Determination of Minimum Suction Level Necessary for Field Dental Units

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ABSTRACT A significant problem with most field dental units is that their suction is too weak to effectively remove debris from the mouth. The purpose of this study was to determine the minimum clinically acceptable suction level for routine dentistry. A vacuum pump was connected to a high-volume dental evacuation line in a simulated clinical setting and different suction airflow rates were evaluated by nine evaluator dentists for their capability to effectively remove amalgam debris and water. Airflow levels were rated as "clinically acceptable" or "clinically unacceptable" by each evaluator. Data were analyzed using a χ^2 test for trend. Analysis indicated a significant linear trend between airflow and ratings ($p < 0.0001$). The first airflow level considered by all evaluators as producing clinically acceptable suction was 4.5 standard cubic feet per minute (0.127 standard cubic meters per minute). This value should be the minimum level required for all military field dental units.

INTRODUCTION/BACKGROUND

During the course of military operations, deployed U.S. warfighters require medical treatment to maintain their readiness level. As part of medical services, dentistry addresses problems such as fractured dental restorations and teeth, loose/lost crowns and bridges, and endodontic and periodontal disease.[1–3] For the U.S. Marine Corps and U.S. Navy, the package of field dental equipment used for this purpose, the Authorized Dental Allowance List (ADAL) 662, includes the equipment and consumables needed to provide routine and emergency dental treatment for a fixed period of time.[4] Most of the equipment in the ADAL 662 performs well, however some items do not meet clinicians' needs or expectations.[5,6] One such item is the field dental unit, which runs the dental handpiece (i.e., drill) and provides compressed air and water for rinsing the mouth and suctioning away fluid and debris.

To successfully perform dental procedures in the military field or austere civilian humanitarian locations, adequate suction is necessary to keep the intraoral treatment area isolated and free of blood, saliva, and debris. In some situations where traumatic injuries to the oral cavity have occurred, adequate suction may be required to establish and maintain a patent airway.[7] Unfortunately, laboratory and user evaluations conducted by the Navy Medical Research Center Detachment–Great Lakes (NMRCD), formerly the Naval Institute for Dental and Biomedical Research (NIDBR), and the U.S. Air Force Dental Evaluation and Consultation Service (DECS) in Kuwait, Okinawa, and Alaska have shown that currently stocked field dental units, even when operating maximally, provide suction that is only marginally adequate for routine dental care.[5,6,8,9] Using weak suction during dental procedures makes it difficult for the clinician to isolate and view the treatment site, maintain a patent patient airway, and control bacterial aerosol production to prevent the spread of infections.[10–12]

In designing field dental units, manufacturers have to compromise between the size of the unit and its performance capabilities. To a great extent, this is because of the restrictive nature of military requirements documents. The military, ever mindful of the need to minimize weight and size ("weight and cube") of equipment for logistical reasons, specifies the maximum weight and/or volume that the dental unit can be. Unfortunately, developers of military requirements documents sometimes err on the side of weight and cube concerns at the expense of performance. Suction levels are a prime example. Because field dental units have certain weight and cube limitations, manufacturers are under great pressure to meet these requirements so their equipment can be considered for purchase by the military. In the case of vacuum pumps, size is one of the major factors determining their performance; generally, the larger the size of the pump, the greater its suction level.[13] However, manufacturers have had to undersize vacuum pumps and other mechanical components that provide suction for the dental unit. This has directly resulted in inadequate clinical performance. Adding to the problem is the fact that both the Medical Procurement Item Description (MPID) and the Operational Requirements Document (ORD), which govern the performance of field dental units, mandate minimum airflow levels that are too low to produce acceptable suction for clinical purposes.[4,14]

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The objective of this study was to identify the level of suction that typical clinicians consider to be the minimum necessary for routine dental purposes. The ultimate goal is to incorporate this value into military requirements documents so that future field dental units will be designed and built to provide adequate suction for dental use.

MATERIALS AND METHODS

The subjective assessment of the clinical acceptability of different suction levels produced by various airflow rates was performed using a traditional dental patient chair (A-dec 500, A-dec Inc., Newberg, Oregon) at NMRCD. An in-line manual adjustment valve (V-1810, Parts Warehouse, Lynden, Washington) was installed between a vacuum pump (Bulldog QT E-Series Combo 1, RAMVAC, Spearfish, South Dakota) and the dental chair's 13-mm internal-diameter high-volume dental evacuation line. The valve was adjusted so that airflow rates as measured at the end of a standard (10-mm internal diameter) high-volume evacuator tip varied from 1.5 to 7.5 standard cubic feet per minute (scfm) (0.042 to 0.212 standard cubic meters per minute [scmm]) in 0.5-scfm (0.014-scmm) increments. To measure the airflow rates, a commercial airflow measurement device (Flowcheck, RAMVAC) (Fig. 1) was used, which measures airflow rate as a function of pressure.

For the study, airflow adjustments were made in random order using a random number generator, and nine dentist evaluators blinded to the airflow setting were individually asked to render an opinion regarding the clinical adequacy of the suction produced by the airflow rates. The evaluators were experienced clinicians, each with a minimum of 10 years of clinical practice. In addition, eight of the nine had received formal postgraduate dental education. All were general dentists except for one oral surgeon and one orofacial pain specialist, and seven of the nine had been deployed during their careers. All were active duty or retired military members. To evaluate the adequacy of the airflow, after each airflow rate was set, the evaluator and an assistant used the suction system in a simulated clinical treatment setup (Fig. 2). The setup consisted of a phantom head patient simulator (AH-1-BP cranium with Manikin XPH-2 Fletcher Mask on M-1R-10 Chair Mount, Columbia Dentoform Corp., Long Island, New York) mounted to the backrest of the dental patient chair. The head contained a dentoform (model M-1560, Columbia Dentoform Corp.) with removable Ivorine teeth. The simulated clinical procedure involved removing an existing mesio-occlusal amalgam (Tytin, Kerr Corporation, Orange, California) restoration in tooth no. 19 using a high-speed air-turbine handpiece (Synea TA-96 LW, A-dec, Inc.) with water coolant. A standard, metal, nonvented, 10-mm internal-diameter, high-volume evacuator tip was used by a trained dental assistant to evacuate the treatment area as directed by the evaluator. Although plastic tips are usually used for infection control purposes, a metal tip was used in the study to enhance standardization of testing. The same assistant was used during all testing and was not blinded to the airflow setting. Before beginning, the assistant was instructed to provide no verbal or nonverbal opinion to the operator regarding the adequacy of the suction. As the standard of care for most routine restorative procedures in the military services, a rubber dam was used. A no. W3 clamp (Kulzer Dental, South Bend, Indiana) was placed on tooth no. 18, and a rubber dam (Dental Dam, Henry Schein, Inc., Melville, New York) was used to isolate teeth nos. 18 through 22. During the procedure, 5 g of set amalgam particles were introduced into the treatment area to further assess the adequacy of the suction level. By weight, approximately 57% of the particles were smaller than 700 μm, whereas 43% were 700 μm or larger. The maximum size of the particles was 6.5 mm. Amalgam was chosen as the test material for evaluating airflow settings because, as a metal, it is one of the heaviest restorative materials used in dentistry. Also, it is not uncommon to remove failed amalgam restorations in large sections, which even further increases the weight of the debris to be suctioned. Each dentist evaluator performed the simulated clinical procedure until he had formed an opinion

FIGURE 1. Flowcheck airflow measurement device (RAMVAC).

FIGURE 2. Simulated clinical testing environment with evaluator and assistant.

regarding the adequacy/inadequacy of the suction level. At that point, the dentist was asked to rate the suction level as "clinically adequate" or "clinically inadequate" for standard restorative care. After each test, the existing tooth no. 19 was removed, if necessary, and replaced with another tooth no. 19 with a similar mesio-occlusal amalgam restoration. A new rubber dam was also placed, if needed.

The data were analyzed using a χ^2 test for trend (significance level = 0.05) to determine whether a significant linear trend existed between the airflow setting and the proportion of evaluators judging the resulting suction to be adequate.

RESULTS

The ratings assigned by the evaluators for each airflow setting are provided in Table I. Statistical analysis indicated that there was a significant linear trend ($p < 0.0001$) between the airflow rate and the proportion of evaluators judging the resulting suction to be adequate for routine clinical purposes. Airflow values of 1.5 and 2.0 scfm were unanimously judged by the evaluators as producing inadequate suction. From 2.5 through 3.5 scfm, an increasing number of evaluators found the suction to be adequate. The first airflow setting that was judged by a majority of evaluators as being adequate for dental treatment was 4.0 scfm (0.113 scmm), and the first setting that all the evaluators judged as producing adequate suction was 4.5 scfm (0.127 scmm). From that setting through 7.5 scfm (0.212 scmm), all the evaluators rated the suction as adequate.

DISCUSSION

During the course of evaluating field dental units, NMRCD reviewed the published scientific literature and found a paucity of information available concerning a specific value or range of values that could be considered to be the minimum airflow level necessary for producing clinically acceptable suction for dental purposes. Some non-literature-based recommendations, however, have been made by a vacuum pump manufacturer (7.25 scfm[15] [0.205 scmm]) and a U.S. Air Force organization (7 scfm[13] [0.198 scmm]). There is no value, however, that is universally accepted by researchers and manufacturers. Because of this, with the support of U.S. Navy policymakers, NMRCD undertook a study to determine that value.

Required minimum airflow levels for producing suction are stated in military requirements documents in terms of the volume of air flowing into a high-volume evacuation tip at a prescribed level of suction (i.e., the number of scfm at a specified number of inches [mm] of mercury). In the case of high-volume dental suction, the required values as provided in the MPID and ORD are 3.5 scfm (0.099 scmm) at 4 inches (101.6 mm) of mercury and 2.0 scfm (0.057 scmm) at 4 inches (101.6 mm) of mercury, respectively. As noted earlier, NMRCD has determined in previous evaluations[5,6,8,9] that these airflow levels are too low for routine clinical purposes.

This study found that a majority of the dentist evaluators believed that an airflow rate of 4.0 sfcm (0.113 scmm) produced adequate clinical suction. However, this was only a bare majority opinion, with 4 of the 9 disagreeing and rating the resulting suction as inadequate. Only when the rate was 4.5 scfm (0.127 scmm) or greater did all the evaluators agree that the suction was adequate. It would appear that this rate (4.5 scfm [0.127 scmm]) is the preferred minimum airflow that future specifications should mandate if clinicians are to be satisfied with the degree of resulting suction.

Judging the capability of an airflow level to produce adequate suction for clinical purposes is, by nature, subjective. As indicated by our results, even experienced clinicians view adequacy differently. From post-testing discussions with the evaluators, it was found that most used the suction's capacity to readily remove larger pieces of amalgam scrap as the important measure, whereas others used the speed with which it removed water and the majority of the scrap as their measure. As a result, the evaluators disagreed in their opinions. This was expected because similar disparities in opinions were received during clinical-user evaluations in the field during testing in Kuwait, Okinawa, and Alaska. Policymakers will have the responsibility of deciding what level of clinician satisfaction is desirable when mandating a particular minimum airflow requirement in future specifications for field dental units.

As with most studies, this one could be improved with some modifications in design. For example, it would have increased the opinion pool by having had a different dental assistant working with each dentist evaluator and soliciting their opinion also, independent of the dentist's. This may have produced particularly useful information because assistants have a better tactile sense of the suction tip's capability to remove large pieces of amalgam debris. Future work in the area of airflow and suction evaluation should include the assistants as additional evaluators. Future studies should also be conducted in actual clinical settings rather than a simulated one. Finally, it is difficult to determine whether the continental design of the dental unit, in which instrumentation is connected to tubing that extends over the top rather than the bottom of the control head, had any effect on the dentists' ability to render

TABLE I. Ratings of the Evaluators for Each Airflow Setting ($n = 9$)

	Airflow Rate (scfm[a])												
Ratings	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
Inadequate	9/9	9/9	7/9	6/9	5/9	4/9	0/9	0/9	0/9	0/9	0/9	0/9	0/9
Adequate	0/9	0/9	2/9	3/9	4/9	5/9	9/9	9/9	9/9	9/9	9/9	9/9	9/9

[a]Standard cubic feet per minute.

an accurate opinion about adequacy of the suction level. In post-testing discussions, one evaluator suggested that a different unit design might affect evaluators' opinions. Future research may benefit from using dental units with different design features.

CONCLUSIONS

Under the conditions of this study, evaluators determined that airflow rates of 4.5 scfm (0.127 scmm) and greater resulted in suction levels they judged to be clinically adequate. Dental policymakers should consider this finding when developing future specifications for military field dental units. The study also determined that the Flowcheck was a fast, easy, and accurate way of measuring airflow rates.

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