, particle penetration, and porosity, and also had higher levels of bacterial and particulate contamination in a dynamic operating room environment. When compared with disposable skull caps, bouffant hats cannot be considered superior. Furthermore, if properly laundered the use of cloth skull caps may yield better sterility compared with standard disposable bouffants.

Author Contributions

Study conception and design: Markel, Gormley, Greeley, Wagner

Acquisition of data: Markel, Gormley, Greeley, Ostojic, Wise, Rajala, Bharadwaj, Wagner

Analysis and interpretation of data: Markel, Gormley, Greeley, Ostojic, Wagner

Drafting of manuscript: Markel

Critical revision: Markel, Gormley, Greeley, Ostojic, Wise, Rajala, Bharadwaj, Wagner

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