Dynamic Ultraviolet Sterilization of Different Implant Types

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This paper investigates the use of the dynamic ultraviolet sterilization process with various dental implants, stainless steel orthopedic cortical bone screws, and polysulfone polymer healing caps. These biomaterials were inoculated with the spores of *Bacillus subtilis* and *Bacillus stearothermophilus*. They were then exposed to dynamic ultraviolet radiation in the chamber of a BUD Ultraviolet Device. Samples were incubated in trypticase soy broth at 37°C and 56°C, and they were subcultured onto an enriched agar medium. Results indicate that 16 seconds of dynamic ultraviolet radiation is effective in sterilizing these materials. This is significantly less time than other sterilization techniques presently used.
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Key words: cortical bone screws, dental implants, polysulfone polymers, sterilization, ultraviolet light

The need for strength, biocompatibility, and minimal bulk has led to a range of commercially available implants that vary considerably in composition and surface characteristics.[1-6] Most commonly used are those made from commercially pure titanium (Ti) or titanium alloy (Ti-6Al-4V). For orthopedic use, 316 L stainless steel (iron-chromium-nickel) is commonly employed. Implants are also made from aluminum oxide in the polycrystalline (alumina) and the single-crystalline (sapphire) form. The hydroxyapatite ceramic is used as a surface coating because of good compositional properties, despite its inapplicability in bulk form. Polymers such as polysulfone are presently used for healing caps for some dental implants. Polysulfone polymer has been used as a surface coating because of its relatively low mechanical strength.

Because of the surgical nature of implant placement, sterilization is of the utmost importance.[7-15] Techniques that not only destroy all microorganisms, but leave a scrupulously clean implant surface with high surface energy are the methods of choice. Contamination of implants during sterilization by conventional methods, such as steam autoclaving, ethylene oxide gas sterilization, or endodontic glass bead sterilization, has been reported.[7-15] It has been speculated that the most common source of contamination of implants is from sterilization procedures.[9] Recently, a new sterilization method, "dynamic ultraviolet sterilization," has been proposed.[11]

Ultraviolet light is part of the electromagnetic spectrum and ranges from 400 nm downward to approximately 150 nm. Although undoubtedly possessing bactericidal and fungicidal properties, the sterilization capabilities of "traditional" ultraviolet radiation are limited[11,16-24] because the energy of the radiation produced is very low, with a resulting low power of penetration. Penetration into solids is virtually zero and into liquids is only slight, depending on their opacities.[21] Thus, only direct ultraviolet rays are effective, and if organisms are "shielded" or otherwise "screened" from the incidence beam, no action against the organism will occur.

The greatest germicidal effect is in the range of 240 to 280 nm, with the optimum being 253.7 nm.[16,21] This is probably not a universal optimum but varies with different types of organisms. Other values such as 254.0, 265.2, and 280.4 have been quoted,[17,18,20] but

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most work has been done using 253.7 nm because it is at this energy level that most of the emission from the most commonly available mercury vapor lamps occurs. This is well within the germicidal range.

Ultraviolet radiation may have various effects on microorganisms. However, most investigators believe that the rays are absorbed by the cellular DNA, inducing cell mutation or death based on chemical changes that affect the genetic mechanisms (Figs 1 and 2).

The newly introduced dynamic ultraviolet sterilization technique has been said to have the capacity to penetrate organic material and to possess the potential to irradiate all surfaces of irregularly shaped objects.[11] Thus, screened zones are eliminated and areas that traditional ultraviolet radiation would not reach are sterilized. This technique uses a modified germicidal lamp, which is capable of causing surface excitation of the molecular particles as well as microcombustion of any unstable surface debris. However, use of the technique has only been documented on commercially pure titanium. Testing on other types of implants is needed.

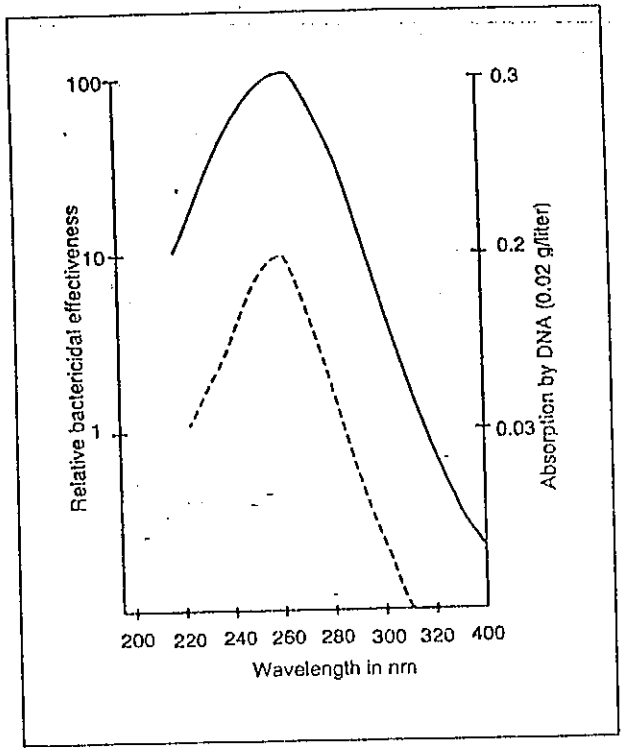

Fig 1 The solid line curve shows the bactericidal effectiveness of various UV wavelengths in killing bacteria. The broken line curve represents absorption by DNA. Note that both curves peak at 260 nm, indicating that death by UV is the result of absorption by DNA.

Sterilization is defined as a process that kills or removes all microorganisms, including resistant bacterial spores.[25,26] Since sterilization is performed to kill microorganisms, biologic indicators are recommended to verify that sterilization has occurred.[27-31] They are usually composed of bacterial spores because of their known higher resistance to various sterilizing processes. To test steam and chemical sterilization, the spores of *Bacillus stearothermophilus* have been used, while the testing of ethylene oxide and dry heat has been done with spores of *Bacillus subtilis* (Table 1). When testing for sterility, the carrier of the biologic indicator should be as similar as possible in shape and composition to the item being sterilized. The best test sample is the product itself.

The purpose of this study was to investigate, using biologic indicators, the efficacy of the dynamic ultraviolet sterilization process on five different types of endosseous dental implants, orthopedic cortical bone screws, and polysulfone polymer healing caps.

Materials and Methods

Five groups of commercially available dental implants, one group of commercially available orthopedic cortical bone screws, and one group of polysulfone polymer healing caps were used in this study (Fig 3, Table 2). Each group consisted of 40 implants, except groups F and G, in which only ten and five specimens, respectively, were available. The individual groups were di-

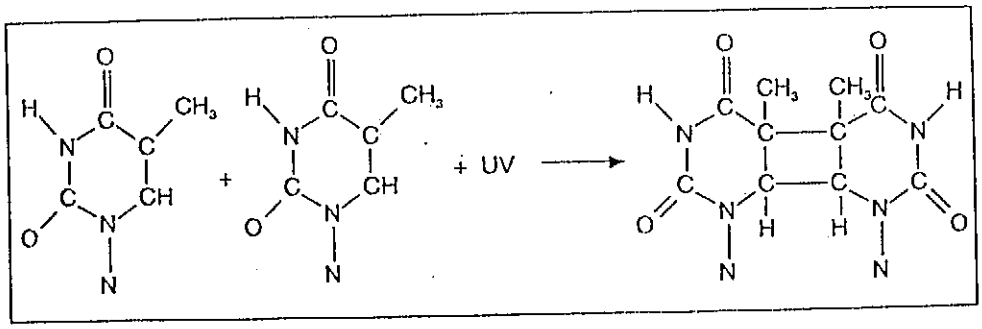

Fig 2 Formation of a thymine dimer by ultraviolet light.

vided into three subgroups, and the study was designed so that the first subgroup (the test subgroup) consisted of 30 implants whenever possible. The other two subgroups of five implants each served as positive and negative controls. Groups F and G did not have controls. A procedure flow chart is shown in Fig 4.

All implants were sterile before testing. The metal implants and all polysulfone polymer samples (groups A, B, C, and E) were sterilized using a commercially standard protocol. The samples were cleaned in the ultrasonic cleaner for 20 minutes with a residue-free detergent and packaged for the autoclave. A cycle of 20 minutes of moist heat at 120°C and 15 psi was used to achieve sterilization. Although the hydroxyapatite-coated dental implants (group D) were individually packaged and sterilized by gamma radiation, they were autoclaved as recommended by the manufacturer (20 minutes at 120°C and 15 psi) to ensure sterility prior to this research. The aluminous dental implants (groups F and G) were sterilized by the manufacturer.

Bacillus subtilis and *Bacillus stearothermophilus* indicator spores were used to verify that sterility had occurred. These gram-positive aerobic rod bacteria spores were grown from a commercially available biologic indicator test strip (Sterilator Co, Cuba, New York). Each strip was placed in 5 ml of trypticase soy broth (TSB) and incubated for 2 weeks at either 37°C (*Bacillus subtilis*) or 56°C (*Bacillus stearothermophilus*) to allow the spore-forming stage of 10^6 concentration to be reached. For each of the two *Bacillus* species, the contents of the two 5-ml test tubes were combined in a sterile petri dish and used as the inoculum reservoir. Small sable brushes (Arttec Series, 165 Red Sable Hair, Arttec, Allendale, New Jersey) were used to inoculate the implants.

All samples in the test subgroups and the positive control subgroups were inoculated with both spore types. Each of the test subgroups was divided so that

Table 1 Biologic Indicators with Recommended Sterilization Methods and Incubation Temperatures

Indicator spore	Sterilization method	Incubation temperature
Bacillus Stearothermophilus	Autoclave Chemical vapor	56°C
Bacillus Subtilis	Dry heat Ethylene oxide	37°C

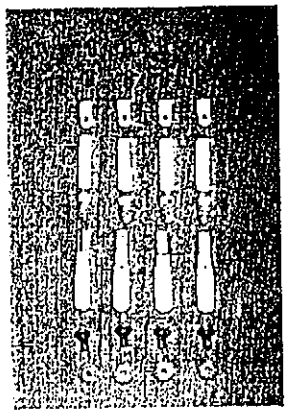

Fig 3 Examples of implants used in this study. From row 1 to 5 are the commercially pure titanium, titanium alloy, hydroxyapatite-coated, single-crystal sapphire, and polycrystalline alumina dental implants, respectively. In row 6 are the stainless steel cortical bone screws and in row 7 are the polysulfone polymer healing caps.

Table 2 Implants Tested

Group	Implant type	Manufacturer	Test subgroup	Positive controls	Negative controls
A	Commercially pure titanium	BUD Industries Holland, NY	A1-A30	A31-A35	A36-A40
B	Titanium alloy (Ti-6Al-4V)	BUD Industries Holland, NY	B1-B30	B31-B35	B36-B40
C	Cortical bone screws (stainless steel)	Synthes Paoli, Pa	C1-C30	C31-C35	C36-C40
D	Hydroxyapatite-coated	Calcitek Carlsbad, Calif	D1-D30	D31-D35	D36-D40
E	Polysulfone polymer healing caps	AL Hyde Co Greenloch, NJ	E1-E30	E31-E35	E36-E40
F	Single-crystal sapphire (Al_2O_3)	Kyocera Int'l San Diego, Calif	F1-F10		
G	Polycrystalline alumina (Al_2O_3)	Kyocera Int'l San Diego, Calif	G1-G5		

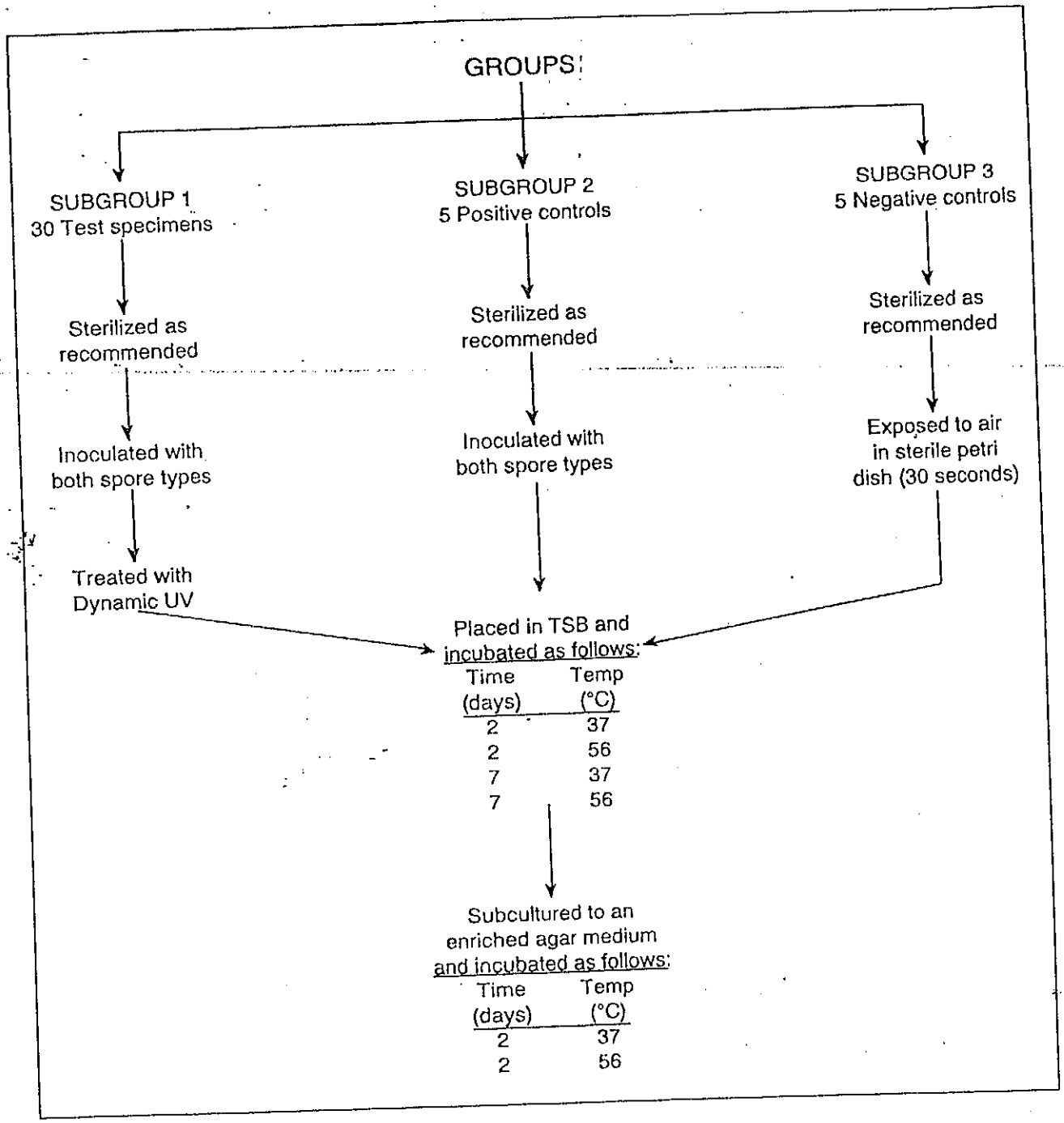

Fig 4 Flowchart of procedure.

half were inoculated with the *Bacillus subtilis* spores first and the other half with the *Bacillus stearothermophilus*. In the subgroups with five members (the positive control subgroups and test subgroup G), three were inoculated with the *Bacillus subtilis* first. Groups A, B, C, F, and G were inoculated at the superior threaded areas (Fig 5). The polysulfone polymers samples, shaped as healing caps, were inoculated on the inner surface and the hydroxyapatite-coated dental implants were inoculated in their inferior fluted areas.

Controls. The positive control subgroups, consisting of five implants each (25 total), were inoculated with both spore types. The negative control subgroups, also consisting of five implants each (25 total), were placed in a sterile petri dish and exposed to room conditions for approximately 30 seconds. Neither of these two subgroups was subjected to dynamic ultraviolet treatment, but each of the samples was placed in individual

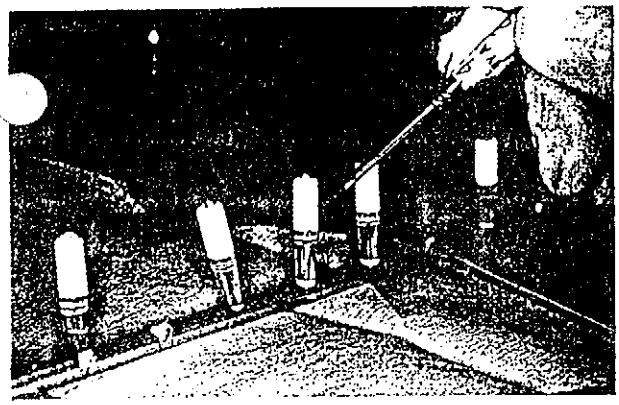

Fig 5 Inoculation of the polycrystalline alumina dental implants with the indicator spores.

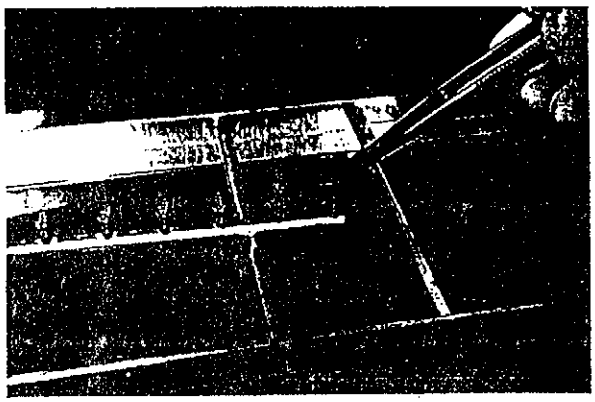

Fig 6 Sterile cotton pliers were used to handle specimens.

Fig 7 Each specimen was placed in a test tube containing 5 ml of trypticase soy broth.

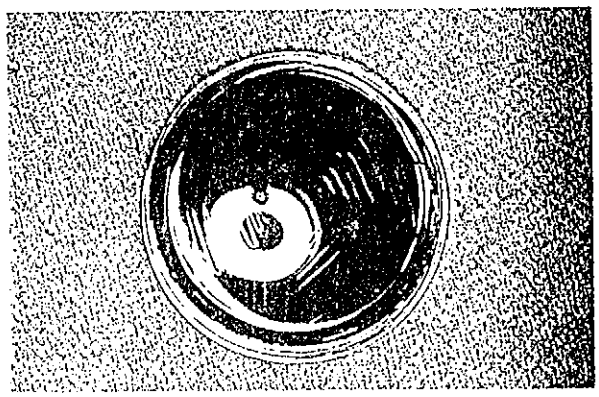

Fig 8 Trypticase soy broth of each specimen was subcultured onto an enriched agar medium. Note that the agar plate is divided into four sections and that the trypticase soy broth of four specimens has been subcultured.

test tubes containing 5 ml of TSB using sterile forceps (Figs 6 and 7).

All samples were incubated for 2 days at 37°C and then for another 2 days at 56°C. Turbidity was checked after each period and results recorded. All test tubes were incubated again at 37°C for 1 week and then at 56°C for an additional week, as recommended by the manufacturer of the test strips. Again, turbidity was checked after each period and recorded. Finally, the TSB in each of the test tubes was subcultured, using a sterile loop, onto a trypticase agar medium enriched with 5% sheep's blood (Fig 8). The agar was incubated for 2 days at 37°C and for another 2 days at 56°C.

Test Subgroups. The specimens were inoculated with both spore types and placed into the chamber of a BUD Ultraviolet Device on a sterile stainless steel tray. The sterilization chamber was 20.3 cm deep × 10.2 cm wide × 5.7 cm high. The dynamic ultraviolet treatment consisted of a 16-second exposure in the chamber. This entails 3 seconds for opening of the shutter, 10 seconds of dynamic ultraviolet exposure, and 3 seconds for closing of the shutter. The BUD ultraviolet lamps of proprietary design and wavelength were located 8.0 cm from the specimens. The two lamps had a lighted length of 8 inches each. Using sterile cotton pliers, each of the treated samples was placed into individual test tubes containing 5 ml of TSB, incubated, and subcultured as the controls. Sterility was maintained throughout the study.

Results

The results of this study are listed in Tables 3 and 4.

Controls. All but one of the positive controls demonstrated growth in TSB. This sample was an HA-coated dental implant (specimen D-35). Results of subculturing onto enriched agar medium were identical, including specimen D-35. These specimens were not treated with dynamic ultraviolet radiation.

Negative control groups failed to demonstrate growth

Table 3 Results of Specimens in Trypticase Soy Broth

Subgroup	Implant number	2 days/37°C							2 days/56°C							7 days/37°C							7 days/56°C						
		A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
Test subgroup	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	
	7	0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	
	8	0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	
	9	0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	
	10	0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0	
	11	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	12	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	13	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	14	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	15	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	16	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	17	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	18	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	19	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	20	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	21	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	22	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	23	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	24	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	25	0	0	+	0	0			0	0	+	0	0			0	0	+	0	0			0	0	+	0	0		
	26	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	27	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	28	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	29	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	30	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
Positive controls	31	+	+	+	+	+			+	+	+	+	+			+	+	+	+	+			+	+	+	+	+		
	32	+	+	+	+	+			+	+	+	+	+			+	+	+	+	+			+	+	+	+	+		
	33	+	+	+	+	+			+	+	+	+	+			+	+	+	+	+			+	+	+	+	+		
	34	+	+	+	+	+			+	+	+	+	+			+	+	+	+	+			+	+	+	+	+		
	35	+	+	+	0	+			+	+	+	0	+			+	+	+	0	+			+	+	+	0	+		
Negative controls	36	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0	0		0	0	0	0	0		
	37	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	38	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	39	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		
	40	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0		

in TSB or enriched agar plates at 37°C or 56°C. These specimens were not inoculated or treated with dynamic ultraviolet radiation.

Test Groups. The spore-contaminated specimens treated in the chamber of the BUD Ultraviolet Device showed no growth at 37°C or 56°C, with one exception. This was a stainless steel cortical bone screw (specimen C-25) and growth was evident at the end of the first period of incubation (48 hours at 37°C). Visual comparison of this specimen with the positive controls revealed differences in density, color, and sediment concentration. A gram-positive stain identified the microorganisms as gram-positive cocci. It is assumed that this environmental contaminant was introduced before placing the implant into broth but after treatment with UV radiation. The results of subculturing onto enriched agar plates were identical to the above, except for specimen C-25, which was negative. The gram-positive cocci were probably killed when incubated at 55°C in TSB. This would explain why the broth produced growth initially, but when subcultured onto enriched agar medium no growth occurred.

Because of the available number of specimens (30 in groups A through E), statistically this technique has at least a 90% success rate. To demonstrate a 99% success rate, 300 implants of each type would have been required for testing. As far as groups F and G are concerned, the results of this study can only be considered

Table 4 Overall Results

Implant	Total number	Test subgroup	Positive controls	Negative controls
Commercially pure titanium	40	0/30	5/5	0/5
Titanium alloy	40	0/30	5/5	0/5
Cortical bone screws	40	1*/30	5/5	0/5
Hydroxyapatite-coated	40	0/30	4/5	0/5
Polysulfone polymer	40	0/30	5/5	0/5
Single-crystal sapphire	10	0/10		
Polycrystalline alumina	5	0/5		
Total	215	1*/165	24/25	0/25

Numerator shows how many specimens tested positive and denominator shows the number of specimens tested.
**Identified as a contaminant.*

as preliminary data since the number of samples tested was insufficient.

Clinically detectable surface changes were not observed in any of the samples, except the polysulfone polymers. In this group, six samples became opaque after exposure. Expansion changes were also suspected and later confirmed by circumferential measurements with a micrometer.

Discussion

Traditional ultraviolet radiation, although having germicidal properties, has not been used in the past for sterilization because of its low penetration capacity and the need for the ultraviolet radiation to contact the microorganism directly. A new technique, dynamic ultraviolet sterilization, has been said to be able to cause surface activation and penetration and has been shown to sterilize titanium implants inoculated with *Bacillus stearothermophilus*. This technique has also been shown to leave "a scrupulously clean and high surface energy character on titanium implants."[10]

Dynamic ultraviolet sterilization is evaluated in this study as a sterilization method for use with dental implants, stainless steel orthopedic cortical bone screws, and polysulfone polymer healing caps. Results indicate that 16 seconds of exposure to dynamic ultraviolet radiation in the chamber of a BUD Ultraviolet Device is sufficient to sterilize these materials effectively. This is significantly less time than required by other sterilization techniques presently used.

It is tempting to speculate why sample D-35 did not show growth. The most likely reason is failure to inoculate the implant with the *Bacillus* spores. Another reason may be that the broth medium in the test tube was inadequate for growth of the spores. This is highly unlikely, since all broth came from the same lot and subculturing onto an enriched agar medium did not change the results. In addition, all positive controls were handled identically. Finally, the quality and quantity of the inoculum used may not have been adequate. This is also unlikely, however, since all other positive controls showed growth within 24 hours after inoculation.

Since an increase in temperature occurs during the dynamic ultraviolet sterilization technique, synergistic effects of temperature and ultraviolet radiation must be considered. If such a process does occur (that is, thermoradiation), four variables need to be analyzed: temperature, wavelength, energy, and time. The synergistic effect of these variables is present in other types of radiation techniques, such as ionizing radiation. Other factors, such as environmental changes that may occur within the chamber during function, may be involved when discussing dynamic ultraviolet radiation.[12]

The reason for the changes in the polysulfone polymer is not attributed to the ultraviolet radiation, since only samples in the posterior area of the trays experienced changes. A more likely reason is that there was a restriction of airflow in the posterior area, creating a hot spot even though the temperature probe in the BUD Ultraviolet Device, located in the center of the cham-

ber, registered an average temperature of 125°C. For changes to have occurred in the polysulfone, temperatures of at least 148°C would have had to be reached, since this is the polymer's critical temperature.[33] Temperatures of this magnitude are not suspected to have occurred in any other area of the chamber. The manufacturer of the BUD Ultraviolet Device has made revisions in its design to avoid such hot spots.[32]

Health care workers who sterilize large volumes of instruments face different criteria from the clinician who uses sterile materials that are to be implanted. The difference is not because of the numbers of items or overall results, since regardless of the methods used, sterility of all items must occur. However, sterilization techniques for materials must not cause surface changes or damage and must render them scrupulously clean with a high surface energy. Theoretically, this would favor rapid wetting of the implant by tissue fluids as well as the spontaneous deposition of biomacromolecules. This is a highly desirable advantage regardless of whether the clinician is using one- or two-stage dental implants or those that do not share two environments (such as orthopedic cortical bone screws).

Criteria for the sterilization of materials would include the following:

1. All microorganisms destroyed consistently, including microbial pathogens.
2. A wide variety of materials able to be sterilized.
3. Material surfaces left scrupulously clean.
4. A high surface energy imparted on the materials.
5. Materials left undamaged or unchanged.
6. Minimal amount of time required for sterilization.
7. Convenient to use (so that the sterilizer can be used in the office or operating room).
8. Cost reasonable without compromising safety.
9. Minimal personnel training for operating the equipment.
10. Virtually maintenance-free.

According to Albrektsson et al,[2] implant failure caused by sterilization methods may occur years after implants are put in function. Thus, with proper attention to surface preparation, an overall increase in success rate may be possible. Correct preparation of the implant surface may also decrease the amount of time a clinician must wait before loading an implant. Recently, Hartman et al[35] showed that titanium implants treated with radiofrequency glow discharge or dynamic ultraviolet radiation are associated with more rapid maturation of new bone compared to those treated with conventional steam sterilization. Thus, it may be concluded that *(1)* the more common sterilization techniques employed for implants may not be optimal and *(2)* with proper surface preparation, bioassimilation may occur faster and more predictably.

In this study, dynamic ultraviolet light sterilization has been shown to prevent the growth of indicator spores on different implant types. This technique requires less than 20 seconds, and in the future it may be a useful adjunct when rapid chairside or operating room sterilization of materials is desired. Further research is needed to determine the effects of this procedure on the surface of the implants tested in this study.

Conclusions

The use of the dynamic ultraviolet sterilization technique was investigated as a sterilization method for use with various dental implants, stainless steel orthopedic cortical bone screws, and polysulfone polymer healing caps. The following conclusions can be drawn:

1. Dynamic ultraviolet radiation can effectively destroy biologic indicator spores on a wide variety of implant types.
2. Dynamic ultraviolet radiation can effectively destroy biologic indicator spores on a wide variety of implant materials.
3. The dynamic ultraviolet sterilization technique is a rapid and convenient method of sterilization.

With improved sterilization techniques and surface characterization of implants, better clinical results as well as a shorter bioassimilation period are possible. □

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Résumé
Stérilisation dynamique par ultra-violets de différents types d'implants

Cet article examine l'usage du procédé de stérilisation dynamique par ultra-violets avec différents types d'implants dentaires, des vis orthopédiques en acier inoxydable implantées dans l'os cortical et des têtes de cicatrisation en polymère de polysulfone. Ces biomatériaux furent inoculés avec des spores de *Bacillus subtilus* et *Bacillus stearothermophilus*. Ils furent alors exposés à des rayons dynamiques ultra-violets dans la chambre d'un appareil BUD à ultra-violets. Les échantillons furent incubés dans un bouillon de culture de soja tryptique à 37 °C et 56 °C, puis furent cultivés dans un milieu de gélose enrichie. Les résultats indiquent qu'un traitement de 16 seconds par rayons dynamiques ultra-violets est efficace pour stériliser ces matériaux. Cette durée est nettement inférieure à la durée nécessaire pour les autres techniques de stérilisation actuellement utilisées.

Zusammenfassung
Dynamische Sterilisation von verschiedenen Implantattypen durch UV-Strahlung

Dieser Artikel untersucht den Gebrauch von dem dynamischen UV-Sterilisationsprozeß mit verschiedenen dentalen Implantaten, orthopädischen kortikalen Knochenschrauben aus rostfreiem Edelstahl und Polysulfonepolymer-Einheilkappen. Diese Biomaterialien wurden mit den Sporen von *Bacillus subtilis* und *Bacillus stearothermophilus* inokuliert. Sie wurden dann dynamischer UV-Strahlung in der Kammer eines BUD-Ultraviolettapparates ausgesetzt. Proben wurden in Trypticase-Soya-Medium bei 37 °C und 56 °C inkubiert, und sie wurden auf einem angereicherten Agar-Nährboden fortgezüchtet. Resultate lassen darauf schließen, daß 16 Sekunden von dynamischer UV-Strahlung diese Materialien wirksam sterilisieren können. Dies ist signifikant weniger Zeit als andere Sterilisationsverfahren, die zur Zeit verwendet werden.

Resumen
Esterilización dinámica con ultravioleta de diferentes tipos de implantes

Este artículo investiga el uso de la esterilización dinámica con ultravioleta para varios implantes dentales, tornillos ortopédicos de acero inoxidable para hueso cortical, y capuchones cicatriciales de polímero de polisulfona. Estos biomateriales fueron inoculados con las esporas de *Bacilus subtilis* y *Bacilus stearothermophilus*. Luego fueron expuestos a radiación dinámica con ultravioleta en la cámara con un dispositivo BUD ultravioleta. Las muestras fueron incubadas en un caldo de soya de tripticasa a 37 °C y 56 °C, y subcultivadas en un medio de agar enriquecido. Los resultados indican que 16 segundos de radiación dinámica con ultravioleta son efectivos para esterilizar estos materiales. Este tiempo es significativamente menor que el utilizado con otras técnicas de esterilización en uso actualmente.