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Protocol 451: Development of Lightweight, Low Cube, Portable Dental Field Equipment.

Task: Dental Field Treatment and Operating System (DeFTOS)

Purpose: Determine if, for operative dental procedures, electric motor dental handpieces are a suitable replacement for air turbine handpieces in military field dental equipment sets.

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I. INTRODUCTION

One mission of the United States Army Dental Research Detachment is to develop a new generation of lightweight, low cube, dental field equipment.

Portable dental field operating and treatment units are used by the U.S. Army Forward Dental Treatment Teams (FDTTs) to provide dental treatment to U.S. Military Personnel and other qualified individuals in field Dental Treatment Facilities (DTFs). These FDTTs provide unit, hospital, and area dental support.

Unit dental support is located in the medical companies of U.S. Army divisions, separate brigades, armored cavalry regiments, and the medical elements of the special forces groups. Hospital dental support is provided by an oral surgeon and comprehensive dentist assigned to the Combat Support Hospital. Their primary mission is the treatment of oral and maxillofacial injuries. When workload permits they provide dental care to the hospital staff and patients. [i]

Area dental support in Medical Force (MF) 2000 is provided by the medical company (dental service). This company has six FDTTs organized into one forward dental treatment section (FDTS). Each FDTT is an independent module with organic power and transportation; one M998, one diesel five kilowatt generator and a trailer. There are also two "heavy sections" that support nine additional dentists and their equipment sets. The Medical Re-engineering Initiative (MRI) area dental support unit has eighteen FDTTs organized into three forward dental treatment

section (FDTS) and one "heavy section" that supports five additional dentists and their equipment sets.

Current portable dental field operating and treatment units utilize air turbine handpieces. The compressed air needs of this sixty-seven pound treatment unit is provided by a 120 pound "portable" air compressor. This air compressor is 5.1 cubic feet and utilizes approximately 19 amperes of power. The air compressor is the major consumer of generated power in the FDTT. The unit support FDTT is the major consumer of power generated by ten kilowatt medical company generator. The area dental support FDTT requires a five kilowatt diesel generator mounted in a towed trailer. The "heavy team" requires two fifteen kilowatt towed generators.

In an effort to reduce generated power requirements, the USADRD developed a prototype Dental Field Operating and Treatment System (DeFTOS) that incorporated an electric motor dental handpiece. The principle advantage of the electric motor handpiece over the conventional air turbine is that compressed air and power requirements are significantly reduced. Utilization of the DeFTOS could reduce 2700 pounds from each area support FDTT by eliminating the need for the five kilowatt diesel generator and trailer. This results in a total savings of 16,200 ponds for the MF2000 unit and 48,600 pounds for the MRI unit. Using the USADRD prototype a FDTT can operate from a military two kilowatt generator (the approximate size and weight of the current dental compressor), rechargeable battery packs, or the 24 volt current available through the outlet of any NATO vehicle.

Electric handpieces are rarely used in the United States for operative dental procedures and there is little published information comparing the performance characteristics of electric motor handpieces to the conventional air turbine handpieces.[ii] Before proceeding with the fabrication of a lightweight, low cube, portable treatment and operating system, the USADRD wanted to verify that the performance of the electric motor handpiece was equal to or greater than the performance of the air turbine handpiece.

II. ELECTRIC MOTOR DENTAL HANDPIECES

There are several companies that manufacture electric dental handpiece motors. All of these motors have similar characteristics. The motor speed is adjustable from a minimum of 1000 rpms to a maximum of 40,000 rpms. Many electric motor systems have a digital display on the control panel that will indicate the motor speed. The operator can precisely control the speed by one of two methods. Some systems have a speed control knob located on the control panel; others have a foot pedal with a lever that moves horizontally to set the speed. The handpiece is activated by depressing the footswitch.

Several electric motor handpieces in the commercial market have built in fiberoptics and internal air-water coolant lines. These electric motors accept a standard ISO “E” type attachment. This standard permits the motors and attachments of several manufacturers to be used interchangeably.

Although the motors can be surface disinfected, they can not be autoclaved. However several brands of electric motors have a removable

outer sleeve that can be sterilized. The motors require virtually no maintenance except to change the carbon brushes approximately every two years. Brushless dental motors are now available. The brushless motor handpieces can be fabricated from autoclavable materials, but require a more complex controller and are slightly more expensive. One manufacturer sells the brushless motors with a five year guarantee.

The electric motor has O-rings in the area where it connects to the attachments. These O-rings keep air and water from leaking between the motor and attachment. The O-rings should last approximately nine months. They should be replaced, as needed, when they are worn. A worn O-ring will cause a water and/or air leak from between the motor and attachment. Both the O-rings and brushes can be changed easily by dental personnel.

There are many attachments that can be utilized with the electric motor handpiece. These attachments can be autoclaved. Speed increasing contra-angle attachments with 1:4 and 1:5 ratios are available. They can increase the bur speed to a maximum of 200,000 rpms. These contra-angles have a push button chuck mechanism and accept conventional friction grip burs. Various speed decreasing contra-angle attachments with ratios of 2.5:1 to 74:1 are available. They can produce bur speeds ranging from 14 to 16,000 rpms. These attachments are available with a push button chuck that will accept friction grip burs, a push button chuck that will accept latch type burs, micro size heads, and prophylactic universal heads. Straight nose cone attachments that accept larger diameter surgical and laboratory burs area are also available.

III. PURPOSE

The purpose of this study was to subject electric motor handpieces to some of the same testing done in a comprehensive performance evaluation of air turbine dental handpieces conducted by the U.S. Air Force Dental Investigative Service (USAF DIS).[iii]

Two types of electric motor handpieces and speed increasing attachments were used in the USADRD study. The KaVo INTRAmatic LUX with the INTRA LUX 2 1:5 speed increasing contra-angle (KaVo of America, Lake Zurich, IL) and the Bien-Air MC3LK Micromotor and the CA1442 1:4 speed increasing contra-angle (Bien-Air USA Inc. Irvine CA) were selected for the study. Although the attachments are interchangeable, for this study a motor and attachment were paired and used together for the duration of the study. The Midwest Quiet-Air L (Midwest Dental Products, Des Plaines, IL) was rated as acceptable in a USAF DIS test evaluation and was used as the control in this study.[iv]

The USADRD examined twelve clinical parameters related to the clinical performance of electric motor and air turbine handpieces. Longevity, power (expressed as cutting efficiency), effect on pulpal thermal states, air exhaust, aerosol production, noise production, speed (in revolutions per minute), fiberoptic transmission, dependability of chuck mechanisms, static parameters (size and weight), price, and clinician acceptance were tested at baseline, 250, 500, 750, and 1000 simulated clinical uses. Each handpiece had a sample size of six. Unless otherwise specified for the electric dental motor, the term handpiece will refer to the motor and speed increasing attachment.

IV. LITERATURE REVIEW

The USAF DIS study controlled the variables that had not been controlled in previous handpiece performance studies.[v],[vi] After measuring handpiece baseline values the USAF DIS fabricated a custom made handpiece wear tester. The tester applied 4 ounces of side load force for four minutes of simulated clinical use. The handpieces were sterilized and tested after baseline, 250, 500, 750 and 1000 simulated use cycles. Using this device the USAF DIS was able to simulate two years of clinical use in a controlled environment. The USAF DIS evaluation was a comprehensive study on the effects of clinical use and sterilization the on the longevity, speed, power, eccentricity, noise level and fiberoptic light intensity of nine commercially available air turbine handpieces).[vii]

Simulated clinical use was accomplished by placing the handpieces in a custom cutting assembly. The handpiece was secured in a "frictionless" bearing and mounted to a vertical wall. (Figure #1) Although "frictionless" may be an inaccurate claim, the amount of friction was assumed to be constant for each handpiece. The air turbine handpiece operated at a regulated pressure of 30 pounds per square inch and a coolant water spray of 20 milliliters/minute. The electric motor handpieces were operated at 100% power and a coolant water spray of 20 ml/min. A new 1158 bur (Midwest Dental Products, Des Plaines, IL) was used to cut the Macor for two simulated clinical uses and then it was discarded. The 1158 is a round end plain fissure taper bur, 1.2 mm in diameter with a cutting length of 4.0 mm.

A cutting force was achieved by attaching a 115 gram weight to the head of the handpieces. Macor (Corning Glass Works, Corning NY) was used as the cutting substrate. Macor is a machineable glass-ceramic with a density of 2.52 g/cm3, modulus of rupture at 94 MPA, comparable hardness at 250 KHN, Young's elastic modulus (66.9 Gpa), and thermal properties to enamel.[viii] The Macor used for this study was supplied in 3/8x 1 x 3 inch pieces.

The simulated cycle was as follows:

a. The handpiece was started and allowed 2 seconds to attained maximum speed.
b. The weight was applied and the bur cut through a 1 inch length of Macor for 30 seconds.
c. The handpiece was stopped for twenty seconds and the Macor was repositioned.
d. Steps 1, 2 and 3 were repeated for a total of eight cycles. This simulated one clinical use.
e. After four clinical uses the handpieces were sterilized four times (273 degrees Fahrenheit for 7 minutes) in a Tuttnauer 2540M Autoclave (Tuttnauer USA Co LTD. Ronkonkoma, NY). The handpieces were allowed to cool at least sixteen hours before the next clinical simulation.

In the case of the electric motors, for the purposes of sterilization, "handpiece" refers to the 1:4 speed increasing contra-angle. Heat sterilization is not recommended for the motors. The external surface can be disinfected or the removable outer sleeve of the motor can be heat sterilized. The electric motor handpiece attachments and the air turbine handpieces were lubricated in

accordance with manufacturers' instructions. The packs were placed in the sterilizer with the head elevated at a 45 degree angle to minimize moisture retention.

All handpieces were subjected to 1000 clinical simulations. Assuming a handpiece is used twice a day, 250 days a year, 1000 clinical simulations corresponds to two years of clinical use.

V. CLINICAL PARAMETERS

A. Handpiece Longevity

Literature Review

The ADA stated in 1992 that every instrument that enters the mouth, including the handpiece, be sterilized between patients. The ADA also stated that heat sterilization with an autoclave or chemical vapor sterilizer was effective method of sterilization between patients to ensure internal as well as external sterilization.[ix] Several studies have suggested that heat sterilization is detrimental to the working lifespan of dental handpieces.

Methods and Materials

Handpiece longevity was determined by recording how many successful clinical simulations were performed by a handpiece before it failed. Failure of the handpiece was determined to have occurred when it became non-operational, when the average cutting time had increased by more than 25% from baseline, or when the handpiece stalled on the substrate when the weight was applied. When a handpiece stalled, a slight digital rotation was used to restart it. If the handpiece did not operate after two attempts it was considered non-operational.

Results

The failures for each model are shown in Table 1. Neither the Kavo nor the Bien-Air electric motor handpieces had an operating failure after 1000 uses. The Midwest had a failure rate of 50% after

1000 uses. Midwest handpiece failures occurred after 260, 805, and 821 clinical simulations. The Midwest handpieces were returned to the study after the turbines were replaced. The handpiece that failed at 260 simulations, failed again at 830. This was not counted as an additional failure.

Table 1. Handpiece Longevity (Percentage Operational). Each handpiece had a sample size of six.

Clinical Simulations/ Handpiece	0	252	500	752	1000	Subset
KaVo	100	100	100	100	100	A
Bien-Air	100	100	100	100	100	A
Quiet-Air	100	100	83	83	50	B

Discussion

Longevity is considered to be the most important factor when evaluating a handpiece.[x] All twelve electric motor dental handpieces were operational operational after 1000 simulations. Three of the six air turbine handpieces had turbine bearing failures. When considering the purchase of a dental handpiece, longevity is an important factor. Handpiece longevity has a direct effect on the frequency and cost of repairs. Handpiece repair cost and "down-time" are two of the factors used to determine life cycle costs.

Conclusion

The longevity of the electric motor dental handpiece is significantly better than the longevity of the air turbine handpiece.

V. CLINICAL PARAMETERS

B. Power/Cutting Efficiency

Literature review

Power is the measure of a handpiece's capability to remove tooth structure. Power is calculated by multiplying torque (Newton meter) and rotation (revolutions per minute), and it is expressed in watts.[xi] To obtain power data it is necessary to measure torque and speed simultaneously. Speed is easily measured with a tachometer, torque with a dynamometer. However attempts to measure the torque of the electric motor at the maximum at bur speed of 200,000 were unsuccessful. At this speed the electric motor handpieces consistently "over torqued" the dynamometer (Kerfoot Dynamometer. KMS Design, Altamonte Springs, FL) and a repeatable measurement of torque could not be obtained.

The USAF DIS successfully measured the torque of the KaVo electric motor with a 1:1 straight nose cone attachment. At approximately 25,000 rpms the KaVo had a stall torque of 1.933 in-ounces and a maximum power is 35.7 watts. For comparison, the Midwest shorty generated a maximum power of 17.4 watts at 15,000 rpm. The stall torque was 2.598 in-ounces at 500 rpm. This demonstrates how the torque measurement can be misleading indicator of power.[xii]

According to data from Bien-Air, their motor has a torque of 2.9 Newton Centimeter (Ncm) (4.113 in-ounces) at 40,000 rpms. KaVo states that their motor has a minimum torque of 2.7 Ncm (3.830 in-ounces). The USAF DIS has published torque values for air turbine handpieces.

However, because of the wide variety of torque measuring methods and apparatus, an accurate comparison of these numbers is not possible.

Several recent studies have compared the cutting efficiencies of burs by placing a known force on a high speed handpiece and measuring the amount of material removed in a certain period of time.[xiii],[xiv] The purpose of these studies was to compare various types of burs, not dental handpieces.

The forced applied by a dentist with a handpiece and revolving bur on a tooth varies according to a number of factors such as operator experience, tactile sense, the type of bur, tooth density, restorative material, handpiece torque, and bur speed. Most studies estimate this force at 50- 150 grams.[xv,xvi,xvii] In these studies a handpiece was placed in a "frictionless" bearing and a known weight placed on the neck of the handpiece. This weight and the fulcrum position of the handpiece resulted in a known force applied by the bur to the surface to be cut. Since identical handpieces were used, the size and weight was constant, and therefore the resulting force was be constant.

Cutting efficiency (CE) was determined to be the amount (volume) of substrate cut by a handpiece, divided by the time required to cut the substrate. If the variables of applied force and the type of bur are held constant then the CE would be a useful method of comparing the power of various handpieces.

$$\text{Cutting Efficiency } mm^3/sec = \frac{\text{Volume of material removed } (mm^3)}{\text{Time to remove material (seconds)}}$$

Methods and Materials

Material selection is an important feature of a cutting efficiency study. Ideally tooth structure should be used, but inconsistencies in morphology would introduce uncontrolled variables.[xviii] Many dental bur cutting studies have taken advantage of the consistent density and availability of glass ceramic materials.[xix],[xx],[xxi]

Macor (Corning Glass Works, Corning NY) was used to simulated enamel and provide a constant material density during the tests. The Macor used for this study was supplied in 3/8x 3/8 x 5/8 inch pieces.

Because different handpieces were to be tested it was necessary to build a device that would move the Macor into the bur at a reproducible force. A table was built that would create a "frictionless" surface. The table had perforations allowed for the passage of pressurized air, similar to an air hockey table. The pressurized air would allow a disc to glide across the table surface.

The Macor was placed on a 1 x 1 inch, 1.4mm thick piece of plastic building block material and stabilized by a stent made of light cured dental acrylic (Triad, Caulk Dentsply. York PA) (Picture #1). These Macor-building blocks weighed 8.560 grams (+/- 0.1 grams), could be securely attached and easily removed from a second thin building block that was glued to a plastic disc. The plastic disc was placed on a table with a perforated surface. Two ¼ inch diameter 18 gauge wires were mounted to prevent the disc from rising more than 1.5 mm from the surface. A cutting force of either 100 grams or 150 grams was applied

by attaching a 100 gram or 150 gram weight to a piece a 25 test fishing line that would pull the disc into the bur. These weights were assumed to approximate the force a dentist would use. The bur depth and angle were set by a series of adjustment screws. Each cut was 3.8 mm deep through the 3/8 inch (0.9525 cm) width of Macor.

These cutting efficiency tests were conducted after the handpieces had been subjected to 204 clinical simulations. Before each series of cuts the handpieces were lubricated and sterilized according to manufacture specifications. Before testing the handpieces were run for 120 seconds without load. An 1158 bur (Midwest Dental Products, Des Plaines, IL) was used to cut the Macor two times before being discarded.

The time required for the bur to cut through the Macor was recorded. After each cut, the Macor was removed from the disc cleaned with compressed air for fifteen seconds and then weighed to determine the amount of material that was removed. Mass was measured using a balance (AT261 Delta Range. Mettler. Toledo, OH). The mass was divided by the known density, in order to reveal the volume of Macor removed. Cutting efficiency was then determined by dividing the volume of substrate removed divided by the time (+-0.1 second) required to complete the cut.

$$\text{Volume } (mm^3) = \frac{\text{Mass (mg)}}{\text{Density } (2.52 \text{ mg}/mm^3)}$$

During preliminary testing, a constant force of 150 grams resulted in the air turbine handpiece occasionally “stalling” against

the surface of the Macor. If the air turbine appear to stall, the force would be momentarily stopped to permit the air turbine to regain full speed. The air turbine handpiece cut the Macor without "stalling" when a constant force of 100 was applied. The Electric motor handpiece did not "stall" at either applied force.

To determine a clinical relevance to the cutting efficiency, five dentists were asked to make preparation on Macor. A stent was used to mark a 8 x 5 mm area on four sides of a 3/8 x 3/8 x 3/4 piece of Macor (Picture #2). The dentists were instructed to make the preparation to the depth of a 330 bur.

Each dentist was given the opportunity to use the electric handpiece on extracted teeth and Macor, to ensure familiarity with the electric handpiece. Use of the air turbine and electric handpieces were randomized. Each dentist prepared four areas with the air turbine handpiece and four areas with the electric motor handpiece. The time required by the dentist to prepare the Macor was measured. The mass of Macor removed was measured. The volume of Macor removed and CE were calculated.

Results

The volume of Macor removed with each cut was calculated by determining the weight before cutting and the weight after cutting. The volume was divided by the amount of time required for the handpiece to cut through the 3/8 inch width of Macor. This was recorded as volume removed per second. The averages for these values are recorded in Table 2.

Table 2. Cutting efficiency with identical force.

Handpiece	Force (grams)	Mean Volume removed (cubic mm)	Mean Time To complete Removal	Mean Cutting Efficiency mm^3/sec	Std. Deviation
Electric Motor	100	45.73	14.8	3.09	.3214
Air Turbine	100	46.95	22.9	2.05	.2346
Electric Motor	150	46.03	8.4	5.67	.8052
Air Turbine	150	46.94	48.9	0.96	.1879

The time required by the dentists to make similar preparations was evaluated and "clinical cutting efficiency" was determined. These preparations are only considered similar because the volume of material removed was not reproducible and the dentists applied variable amounts of force during the preparations. This data is listed in Table 3.

Table 3. Clinical cutting efficiency of five dentists making similar preparations.

Handpiece	Electric		Air Turbine		Highest Cutting
Dentist	Mean	Std.Dev	Mean	Std.Dev	Efficiency
1	1.99	.469	1.34	.349	Electric
2	1.52	.237	1.72	.097	Electric
3	1.39	.128	1.06	.407	Electric
4	1.20	.125	1.55	.225	Air Turbine
5	0.81	.050	1.29	.683	Air Turbine

Discussion

Power is the measure of a handpiece's ability to remove tooth structure. Power in air turbine handpieces is usually measured by determining torque. However, even among air turbine testing, standardized regimens are difficult to achieve.[xxii]

This study involved a reproducible test to evaluate the cutting efficiency of the KaVo electric motor dental handpiece compared to an air turbine handpiece rated highly by a government testing organization. The results show that with equal amounts of applied force (100 and 150 grams), the electric motor handpiece cut a glass ceramic material significantly more effectively (volume per second) than the air turbine handpiece. The cutting efficiency of the air turbine handpiece significantly decreased with the greater force. This was due to the fact the air turbine handpiece had insufficient torque to operate effectively at the greater force.

There may be concern that this more rapid removal of tooth structure may have an adverse effect on the pulpal temperature. Data listed later in this report show no significant difference in the pulpal temperature increase between the air turbine and electric motor handpiece despite the more rapid removal of tooth structure with the same applied force.

It was attempted to determine if the greater CE of the electric motor handpiece in laboratory studies was repeated in a clinical setting. For the group of five dentists, three dentists achieved significantly higher cutting efficiency with the electric motor handpiece. Two of the dentists achieved significantly higher cutting efficiency with the air turbine handpiece. Overall, there was no significant difference in the clinical cutting efficiency of the air turbine and electric motor handpieces in this study.

Conclusion

Laboratory tests indicate that the electric motor dental handpiece has a higher cutting efficiency than the air turbine handpiece. This may not be clinically significant. It is possible that the dentists have learned to remove tooth structure at a certain "speed" and some dentists are not taking full advantage of the increased torque of the electric motor. Further studies may be needed to determine if dentists will take advantage of the increased torque as they become accustom to the electric motor handpiece.

The testing regimen in this study may be unorthodox but the testing method was simple, reproducible, and provided for control of the variables. It has been assumed that the individual 1158 carbide burs from this manufacturer have similar cutting characteristics.

V. CLINICAL PARAMETERS

C. Pulpal Temperature

Literature review

It was determined that pulpal temperature changes created by electric motor handpieces would be useful information to the USADRD research project. However there were no studies comparing the heat generated during operative procedures by electric motor handpieces and air turbine handpieces.

Early studies indicated that the heat generated by operative procedures was a major cause of pulpal injury.[xxiii],[xxiv] A recent study isolated the effect of heat from other potentially harmful factors and concluded that average increases in pulpal temperature of 11.2° Celsius does not damage the pulp. The study also concluded that heat plays a secondary role to bacterial intrusion and chemical irritation.[xxv]

Other studies measured the temperature changes in the pulp chamber when teeth were subjected to a bur on a highspeed handpiece. In some of these studies pulpal temperature decreased when air-water spray coolant was employed.[xxvi,xxvii] In other studies the pulpal temperature increased.[xxviii]

USADRD replicated the testing techniques used in several studies that measured pulpal temperature changes by using a thermocouple temperature probe inserted into a pulp chamber that was filled with a heat conducting compound.[xxix,xxx,xxxi,xxxii]

Methods and Materials

The teeth of 18-24 year old patients who had bilateral extraction of mandibular third molars were examined. Pairs of mandibular third molars were accepted if the teeth were caries free and approximately the same mesial-distal length (+/- 5%). Immediately after extraction the teeth were stored in physiologic saline solution with 10% formalin solution to prevent dehydration. The teeth were stored under 100% humidity except when used for testing.

The root portion was sectioned with a carborundum disk perpendicular to the long axis of the tooth, approximately 3 mm below the Cemento-Enamel Junction (CEJ). The pulp chamber was cleaned of remnant pulpal tissue by spoon excavator and irrigated with 10 cc of 5.25% sodium hypochchlorite.

Since handpieces of different sizes and weights were being evaluated, placing a known weight on the handpiece head to move the bur through the tooth would not result in an equal force being applied by the different handpieces. In order to assure that an equal and repeatable force was placed on the tooth by the bur a device was made that allowed the tooth to be moved into the bur at a repeatable force.

The tooth was affixed with acrylic to a 1.6 x 1.6 cm x 1.6 cm plastic building block. The plastic block had a hole drilled in the middle of the top surface with a 2 round bur (1.0 mm diameter). The tooth was positioned with the chamber centered over the hole in the plastic block. The acrylic was applied in varying amounts so that each

tooth-plastic block unit weighed approximately the same (4.940 grams +/- 0.1 gram). A 1.4mm thick piece building block was glued to a plastic disc (Picture #3). The tooth-plastic block unit could easily be attached and removed from the disc. Two 18 gauge orthodontic wires were mounted to prevent the disc from rising more than 1.5 mm from the surface of the table (Picture #4).

The disc was placed on a table with a perforated surface. The perforations allowed for the passage of pressurized air. The pressurized air caused the disc to glide without friction across the table surface.

Earlier test regimens indicated that some dentists would cut a greater volume of material per second when the used an electric motor handpiece than when they used an air turbine. During bench top studies, the air turbine handpiece would occasionally stall when a force greater than 140 grams was utilized. The electric motor would accept a force of up to 150 grams without “stalling”.

Clinical studies indicated that some dentists use a greater force with the electric motor handpiece than with the air turbine. To simulate this finding, unequal amounts of force were applied to the two handpieces. A cutting force of 100 grams was applied to the air turbine handpiece by attaching a 100 gram weight to a length of 25 pound test fishing line. A 135 gram weight was applied to the electric motor handpiece. These weights would pull the tooth into the bur.

A silicon heat transfer compound (Z9, GC Thorsen, Inc. Rockford, IL) was injected into the pulp chamber to facilitate heat transfer and

simulate pulpal tissue. A thermocouple probe (Type K, Omega Engineering, Stamford, CT) was inserted through a small hole in the side of the plastic building block, through the top of the block, into the tooth. Sticky wax (Moyco, Philadelphia, PA) was used to fix the probe in the proper location against the pulp chamber roof. Probe placement was confirmed by digital radiography and positions were corrected as needed (Picture #5). The probe was then connected to an electronic digital thermometer (DP41-TC, Omega Engineering). The results were recorded every second on a Data Acquisition and Analysis Software (Windows 3.1).

The handpieces were tested after 100 clinical simulations. Before each series of cuts the handpieces were lubricated and sterilized according to manufacture specifications. Before testing they were run for 120 seconds without load. A new 1558 round end taper bur was used to prepare each tooth.

The bur depth and angle were set by a series of adjustment screws. Three preparation cuts, parallel to the sagital plane, were made in a mesial distal direction on the occlusal surface. Each cut was set to a depth of 2.5 mm.

The left mandibular third molars were prepared with the air turbine handpiece. The right mandibular third molar prepared with the electric motor handpiece. The tooth and bur were aligned so that the bur would enter and exit the tooth at a depth of two millimeters.

The temperature of the coolant water was maintained at a constant temperature by a water bath (23.0 C). The water coolant was set to flow

at 20 ml/min for both handpieces. Several previous studies documented pulpal temperature changes when the initial pulpal temperature was approximating body temperature at 37 C. Since the purpose of this study was simply to compare heat generation from air turbine and electric motor handpieces; the teeth were tested at room temperature.

The temperatures in the pulp were automatically recorded every second. The preparation time for each cut was recorded. After the teeth were prepared, they were sectioned to determine residual dentine thickness. Teeth with a residual thickness of less than 1.25 mm from the floor of the preparation to the roof of the pulpal chamber were to be removed from the study.

The time required for each preparation was also recorded in order to determine any correlation between the cutting speed and maximum pulpal temperature.

Results

Table 4 shows the average pulpal temperature and average pulpal temperature increase generated by the two types of handpieces. The average time that the handpiece was in contact with the tooth is also listed. Paired sample statistics for the maximum pulpal temperature and adjusted temperature increase from the baseline.

On average the relative temperature within the pulp chamber increased by 3.48 degrees Celsius for the electric motor and 3.62 degrees Celsius for the air turbine. The electric motor preparation were accomplished 4.2 seconds quicker (SD 6.76) than the air turbine

preparations. When the two sets of teeth with shorter air turbine preparation times are excluded from the calculations, the electric handpiece preparations were accomplished 7.0 seconds quicker (SD 3.86).

Table 4. Pulpal temperature changes and preparation time with air and electric handpieces.

	Electric Handpiece	Air Turbine
Mean preparation time (secs)	29.13	35.52
Std. deviation	1.405	0.405
Mean Maximum Temperature increase (^{0}C)	3.76	3.86
Std. deviation	0.09	0.10

Remaining tooth structure thickness between the apical floor of the preparations and the roof of the pulp chamber was always greater than 1.2 mm.

Discussion

The testing regimen in this study may be unorthodox, but this test was designed to be simple, reproducible, and provide for control of the variables.

Because the teeth were tested at a controlled room temperature, the amount of thermal change in this study may have been different than if a simulated body temperature had been utilized. However, the amount of heat generated by the handpieces, measured by pulpal temperature changes, is statistically similar. This finding is remarkable because the electric motor handpiece removed tooth structure significantly faster (approximately 20%) than the air turbine handpiece

Conclusion

The electric motor handpiece with its increased cutting efficiency and ability to cut tooth structure at a greater applied force than the air turbine handpiece does not create an increased thermal hazard to the pulp than the air turbine handpiece.

V. CLINICAL PARAMETERS

D. Air Exhaust

Literature review

In the air turbine handpiece, most of the air driving the turbine is vented to the rear of the handpiece. However, a cooling stream of air from the drill head enters the mouth.[xxxiii] Although air turbine handpieces are contraindicated for dental alveolar surgical procedures, since the introduction of the air turbine handpiece the incidence of iatrogenic subcutaneous emphysema has increased.[xxxiv] The compressed air requirements for the brush type electric motor handpieces is significantly less than the requirements for the air turbine. The electric motor handpiece requires a stream of compressed air to cool the motor. Without this cooling air the motor will become hot to the touch and eventually stall.

The purpose of this test was measure the volume of drive air, coolant air, and the air component of the air-water bur coolant spray that exited the electric motor and air turbine handpiece.

Methods and Materials

A ½ inch diameter rubber hose was secured over the handpiece head. A graduated 1000ml cylinder full of water was inverted in a water filled four liter pan. The hose from the handpiece exited in the graduated cylinder. For each handpiece the coolant spray was set at 20 ml/min of water. The amount of air that exited the handpiece was

determined by measuring the time required to displace water from the graduated cylinder. (See Figure #2) This test was performed ten times for each handpiece to obtain an average volume of air exhaust coming from the head of the handpiece. The air water coolant spray was then switched off. The same technique was used to measure the amount of air that exited the head of the handpieces. This test was also repeated ten times for each handpiece.

The control units for both types of electric handpieces can be configured so that the coolant air to the motor can be inactivated. Attempts were made to measure the amount of air exhaust from the handpiece head when the motor coolant air was turned-off. A speed increasing contra-angle was placed on the electric motors. The air exhaust was measured in a similar fashion. Since large amounts of air exhaust were not generated a 10ml vessel was substituted for the 1000 ml cylinder. When the motor coolant air is off, the motor may overheat resulting in damage or performance changes.[xxxv] Because of this risk measurements of the air exhaust without a motor coolant spray were conducted at the end of the 1000 clinical simulation study.

Results

The amount of time required for the handpiece to release 1000 cubic centimeters of air at 1 atmosphere was recorded. Table 5 lists the average volume of air exiting from the handpiece heads. The table also lists the amount of air exhaust measured when the coolant air to the motor was turn-off.

Table 5. Volume of air (mm3/min) exiting handpiece head.

		Mean Volume Air(mm3/min)	Std. dev	
Without Air-water spray	KaVo	16.99	0.290	A
	Bien-Air	20.69	0.167	B
	Air Turbine	59.55	1.867	C
With Air-water spray	KaVo	39.87	1.654	I
	Bien-Air	46.94	0.790	II
	Air Turbine	112.89	9.018	III
Without motor air coolant	KaVo	0.11	0.03	
	Bien-Air	0.13	0.06	

Discussion

When the air-water coolant spray is set for 20 ml/min of water the air turbine handpiece emits significantly more air from the handpiece head than either electric motor handpiece. The Bien-Air electric handpiece emitted significantly more air than the KaVo.

When the air-water coolant spray is turned-off, the air turbine handpiece emits significantly more air from the handpiece head than either electric motor handpiece. The Bien-Air electric handpiece emitted significantly more air than the KaVo.

For each handpiece, the level of air emitted without the air-water coolant spray is approximately 50% of the amount air of exhaust when the air-water spray is operational.

Air turbine high speed handpieces are used by some practitioners during periodontal surgery involving boney recontouring. These results suggests that if used for dental alveolar or periodontal surgery either type of handpiece (air turbine or electric) could cause an air emboli

in the tissues of the patient, even if a separate irrigation syringe is used instead of the air-water spray.

In the electric motor handpieces studied, the air exhaust measured when the air-water coolant spray was turned-off could be the result of the motor coolant air migrating through the contra-angle attachment. Depending on the electric motor handpiece delivery system, this motor coolant air can be turned-off. When this is done, the measured air exhaust is reduced to less than 1.0 mm^3/min. Because of the significant air exhaust reduction, the electric motor handpiece may be better suited for these periodontal procedures because of the probable reduced risk of air emboli. However this procedure can reduce the life of the handpiece. With continued use the handpiece will become hot to the touch and eventually overheat. Manufacturers claim that the newer, brushless electric motor handpieces do not require this motor coolant air and will not produce an air exhaust without the air-water coolant spray.

Conclusion

This data suggests that the electric motor maybe suitable for dental-alveolar surgical procedures. The handpiece has sufficient torque and the measured air exhaust is negligible. This data also suggests that the electric motor handpiece with a contra-angle attachment may be suitable for dental-alveolar surgical procedures if the air-water spray is turned-off and a separate irrigation syringe used. It may be possible to substitute this handpiece for a surgical Hall or Stryker drill in some instances.

V. CLINICAL PARAMETERS

E. Aerosol Production

Literature review

Microorganisms in saliva and plaque are present in the aerosol created when a dental handpiece is used in an operative procedure.[xxxvi] Bacteria and other microorganisms in the oral cavity can be transmitted to dental personnel by aerosols generated during dental procedures.[xxxvii]

Fine aerosols generated by highspeed dental equipment consist of moisture droplets and contaminants that are less than 5 microns in diameter.[xxxviii] Particles in the 0.5-10 micron range are carried for hours at great distances and the size of these particles allow them to remain airborne for hours and travel deep into the respiratory tract.[xxxix]

Micik suggested that the bulk of the aerosol production was from the spray action, not the cutting operation.[xl] Another study determined that the bacteria in aerosol were generated mostly by the actual cutting.[xli]

Methods and Materials

Part I

In vitro testing was conducted utilizing extracted teeth, a clean room, and a HazDust II Aerosol Monitor (Environmental Devices Corp,

Haverhill, MA). The monitor with the inhalable sampler, detects particles in the 0.1-10 micron range with an air sample flow rate of 2.0 liters per minute. The monitor allows the calculation of minimum particle concentration; time weighted average particulate concentration over a period of time (TWA); and short term exposure level (STEL), the maximum concentration of particulates over a period of time. The unit was maintained and calibrated in accordance with manufacturer's instructions. Sensor optics on the HazDust were cleaned daily.

Three hundred non-carious extracted third molars were obtained for the study. Immediately after extraction the teeth were stored in physiologic saline solution with 10% formalin solution to prevent dehydration. The teeth were stored under 100% humidity except when used for testing.

A clinical day was simulated in the following manner. A dental operatory (12 x 12 foot) located in the US Army Dental Research Institute was chosen for the study. No other procedures were performed in this operatory for the duration of the study. The teeth were mounted in an acrylic based that could be mounted on a lab bench. Every thirty minutes a 4 x 8 mm class V preparation was made to the depth of a 330 carbide bur (0.8 mm diameter, 1.2mm long). High velocity suction was used.

The air turbine handpiece and electric motor dental handpieces were each used for ten days. The air-water coolant spray was set at 20 ml/min for both handpieces. The monitor was placed on a tripod three feet away from the operative field at the same height (See picture #6).

The amount of aerosol produced during a simulated clinical day was recorded.

Part II

To determine if the HazDust findings were clinically significant, clinical testing was conducted. Volunteers were recruited from active duty military personnel who had at least two carious lesions. Patients were excluded if they had active systemic infections, cold or flu symptoms within seven days, HIV positive, or any other conditions that contraindicate restorative dental treatment. Patients were treated in a 16 x 12 foot operatory with 9.5 foot high ceilings at the Great Lakes Naval Hospital Dental Clinic.

The patients were scheduled for two appointments in a dental operatory exclusively reserved for this study. During one appointment, a tooth was prepared with an air turbine handpiece. During the other appointment, the tooth was prepared with an electric motor dental handpiece. The treatment was completed before the clinic opened for the general patient population. Any treatment not completed during these two appointments was scheduled for a later date.

A Burkard Model PASA Portable Air Sampler for Agar Plates (Spiral Biotech Company. Bethesda, MD) was used to collect aerosolized bacteria and particle matter onto sheep's blood agar medium in a 9 cm diameter petri dish. Sheep blood agar was selected because it is a good growth medium for oral bacteria. It had been used in the majority of the past studies found in the literature. The air sampler passed air over the petri dish at a flow rate of 20 liters per minute.

The air sampler was located three feet from the patient's mouth, at waist level, on the patient's right side. Air samples were collected by exposing the petri dish for a three minute period of time. A baseline air sample was collected five minutes before the patient was seated in the operatory. A second baseline air sample was collected after the patient was seated in the chair. Starting at the time that the dental bur was first applied to the tooth, a third air sample was collected. This air sample measured the bacterial levels in the aerosol produced during dental treatment. A fourth air sample was collected one hour after the treatment had started.

The petri dishes were incubated at 37 degrees Celsius in an atmosphere of 5% carbon dioxide for 48 hours. Following incubation, all bacterial colonies were enumerated by counting a 10 cm section grid. Data was be reported as total colony forming units per sample.

Part III

Clinical and laboratory testing revealed contradictory information. The air sampler was used in a clean room (Airo Clean Model 823, Extron PA) in USADRD facilities. Dimensions of the clean room were 8.5 x 22.5 foot with an 8.25 foot high ceiling. The atmosphere displacement was approximately 700 cubic feet per minute (CFM).

An *in vitro* carious lesion model was used to assess the rates of bacterial aerosolization. A series of 3/8" x 3/8" x 3" Macor blocks were sterilized and aseptically embedded into 10 ml of Todd Hewitt Agar (1.50% w/v) in a 9 cm petri dish. Cultures of *Streptococcus mutans*

25175 were grown to mid-logarithmic phase (A_{660nm}= 0.20) in Todd Hewitt (TH) broth; 300 *u*l of this culture was used to inoculate 15 ml aliquots of 0.75% TH top agar at 37°C. After the primary agar layer had solidified around the base of the Macor blocks, the *S. mutans*-dosed top agar was poured into the dish, encasing the remainder of the exposed Macor sample. Plates were incubated 48 hours to permit proliferation of the cariogenic organism throughout the top agar-Macor matrix. At the completion of the incubation period, extensive bacterial growth was easily evident.

The handpieces were set to have a 20 ml/min water spray. Three 8 x 5 mm, 1.2 mm deep spaces was prepared in the Macor. The air sampler was placed 24 inches from the work site at the same horizontal level. Air samples were collected by exposing the blood agar petri dish for three minutes with air passing over the dish at 20 liters per minute. Ten minutes before the cutting procedure, a baseline air sample was collected. Another baseline air sample was collected five minutes before the cutting procedure. Only one Macor sample was tested each day to assure that residual aerosol contamination had been cleared.

An air sample to measure the aerosol created by the procedure was collected when the cutting procedure started. Ten minutes after the preparation was completed an air sample another air sample was collected.

Each blood agar plate was incubated at 37 degrees Celsius in an atmosphere of 5% carbon dioxide for 48 hours. Following incubation, individual plates were enumerated by counting total colony forming units.

Results

Part I

The results from the HazDust monitoring are listed in table 6. The results indicate that in an isolated operatory the electric motor handpiece produces significantly less aerosol than the air turbine handpiece.

Table 6. Aerosol (particles per cubic meter) produced by handpieces, measured by HazDust monitor.

	Air Turbine	Electric Motor
Maximum aerosol Concentration	3.59	1.38
TWA. Time weighted Average	2.13	0.66
STEL. Short term exposure level	2.97	1.17

Part II

The results from the air sampler in the hospital dental clinic are listed in Table 7. The air sampler attempted to measure the amount of aerosol produced as a function of CFUs counted on the petri dishes. Since the two initial (baseline) measurements, taken each morning, are statistically similar, they are grouped together as “pre-operative” CFU level. There is no significant difference between the electric motor and air turbine handpieces in the number of colony forming units that were collected on the petri dishes.

Table 7. Average CFUs detected in clinical study

CFU levels	Handpiece	Mean CFUs	Standard deviation	Std error mean
Pre-operative	Electric Motor	3.21	1.31	0.350
	Air Turbine	3.43	1.22	0.327
Operative	Electric Motor	6.79	4.74	1.267
	Air Turbine	6.29	3.29	0.880
Post-operative	Electric Motor	4.50	2.74	0.732
	Air Turbine	4.00	1.96	0.524

Part III

The results from the air sampler in the laboratory clean room are listed in Table 8. The air sampler attempted to measure the amount of aerosol produced as a function of CFUs counted on the petri dishes. Since the two initial (baseline) measurements are statistically similar, they are grouped together as "pre-operative" CFU level.

Table 8. Average CFUs detected in clean room study

CFU levels	Handpiece	Mean CFUs	Standard deviation	Std error mean
Pre-operative	Electric Motor	0.00		
	Air Turbine	0.00		
Operative	Electric Motor	6.64	4.11	1.0975
	Air Turbine	7.79	2.19	0.5853
Post-operative	Electric Motor	3.71	2.09	0.5589
	Air Turbine	4.07	1.90	0.5078

Discussion

Because of the significant difference between the amount of air that is emitted from the handpiece head, it was anticipated that the electric motor handpieces would produce less aerosol. However, the various testing methods provide conflicting results.

The results of the HazDust Monitor in an isolated dental operatory reveals that use of the electric motor handpiece results in significantly less aerosol production than the air turbine handpiece. This is believed to be a result of the smaller amount of compressed air entering the patient's mouth from the handpiece head.

Table 7 indicates that there is no significant difference between the electric motor and air turbine dental handpieces in the amount of aerosol created. These non-significant differences in the hospital dental clinic may have been the result of "background" contamination. The findings suggested that ambient room air in the operatory/clinic contained residual levels of aerosolized organisms. There are eight other operatories in the dental clinic, which is located on the seventh floor of an eleven story building. This study has practical applications for large dental clinics. Although an electric handpiece may produce less aerosol than an air turbine, in a large dental clinic with both electric motor and air turbine handpieces, the amount of aerosol in the clinic may not be significantly altered.

Table 8 indicates that there is no significant difference between the electric motor and air turbine dental handpieces in the amount of aerosol created in the clean room.

Conclusion

Final analysis of the data indicates that with an air-water coolant spray, the electric motor handpiece and the air turbine handpiece produce statistically similar levels of aerosol contamination.

V. CLINICAL PARAMETERS

F. Noise

Literature review

Noise is defined by its sound level and frequency. Since noise, including dental drills, includes frequencies throughout the audible range, sound measurements are adjusted to account for frequency dependent human hearing. This measurement is called A-weighted (dBA).

Many studies have indicated that there is a risk of noise induced hearing loss (NIHL) resulting from dental practice. A 1985 literature review 11 of 19 studies indicated that dental drills cause NIHL.[xlii] A Scandinavian study followed a group of dentists for seventeen years and concluded that dental drills are not a risk to dentist's hearing.[xliii] A study published in 1990 concluded that dentists received, on average, only 8-12% of their 24 hour noise exposure from their dental practice.[xliv] However, these studies did not test multiple dentist clinics and recorded exposure to dental drill noise as little as 15-30 minutes per 8 hour day. A dental school study concluded that in a large preclinical lab personnel protective devices may be indicated and indicated that personnel who spend time in "noisy" dental labs show that these individuals may be at risk for hearing problems.[xlv]

Although noise levels of dental handpieces may not cause hearing loss, noise can interfere with communication, cause an increase in blood pressure, quicken the pulse, and constrict blood vessels.[xlvi,xlvii]

Field DTFs can have high noise levels because of the field air compressors, lack of noise reduction materials, and the background noise levels in the clinic area. Recent essential characteristics for portable field dental treatment unit limited the noise levels to 75dBA at 1 meter for the compressor. Any substitution for the air turbine handpiece in a field dental treatment facility of clinical environment should not increase the noise risk.

Methods and Materials

Part I

The noise level of the air turbine handpiece and two electric motor handpieces were measured in a 12x12 dental operatory located in the U.S. Army Dental Research Institute. The air compressor was located in a basement so that the background sound level was not affected by the air compressor operation. The handpieces were the only source of noise in the operatory.

An Extech Noise Dosimeter RS-232 (Extech Instruments. Waltham MA) was used to measure the one minute average decibel level of the handpieces. The microphone was mounted on a tripod at the approximate location of the right ear of a right-handed dentist.

Since the handpieces are most often place intraorally when operational, sound levels were recorded when they were operating inside the mouth of a dental mannequin. The noise levels were recorded when running at full speed cutting blocks of Macor (Corning Glass Works, Corning NY) was used as the substrate.

The Macor was mounted in the area of the lower right molar. Since dental handpieces are almost always used with the air-water spray, the spray was utilized during testing and set at 20 ml/min. Suction was not employed. The water accumulated, via a drain tube, in a basin at the base of the chair. Background noise level was recorded before each one minute test. The handpiece was operational for five seconds before the noise level was recorded.

This test was conducted for the after 208 simulated clinical uses. The test was repeated after 232 clinical simulations, with one altered variable. The handpieces were held approximately 10 mm above the Macor and the noise was recorded while the burs were "free-running".

Part II

The second part of the study utilized the dental sets and equipment of an U.S. Army Forward Dental Treatment Team (FDTT). The FDTT consists of one dentist, one assistant, dental supplies and equipment usually working in a canvas tent. The noise level (dBA) of the present air turbine portable dental field treatment unit (ADEC, Newberg, OR) and air compressor (Air Techniques, Hicksville, NY) were recorded with the same instrument as in part I. The noise detector also recorded the exposure time, dose value, the eight hour time

weighted average (TWA), average noise dosimeter level (dBA), and background noise levels.

The air turbine treatment unit was placed just behind the dentist. The compressor was outside of the tent, twelve feet from the noise dosimeter, behind a wall of sandbags (30 inches high, 30 inches wide, and 12 inches thick).

The USADRD prototype DeFTOS was placed immediately to the left of the patient chair.

Dentaforms with Macor mounted inside the mouth were also utilized to simulate patients for this study. A four minute simulated operative procedure was performed utilizing a highspeed handpiece and high velocity suction. Twenty-eight simulated procedures were performed for each system.

Results

The average decibel levels for the handpieces, with the bur "free-running" and with the bur cutting Macor are recorded on Table 9. Table 10 records the data for the current air turbine based dental field treatment system and the USADRD electric motor DeFTOS.

Table 9. Average noise level (dBA) of handpieces after 262 clinical simulations. Average background noise was 62 dBA.

	KaVo	Bien-Air	Air Turbine
Average Noise level (dBA) while cutting	77.00	77.33	83.33
Standard deviation	1.54	1.75	1.86
Standard error	0.632	0.715	0.760
95% confidence, lower bound	75.37	75.50	81.38
95% confidence, upper bound	78.63	79.17	85.28
Average Noise level (dBA) with "free-running" bur	75.00	75.33	81.66
Standard deviation	2.61	1.37	2.88
Standard error	1.064	0.558	1.174
95% confidence, lower bound	72.26	73.90	78.65
95% confidence, upper bound	77.74	76.77	84.68

Table 10. Noise comparison of current air turbine field treatment unit to field treatment system utilizing and electric motor. Average background noise 67dBA.

	Field Unit with Air Turbine Handpiece	Field Unit with Electric Motor Handpiece
Average exposure time	4 min	4 min
Noise dose level	0.21	0.08
T.W.A.	45.43	38.70
Noise average (dBA)	79.2	69.0

Discussion

The electric motor handpieces produce significantly less noise than the air turbine handpieces in both the cutting and "free-running" decibel measurements. However, the testing also indicated that all of the handpieces produce noise levels well below the OSHA eight hour limit of 85 dBA for noise induced hearing loss (NIHL).

These results indicate that there is no significant difference in the noise levels between a bur cutting a substrate and a bur that is

"free-running". This finding disagrees with those of Bahannan[xlviii], and Setcos.[xlix] Bahannan determined that a cutting handpiece created more noise than a free running handpiece. Setcos determined that a free running handpiece created more noise than a cutting handpiece.

This test only recorded the noise from one operating handpiece. In a large multioperatory setting there may be a risk for noise induced hearing loss. Multiple handpieces and high velocity evacuators (HVE) in one area may combine to produce noise levels above the OSHA eight hour limit.

The results in Table 10 indicate that the portable field treatment system utilizing an electric motor handpiece produces significantly less noise than the field treatment system that utilizes an air turbine handpiece.

Conclusion

The electric motor dental handpiece is significantly quieter than the air turbine handpiece. The reduced noise of the electric motor handpiece may minimize the NIHL risk in a clinical setting. In a field setting, a field treatment and operating system that combines a quieter handpiece and HVE with a reduced need for portable generator power will create a quieter work environment for the forward deployed treatment teams. It must be acknowledged that other factors such as compressor noise and vacuum system may account for some of the difference between the two portable treatment systems.

In all field environments where the air turbine and electric motor portable dental treatment systems were tested the treatment systems utilizing the electric motor dental handpiece was significantly quieter than the current air turbine systems.

V. CLINICAL PARAMETERS

G. Speed

Literature Review

The electric motor handpiece is capable of well-controlled bur speeds of 5-200,000 rpms depending on the type of attachment placed on the motor. The speed without load readings for the air turbine are significantly higher than for the electric motor handpieces. Most ball-bearing air turbine handpieces operate at 350,000- 400,000 rpms. Precise control of the air turbine bur speed is difficult to achieve with the present rheostat. The speed for any air turbine will dramatically decrease as load is increased.[1]

The USAF DIS found that for air turbine handpieces there was no correlation between baseline rpm and handpiece longevity.[1i] According to the formula Power = Torque x Speed, a reduction in handpiece speed over a period of time will result in a decrease in power. It has also been reported that changes in free running speeds are primarily related to bearing deterioration.[1ii] The purpose of this test was not to compare the handpieces to each other, but to determine if clinical use and sterilization adversely affected the tested handpieces.

Methods and Materials

The speed in revolutions per minute (rpms) was measured with a Tach-4AR tachometer with Remote Optical Sensor (Monarch Instruments. Amherst NH). Bur speed of the air turbine and two different electric

motor handpieces was measured at initial baseline and after 252, 500, 752 and 1000 clinical simulations. Each group consisted of six handpieces.

It was desired to determine if any speed change in the electric motor handpieces was related to the motor or to the attachment. A 10CN Intra 1:1 straight nose cone attachment (KaVo of America, Lake Zurich, IL) was reserved for this determination. This attachment was used on the twelve electric motors just after baseline determination and just after 1000 clinical simulation determination. This attachment was not subjected to sterilization procedures.

Results

Mean speed values, in revolutions per minute (rpms), for each handpiece are shown in Table 11. Readings were taken at baseline, 252, 500, 752, and 1000 simulated clinical uses.

When a handpiece failed it was no longer included in calculating the mean for the group. The Midwest handpieces that failed at 260, 805, and 821 clinical simulations were not included in the mean speed values.

Table 11. Mean Handpiece speed in rpms over use

Handpiece Number of clinical simulations	KaVo Motor and attachment	Bien-Air Motor and attachment	Midwest Quiet-Air
Baseline (0)	190,067	157,173	370,308
Std deviation	696.18	1,199.11	6,808.99
252	190,242	156,633	362,348
Std deviation	1,195.16	1,049.13	9,218.98
500	189,423	155,447	365,804
Std deviation	991.50	787.06	9,979.80
752	189,095	154,593	363,370
Std deviation	1,118.81	1,241.48	6,355.63
1000	189,173	155,768	355,347
Std deviation	840.83	1,603.24	9,079.85
Mean loss from 0 to 1000 uses	894	1,405	14,961
% Mean loss from 0-1000 uses	0.4	0.9	4.0

Table 12 records the average speed of the electric motors when the speed of the motor was calculated with a 1:1 straight nose cone attachment.

Table 12. Mean electric handpiece motor speed (in rpms) with 1:1 straight nose cone attachment.

	KaVo E.M With 1:1	S.D.	Bien-Air With 1:1	S.D.
Baseline 0 simulations	38,177	360.37	37,517	359.81
1000 clinical simulations	38,112	396.66	37,012	430.18
% change in motor speed (rpms)	-0.14		-1.34	

Discussion

It is unclear if decreasing handpiece speed indicates a gradual failing of handpiece. However USAF DIS data indicates that handpieces fail abruptly and that decreased speed may indicate improper

maintenance and lubrication.[liii] However manufacturer's instructions were closely followed during this study.

The speed of the motor with both a contra-angle speed increasing attachment and 1:1 straight nose cone was measured. This allowed separate assessments of the degradation of the attachments and motors over 1000 simulated uses. With their speed increasing contra-angles, the KaVo and Bien-Air showed no statistically significantly speed degradation over 1000 simulated clinical uses. The electric motors with the straight nose cone also demonstrated no statistically significantly speed degradation. The air turbine handpiece showed a significant decrease over 1000 simulated clinical uses.

Conclusion

The electric motor handpieces did not demonstrate a significant loss in speed after 1000 simulated clinical uses and sterilizations. A significant decrease in the bur speed of the air turbine handpiece was noted, although a similar USAF DIS study did not detect significant decrease in the bur speed for this air turbine handpiece.

V. CLINICAL PARAMETERS

H. Fiberoptic Transmission

Literature Review

The air turbine and electric motor handpieces had two different types of fiberoptic systems. The air turbine had a remote light source. The light was transmitted through a fiberoptic bundle in the handpiece hose that connected to the handpiece. The electric motor handpieces have a light source in the handpiece motor. A fiberoptic rod in the handpiece attachment connects to the light source.

Light degradation may be caused by handpiece lubricants, water contaminants, or damage from the material that is cut. The purpose of this study was not to compare the fiberoptic delivery system but to determine the affect of 1000 simulated clinical uses and sterilizations on the fiberoptic light transmission capability within the handpiece.

Methods and Materials

The fiberoptic light transmission was determined by measuring the light that was emitted from the handpiece. The photometer, AEMC Light Meter, Model 814 (AEMC Corporation, Boston, MA) was placed at the tip of an 1158 bur that was fully seated in the chuck. The angle of the photometer to the handpiece head was adjusted so that the greatest reading was recorded. Measurements at baseline, 252, 500, 752, and 1000 simulations were used to determine changes in the light transmission intensity for each handpiece. After 1000 simulated uses, a very fine

rubber abrasive point, Shofu super-greenie gold polishing point (Shofu Dental Corp, Menlo Park, CA) was used to polish the fiberoptic lens and remove any contaminants or scratches. The polishing was accomplished with an electric handpiece at 5000 rpms. The illumination measurements were then recorded.

Although different light sources were used for each type of handpiece, the source for that handpiece remained constant. The fiberoptic system was not active during the simulations. This reduced the chances of light source failure affecting the light intensity measurements.

Results

The fiberoptic intensity measurements for each handpiece are shown in Table 13. Handpieces that failed the longevity test were included in the fiberoptic transmission test. It was theorized that the handpiece repair would not affect the fiberoptic transmission capability of the handpiece

Table 13. Mean Fiberoptic Transmission Test.

	KaVo	Bien-Air	Air Turbine
Initial baseline illumination reading (LUX)	45,142	45,382	36,560
Standard deviation	66.76	80.35	845.00
Illumination reading (LUX) after 1000 simulated uses	33,125	34,407	24,967
Standard deviation	1,658.21	1,440.45	1,139.66
Percent decrease from baseline	73.4	75.8	70.5
Illumination reading (LUX) after 1000 simulated uses and polishing	42,075	41,958	29,048
Standard deviation	1,010.40	1,153.82	1,679.66
Percent decrease from baseline	93.2	92.5	82.1

Discussion

All of the handpieces had a decreased fiberoptic output after 1000 simulated clinical uses. Polishing of the fiberoptic lens was done to eliminate external sources of light degradation such as lubricants, minerals from water, and scratches caused by the substrate. It is assumed that the data recorded after polishing of the lens is the best indicator of light transmission degradation. The KaVo and Bien-Air had significantly less decrease in light intensity than the air turbine.

A fiberoptic rod in the contra-angle attachment transmits the light from the motor to the handpiece head. The fiberoptic bundle in the air turbine handpiece is held together with epoxy resin that may discolor and darken after exposure to the heat and moisture from an autoclave.[liv] It is unlikely that any decrease in transmission is due to damage of the handpiece hose, because of the testing took place in a research operatory. In a clinical setting it is possible that some transmission intensity decrease would be the result of damaging the fiber bundle in the hose.

Polishing may cause the degradation of epoxy resin bundles because water and other contaminants may enter the space between the bundles. Although polishing may result in a rapid degradation of fiberoptic transmission, no further measurements were recorded.

As expected, because of the light source, the KaVo and Bien-Air have a significantly higher LUX reading than the air turbine. This finding is not significant because it was not the purpose of the study

to compare the light sources, but the percent decrease in transmitted light.

Conclusion

The ability of the fiberoptic rod in the electric motor handpieces to transmit light after 1000 clinical uses is significantly better than the ability of the tested air turbine handpiece. However, this is not a result of the handpiece type but a result of the type of fiberoptic rod in the handpiece. It must be noted that there are air turbine handpieces currently available that utilize the same type of rod found in these electric motor handpieces.

V. CLINICAL PARAMETERS

I. Chucking Mechanism

Literature Review

The USAF DIS study of air turbine handpieces indicated that all handpiece chucking mechanisms tested safely retained the bur in the handpiece throughout the evaluation.[lv] The USAF DIS test was repeated on the electric motor handpieces to determine if the performance of the electric motor handpieces was equivalent to the performance of the air turbines. In this study both electric motor handpieces utilized a push-button type chucking mechanism. The air turbine used a latch type mechanism.

Methods and Materials

Measurements for chuck failure, indicated by bur slippage, were conducted at 12, 258, 512, 760, and 992 clinical simulations. A Digital Caliper Mark III, (Fowler Ultra-Cal, Switzerland) accurate to +-0.01 mm was used. A standardized 19-mm test mandrel was placed in the handpiece and the distance from the back of the handpiece head to the tip of the mandrel was measured (See figure 3). The handpiece was then subjected one clinical simulation test and the distance was re-measured. An increase in length of over 0.5mm was considered an indication of bur slippage and chuck failure.

Results

All handpiece chucking mechanisms safely retained the bur in the handpiece during the evaluation. The final measurements of the bur length after simulated clinical use are found in table 14. Only air turbine handpieces that had not been repaired had the chucking mechanism tested.

Table 14. Average amount of increase in bur length (mm) with simulated clinical use.

Handpiece Clinical uses	KaVo	Bien-Air	Air turbine Non-failures
12	.01	.03	.02
S.D.			
258	.11	.18	.14
S.D.			
512	.12	.35	.22
S.D.			
760	.12	.29	.33
S.D.			
992	.23	.30	.29
S.D.			

Discussion

None of the handpieces experienced a chuck mechanism failure. There is an increase of bur length relative to the number of clinical simulations. There is no statistical difference in bur length among the three tested handpieces. Although the bur length increased with the number of simulations, the increases were less than 0.50 mm and not considered clinically significant.

Conclusion

There were no chucking mechanisms failures among the tested electric motor dental handpieces and the air turbine handpieces.

V. CLINICAL PARAMETERS

J. Static Parameters

Literature Review

There is a large variation in the length, weight, and head size of various dental handpieces. Head diameter is largely determined by the rotor diameter. Head length is often cited by manufacturers, but head length does not necessarily indicate the interocclusal distance required to access an area of the mouth. The head length plus the length of the bur protruding from the handpiece will determine the minimum interocclusal distance. However, visibility of the operative area is more a function of "visibility angle.[lvi] The International Standards Organization (ISO) has defined measurements for the visibility angle and interocclusal clearance of dental handpieces.[lvii]

Methods and Materials

Using the Digital Caliper Mark III, (Fowler Ultra-Cal, Switzerland) accurate to +-0.01 mm, the handpiece visibility angle and interocclusal clearance were determined. The handpieces were weighed on a scale accurate to 0.01 grams (AT261 Delta Range. Mettler. Toledo, OH).

Results

Table 14 lists the visibility angle, interocclusal access distances, and weight of each handpiece. The handpiece head length and

width have a direct influence on visibility angle and interocclusal distance. The handpiece data from the USAF DIS study is included in order to compare the size and angle of the electric motors to a greater number of air turbine handpieces.

Table 14. Handpiece visibility angle and interocclusal distance

	Visibility angle (degrees)	Inter-occlusal distance (mm)	Head width (mm)	Head length (mm)	Total weight (grams)
KaVo	23	23.1	9.5	16.1	172.00
Bien-Air	22	22.9	11.0	15.2	176.00
Midwest Quiet Air	21	23.8	10.5	16.5	69.68
Lares 557*	17	21.0	10.0	11.5	38.67
Lares 757*	25	21.0	12.8	13.8	42.73
Midwest Tradition*	20	22.3	10.5	12.8	54.81
KaVo640B*	25	22.8	12.4	15.1	83.90
KaVo 642B*	19	21.8	11.0	13.2	80.80
Star 430*	20	22.5	11.0	12.8	66.44

*-USAF DIS data

Discussion

It is evident from this data that the electric motor handpieces are significantly heavier than the air turbine handpieces. Visibility angles and interocclusal distances for the electric motor handpieces are greater than for the air turbines.

Conclusion

The size and weight of the electric motor handpiece are significantly greater than the size and weight of the air turbine handpieces. Results of a clinical survey, listed later in this report,

indicate that the increased size and weight are not clinically significant.

V. CLINICAL PARAMETERS

K. Price

Introduction

The actual cost of a handpiece or any piece of equipment is the life cycle cost. The life cycle cost can be calculated by determining the cost of the investment phase, the cost of operations and support, and the longevity of the equipment. The investment phase consists of procurement, fielding, and support equipment. Operations and support consists of personnel labor costs, training, lubricants, and spare parts.

The electric motor and air turbine handpiece have different capabilities and delivery systems. The electric motor handpieces can replace both the air turbine highspeed and slow speed handpieces. In addition, the electric motor can also be used to replace the laboratory handpiece. Because of these facts, the price of the electric motor and attachments should be compared to the combined price of the high speed and slow speed. Although a slow speed handpiece may not be used for every patient, the comparison is based on the assumption that a dentist will need high and slow speed capabilities for each operative patient.

Methods and Materials

The manufacturer's government price (August 1999) was obtained so that an estimate of life cycle costs could be established. The price

list should only be used as an estimate of initial costs. Handpiece prices and availability can change without notice.

This price comparison was based on a requirement to have four sets of handpieces. Four sets of handpieces permit the operative dentist to treat a large number of patients and yet have sufficient time for a handpiece to return from sterilization. Therefore the electric system includes the price of one motor, four high speed and four slow speed attachments. The air turbine system includes the price of four Midwest Quiet-Air high speed handpieces, one Midwest Quiet-Air Shorty low speed handpiece, and four Midwest Quiet-Air slow speed contra-angles with latch type head (Midwest Dental Products, Des Plaines, IL).

Air Turbine Costs =	4 highspeed handpieces	+ 1 slow speed motor	+ 4 contra-angle slow speed motors	
Electric Handpiece Costs =	1 electric motor	+ 4 speed increasing contra-angle attachments	+ 4 speed increasing contra-angle attachments	

Results

The cost of the individual handpieces, handpiece motors, and attachments for the two electric motor handpieces and the air turbine control are listed in table 15. Also calculated was the lowest possible price for an electric system utilizing the interchangeable components from both manufacturers. The cost of a “four handpiece set” was also calculated.

Table 15. Government price for individual dental handpiece components and of dental handpiece systems

	KaVo	Bien-Air	Electric hybrid	Midwest
Motor/handpiece	$600	$650	$600	$560
Speed increasing contra-angle	$649	$432	$432	-NA-
Slow speed motor	-NA-	-NA-	-NA-	$829
Speed increasing contra-angle	$606	$489	$489	$226
System cost	$5620	$4334	$4284	$3973
% price difference from air turbine system	+41.5%	+9.1%	+7.8%	-NA-

Discussion

At first glance, the electric motor handpiece system appears to significantly more expensive than the air turbine system. However this cost is not a life cycle cost. A more accurate estimate of the cost of a dental handpiece system would be the cost per patient procedure. This would be calculated by the life cycle cost divided by the number of patients treated during the life of the system.

Conclusion

Placing electric motor handpieces in military dental clinics for use in operative dentistry is not likely to result in a significant cost savings to the government.

However, the cost of utilizing an electric motor dental handpiece instead of an air turbine handpiece in a portable field unit, should significantly decrease costs to the government. Portable treatment units that utilize air turbine handpieces cost approximately the same as portable treatment units that utilize electric motor handpieces.

However there will be a significant cost savings in support equipment. The electric motor unit will operate on less than 1 kilowatt of power, eliminating the need for a five kilowatt trailer mounted generator. This will save 2700 pounds and one vehicle per forward dental treatment team (one dentist).

Further studies should be conducted to determine if the electric motor handpiece and attachments could be substituted for the surgical handpiece.

V. CLINICAL PARAMETERS

L. Clinician survey

Introduction

Laboratory testing is important. But it is also important that any new piece of dental equipment is accepted by the clinicians. Although electric motor dental handpieces have a large share of the European marketplace, there were no published reports on the acceptability of electric motor dental handpieces for operative dentistry in the U.S.

Methods and Materials

The USADRD provided electric motor handpieces and attachments to several military dental clinics. There are several systems that will convert a conventional air turbine operatory into an electric dental motor operatory. One of the following adapter systems were utilized for this study; KaVo Combident (KaVo of America. Lake Zurich, IL), KaVo ElectroMatic (KaVo of America. Lake Zurich, IL), ADEC Adapter (ADEC Inc. Newberg, OR) or Bell Converter (Bell Dental Products. Denver, CO) (See pictures #7-#10). All of these systems are fiberoptic capable. Both the ADEC and Bell systems utilize the Bien-Air electric motor handpiece.

The electric dental motor in the “adapter systems” is powered by 120 volt current. A high speed handpiece hose is connected to provide the cooling air and water. In the KaVo Combident, a separate electric motor rheostat

controls motor speed, water spray, motor speed control, and motor on/off. The ElectroMatic and Bell Converter utilize the operatory's air rheostat to control the motor on/off, with speed controls on the converter box mounted to the bracket table. The ADEC Adapter is a separate "mobile cart" with an independent rheostat for motor on/off and the speed control located on the cart.

The dentists were asked to treat healthy adult patients with at least two carious lesions of similar size and caries classification (I, II, III, IV, or V). At least one tooth was prepared using the electric motor handpiece and at least one other tooth was prepared with the air turbine currently used by the dentist. The dentist completed a survey form after every patient treated with the electric motor handpiece. The survey collected information about the dentist such as the number of teeth prepared with an electric handpiece, specialty training, years of practice, and gender. The dentists were asked to evaluate the handpiece, not the adapter system. They evaluated the electric handpiece and their air turbine handpiece based on twelve performance characteristics. These characteristics were graded on a seven point scale.

1. The size of the head of the handpiece related to the operator's visibility of the tooth.
2. The quality of the fiberoptic lighting.
3. The general feel (balance, length, weight) of the handpieces.
4. The amount of vibration produced by the handpiece during the procedure.
5. The ability of the practitioner to control the movement of the handpiece.
6. The quality of the coolant water spray (aim and control).
7. The level of noise produced by the handpiece.

8. The ease of changing burs in the handpiece.
9. The ease of changing handpiece attachments on the motor.
10. The cutting efficiency of the handpiece on tooth structure, amalgam, composite resin, acrylic and metal or porcelain fixed prosthetics.
11. The ability to control the handpiece to create a precise margin.
12. The overall operation of the handpiece.

After the procedure, patients were also questioned to determine if they could discern a difference between handpiece #1 and #2. If a difference was noted, the patient was asked which handpiece would be preferred if another procedure was required.

Results

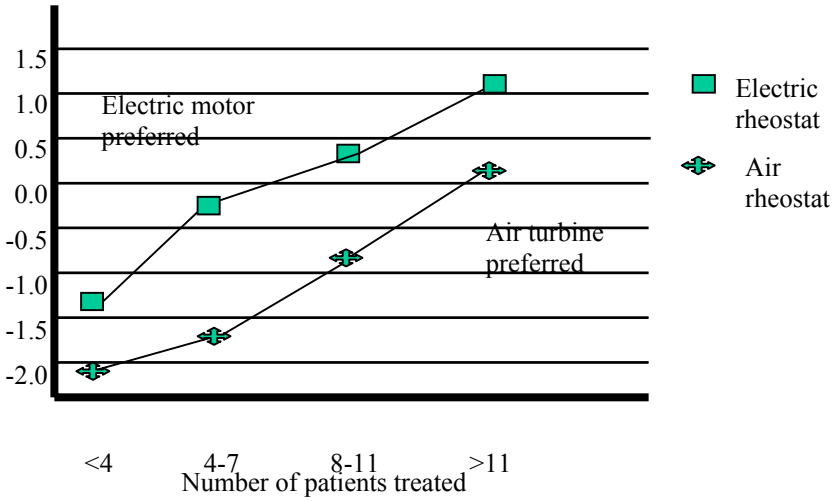
The dentists used the electric motor handpieces for operative procedures between 6 and 20 times. If at any time they felt uncomfortable using the electric motor they were encouraged to stop the comparison. Table 16 plots the experience of the dentist with electric handpieces against the rating the dentist gave the handpieces. The difference between the numerical ratings for the handpieces was determined. Zero is neutral or equal ratings, a positive number means the electric motor rated higher, and a negative number means the air turbine rated higher. Table 17 lists several of the performance parameters and demonstrates how the ratings of certain handpiece performance parameters changed with experience.

Table 16. Clinician Evaluation of handpiece performance characteristics based on experience using electric handpieces.

Number of clinical procedures with electric handpiece	< 4	4-7	8-11	>11
Ability to control	A	A	-	E
General feel	A	A	A	-
Fiberoptic quality	E	E	E	E
Noise level	E	E	E	E
Handpiece vibration	A	-	E	E
Visibility of tooth	A	A	A	A
Water spray	E	E	E	E
Overall preference	A	A	-	E

E- Electric handpiece preferred
A- Air turbine handpiece preferred

Table 17. Handpiece Preference versus Clinical Experience with the Electric Handpiece.



Discussion

A tabulation of the surveys indicated the following:

1. Practitioner acceptance of an electric handpiece increases with an increasing level of clinical experience with the handpiece.
2. Practitioner acceptance of electric handpiece is greater when delivery system uses an electric motor rheostat instead of an air turbine rheostat.
3. There were no significant differences among the electric motor handpieces.
4. After a learning curve of eleven patients, 82.1% of the dentists rated the electric handpiece as equal to or better than their air turbine handpiece.
5. After a learning curve of eleven patients, 64.3% of the dentists utilizing the electric motor and rheostat would purchase the system if the cost per patient procedure was approximately equal to the air turbine.
6. 48% of the patients preferred the electric handpieces, 18% preferred the air turbine handpieces, and 34% had no preference.

Conclusion

Based on these results it is anticipated that if a fiberoptic capable, internal air-water coolant spray electric motor dental handpiece were incorporated into a portable field dental treatment and operating system, that handpiece would be acceptable to military dentists.

VI. STUDY CONCLUSION

This evaluation was a necessary phase of the research and development of a new lightweight field dental equipment protocol. Before a new dental treatment system utilizing electric motor could be developed it had to be determined that the electric dental motor with fiberoptic capability and internal air-water coolant spray was a suitable replacement for the air turbine handpiece.

Based on this evaluation USADRD determined that the desired characteristics of an electric motor dental handpiece are:

1. Internal air-water coolant spray line.
2. Fiberoptic capability.
3. A tachometer to display rpm speed of motor. In addition the system should be capable of providing the speed with various gear ratio attachments.
4. An audible warning that will sound when motor is placed in reverse.

The electric motor performed as well as or better than the air turbine handpiece in at least ten of the twelve performance parameters.

To summarize the findings:

1. Longevity. The longevity of the electric motor dental handpiece is significantly better than the longevity of the air turbine handpiece.

2. Power/ cutting efficiency. Laboratory tests indicate that the electric motor dental handpiece has a higher cutting efficiency than the air turbine handpiece. This may not be clinically significant. It is possible that the dentists have learned to remove tooth structure at a certain "speed" and some dentists are not taking full advantage of the increased torque of the electric motor. Further studies may be needed to determine if dentists will take advantage of the increased torque as they become accustom to the electric motor handpiece.

3. Effect on pulpal thermal states. The electric motor handpiece with its increased cutting efficiency and ability to cut tooth structure at a greater applied force than the air turbine handpiece does not create an increased thermal hazard to the pulp than the air turbine handpiece.

4. Air exhaust. This data suggests that the electric motor maybe suitable for dental-alveolar surgical procedures. The handpiece has sufficient torque and the measured air exhaust is negligible. This data also suggests that the electric motor handpiece with a contra-angle attachment may be suitable for dental-alveolar surgical procedures if the air-water spray is turned-off and a separate irrigation syringe used. It may be possible to substitute this handpiece for a surgical Hall or Stryker drill in some instances.

5. Aerosol production. Final analysis of the data indicates that the electric motor handpiece does not generate more aerosol contamination than the air turbine. One test indicates that the aerosol production from the electric motor handpiece is

significantly less than the production from the air turbine handpiece.

6. Noise production. The electric motor dental handpiece is significantly quieter than the air turbine handpiece. The reduced noise of the electric motor handpiece may minimize the NIHL risk in a clinical setting. In a field setting, a field treatment and operating system that combines a quieter handpiece and HVE with a reduced need for portable generator power will create a quieter work environment for the forward deployed treatment teams.

7. Speed in revolutions per minute. The electric motor handpieces did not demonstrate a significant loss in speed after 1000 simulated clinical uses and sterilizations. A significant decrease in the bur speed of the air turbine handpiece was noted, although a similar USAF DIS study did not detect significant decrease in the bur speed for this air turbine handpiece.

8. Fiberoptic transmission. The ability of the fiberoptic rod in the electric motor handpieces to transmit light after 1000 clinical uses is significantly better than the ability of the tested air turbine handpiece. However, this is not a result of the handpiece type but a result of the type of fiberoptic rod in the handpiece. It must be noted that there are air turbine handpieces currently available that utilize the same type of rod found in these electric motor handpieces.

9. Dependability of chuck mechanisms. None of the handpieces experienced a chuck mechanism failure. There is no statistical difference in bur length among the three tested handpieces.

10. Static parameters (size and weight). The size and weight of the electric motor handpiece are significantly greater than the size and weight of the air turbine handpieces. Results of a clinical survey, listed later in this report, indicate that the increased size and weight are not clinically significant.

11. Price. Placing electric motor handpieces in military dental clinics for use in operative dentistry is not likely to result in a significant cost savings to the government. However, the cost of utilizing an electric motor dental handpiece instead of an air turbine handpiece in a portable field unit, should significantly decrease costs to the government.

12. Clinician acceptance. Based on these results it is anticipated that if a fiberoptic capable, internal air-water coolant spray electric motor dental handpiece were incorporated into a portable field dental treatment and operating system, that handpiece would be acceptable to military dentists.

13. Neurologic effects. As a group, dentists have a higher rate of neurological symptoms in their hands than the average population. Recent studies indicate that these symptoms are not caused by traditional vibrating handpieces, but by repetitive hand grip, abducted shoulders, flexed spine, and rotational body movements.[lviii] Therefore use of the electric motor instead of an air turbine motor

is not expected to cause additional long term neurologic problems for the military dentist.

VII. APPLICATIONS OF STUDY TO FIELD DENTISTRY

This study indicates that electric motor dental handpieces utilized in dental field treatment systems offer several advantages.

1. There is significant reduction in the need for compressed air. Compressed air needed for the electric motor coolant spray could be supplied with an external compressed air source (manual pump, electric pump, and compressed air cylinder).

2. There is less noise produced by the electric motor handpiece and the principle source of noise in the DTF, the dental compressor, is eliminated.

3. The electric motor handpiece can be used in dental-alveolar surgical procedures. This will eliminate the need to have a separate surgical handpiece with treatment team.

4. A separate slow speed handpiece is not required for the treatment system.

5. There is a significant reduction in the need for generated power, which means significantly less cube and weight requirements for each dentist. The acquisition of an electric motor handpiece portable field dental treatment system will allow the Forward Dental Treatment Teams (FDTT) to reduce their weight by 2700 pounds. This is calculated on the weight of the five kilowatt generator and trailer. The FDTT could be powered by a two kilowatt diesel

generator that is presently in the military procurement system or by rechargeable batteries.

6. According to the Directorate of Combat Developments, the Forward Dental Treatment Sections (FDTS) will lose 50% of their transportation assets (3 of the 6 M998 vehicles and 3 of the 6 generators and trailers). This will reduce the mobility of the FDTS from 100% to 50%.[lix] The acquisition of an electric motor handpiece portable field dental treatment system in combination with the handheld x-ray, digital radiography laptop computer, lightweight dental chair, lightweight operatory light may enable the FDTS to be 100% mobile with 50% of its present transportation assets.

7. The principle disadvantage of most electric motor field dental treatment and operating systems is that the compressed air capabilities will not directly support a sonic scaler. This may be a minor inconvenience and scaling can be performed with hand instruments. However most of the patient population will be dental readiness class I and II and should not have heavy calculus deposits on their teeth. It will be possible to support a sonic scaler with an electric motor system, but the electrical requirements of the treatment system will increase.

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