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Bacterial colonization of rigid gas permeable and hydrogel contact lenses by *Staphylococcus aureus*

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Staphylococcus aureus **ATCC 6538 and a clinical isolate of *S. aureus* from a bacterial keratitis patient were examined for their ability to adhere to etafilcon A, polymacon, silafocon, and pauflufocon A, B and C contact lenses. Both isolates adhered more to the rigid gas permeable (RGP) materials than to the hydrogel lenses tested ($P < 0.05$). *S. aureus* ATCC 6538 adhered to the etafilcon A material to a greater extent than did the clinical isolate ($P < 0.05$). There were no statistically significant differences in the recovery of staphylococci from unworn lens materials when surface area, composition and ionicity were evaluated for either the hydrogel or RGP lenses tested against lenses of a similar type. However, differences were observed when hydrogel lenses were evaluated against RGP lenses ($P < 0.05$). These differences may be related to water content.** *Journal of Industrial Microbiology & Biotechnology* (2000) **24,** 113–115.

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Introduction

Bacterial adhesion to medical devices is a source of concern in the medical device community because of the serious post-operative complications that may occur [6]. In industrial settings biofouling of drains and other fluid-carrying pipes costs millions of dollars annually [7,8]. Contact lens wear, which has become increasingly popular, is not immune to the effects of biofouling by human proteins and various types of bacteria [1,3–5]. Bacteria are thought to attach to a matrix such as a contact lens by interaction of the outer lipoprotein layer with the lens. This attachment is important because the lens may act as a reservoir or substrate for the bacteria. The ability of the bacteria to attach to the lens may depend on the type of lens material, immediate environmental conditions or the bacterium itself. Should an epithelial break occur on the eye, the bacteria could colonize this break, perhaps inducing a medical emergency.

Hydrogel and rigid gas permeable (RGP) lenses differ in several ways. Hydrogel lenses are soft and pliable with varying amounts of water as part of their composition. RGP lenses have a water content of zero, are more rigid and generally smaller than hydrogel lenses. As a result, the limbal area of the eye is not covered with RGP wear as it is with hydrogel lens wear.

The most common physiological abnormality associated with contact lens wearers is the occurrence of corneal infiltrates. In comparison to RGP lenses, the risk of infiltrates is 1.6–2.3 times higher with daily-wear soft lenses and 2.3–4.6 times higher with extended-wear soft lenses [2,12].

Because *S. aureus* is the most common ocular pathogen, we have evaluated the ability of different strains to adhere to several RGP and hydrogel lenses. The selected lenses have significant differences with respect to lens size, polymer composition, oxygen transmissibility, base curve and water content. Using the modified vortex device (MVD) [11] protocol to evaluate adhesion, we were able to demonstrate differences in the amount of bacterial adhesion between hydrogel contact lenses and RGP lenses in their affinity for staphylococci.

Materials and methods

Preparation of test microorganisms

S. aureus ATCC 6538 and an *S. aureus* clinical isolate obtained from a patient diagnosed with bacterial keratitis, were grown on soybean casein digest medium (TSB) (Difco, Detroit, MI, USA) and incubated at 37°C for 18 h resulting in cell densities of 5.0×10^8–1.0×10^9 cells per milliliter (CFU ml^{-1}). One milliliter of this culture was diluted in physiological saline for a final concentration of 1.8–2.4×10^4 CFU ml^{-1}.

Contact lenses

The hydrogel contact lenses were etafilcon A, base curves (B.C.) 8.4 and 8.8, (Vistakon, Jacksonville, FL, USA) and polymacon contact lenses, B.C. 8.7 (Bausch and Lomb, Rochester, NY, USA). These lens types have water contents of 58% and 38%, respectively. The oxygen transmissibility measurements for the unworn hydrogel lenses were 27 for etafilcon A and 10 for polymacon.

The RGP lenses used were silafocon A (Pilkington Barnes Hind, Sunnyvale, CA, USA) and pauflufocon A (B.C. 9.0); B (B.C. 6.5); and C (B.C. 9.0) (Paragon Vision Sciences, Mesa, AZ, USA). The oxygen transmissibility for the unworn pauflufocon A, B and C materials are 30, 60 and 92, respectively. The water content of RGP contact lenses is zero. Distinguishing between the RGP lenses used in this study, silafocon is a silicone acrylate-based matrix, while pauflufocon contains fluorine as a part of the compo-

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sition that also includes silicone acrylate. All contact lenses used in this study were unworn.

The contact lenses were transferred aseptically into 50 ml conical centrifuge tubes (one lens per tube) and washed three times in 10 ml of sterile PBS for 20 min per wash. This step removed the packing solution. Three lenses of each type were examined in each test.

Bacterial adhesion evaluations using the Modified Vortex Device

The Modified Vortex Device (MVD) was used in the evaluation of the contact lens materials [11]. Briefly, the washed contact lenses were placed in one milliliter of bacterial suspension at a concentration of about 2.0×10^4 CFU ml^{-1}. The lenses were allowed to incubate with the bacteria with gentle agitation for 5 h. Following this incubation period, the lenses were rinsed to remove bacteria in the fluid phase and vortexed for 3 min at about $564 \times g$. The supernatant fluid was then plated using soybean casein digest agar (TSA; Difco). Due to size discrepancies between the lens types, the recovery (CFU ml^{-1}) for each lens type was converted to standardized units (CFU mm^{-2}).

Statistical analysis

An analysis of variance test (ANOVA) was applied to evaluate the statistical significance of the results at the 95% confidence level ($P \leqslant 0.05$).

Results

Effect of lens composition on bacterial adhesion

The adhesion of *S. aureus* ATCC 6538 and the *S. aureus* clinical isolate to etafilcon A, polymacon, and silafocon A contact lenses is shown in Figure 1. Bacterial adhesion was greater for the RGP lens compared to the hydrogel lens types ($P < 0.05$). There were no statistically significant differences in bacterial adhesion to the etafilcon A and polymacon lenses. *S. aureus* ATCC 6538 adhered to a greater extent to etafilcon A ($P < 0.05$), silafocon A ($P > 0.05$), and polymacon ($P > 0.05$) lenses than did *S. aureus* from a keratitis patient.

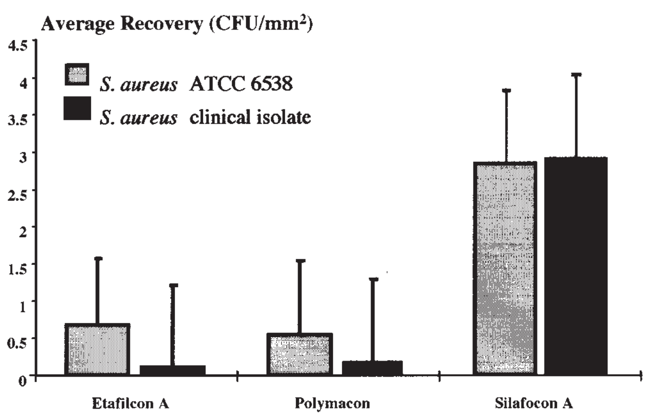

Figure 1 Adhesion of *S. aureus* ATCC 6538 and *S. aureus* (clinical isolate) to etafilcon A, polymacon and silafocon A.

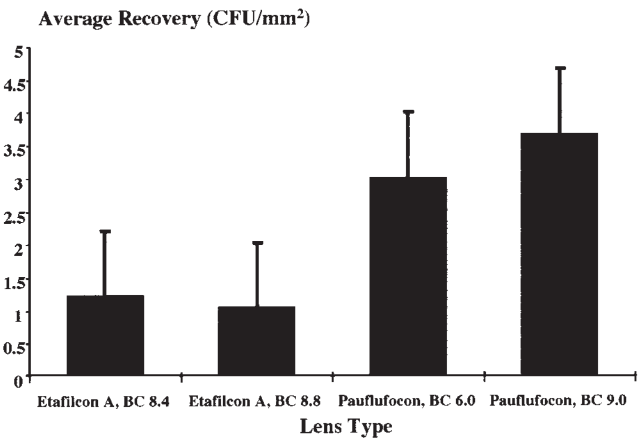

Figure 2 The effect of base curve on the adhesion of *S. aureus* to etafilcon A and pauflufocon. Inoculum = 1.5×10^4 CFU ml^{-1}; $n = 3$.

Effect of base curve on bacterial adhesion

The results of experiments comparing the effect of base curve on adhesion of *S. aureus* ATCC 6538 to etafilcon A and pauflufocon B lens materials are shown in Figure 2. Bacterial recovery was significantly higher statistically from the pauflufocon B materials than from etafilcon A ($P < 0.05$). In contrast, there were no statistically significant differences in bacterial recovery observed when base curves were compared for the given RGP or hydrogel lens materials ($P > 0.05$).

Effect of oxygen transmissibility on bacterial adhesion

The results of adhesion experiments conducted with *S. aureus* ATCC 6538 to unworn etafilcon A, pauflufocon A, B and C contact lens materials are shown in Figure 3. Bacterial recovery from the three RGP lens types was significantly higher statistically than from the hydrogel lens ($P < 0.05$). However, there were no statistically significant differences in adhesion when the RGP lens types were compared to each other.

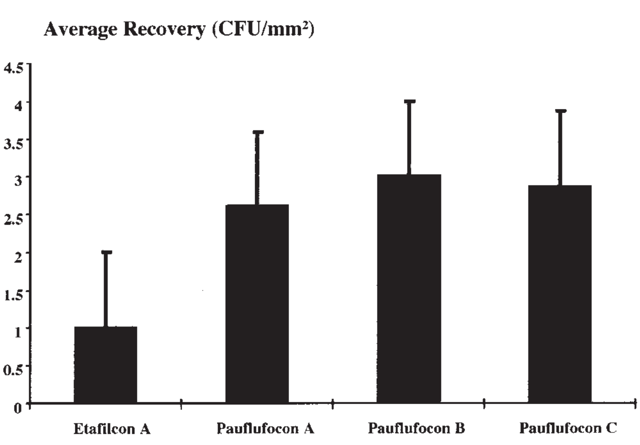

Figure 3 Adhesion of *S. aureus* to lens types with different oxygen transmissibilities. Inoculum = 2.4×10^4 CFU ml^{-1}; $n = 3$.

Discussion

The parameter that provides for the greatest variation in bacterial adhesion is water content. RGP materials have a water content of 0%, while polymacon has a water content of 38%. The data show statistically significant differences in bacterial adhesion when this lens type is compared to RGP materials. Data from other experiments showed no differences when polymacon, vifilcon (water content 55%), and etafilcon A materials were compared using the MVD with non-clinical isolates as the indicator organism [11]. It is possible that a water saturation point is reached whereby no further addition of water to the polymer will affect bacterial adhesion.

Pseudomonas aeruginosa demonstrated a higher level of adhesion to RGP lenses than to hydrogel lenses [10]. In our experiments *S. aureus* demonstrated a significantly higher statistical level of recovery from the RGP contact lens types than from the hydrogel contact lenses. The chemical composition and/or surface properties which give rise to different oxygen transmissibilities of RGP lenses (pauflufocon A, B and C materials) have no apparent influence upon bacterial adhesion and recovery. This was also evident with the hydrogel lenses tested. The data did not support the proposition that ionicity of these materials played a major role in adhesion. When a non-ionic hydrogel (polymacon) was evaluated against an ionic hydrogel (etafilcon A), no differences in bacterial adhesion were observed. This is consistent with previous findings [11].

The data also show a difference in adhesion when the *S. aureus* ATCC 6538 and the clinical isolate are compared. The reasons for this are unclear. It is possible that since the early stages of adhesion to medical devices is attachment, this process is aided in some non-clinical strains by the lack of a slime layer or polysaccharide capsule which tend to protect clinical isolates from immune system attack by phagocytosis.

A key issue is how these data relate to the human experience. Other groups have reported that contact lens-associated infections are less often observed with RGP lenses as compared to hydrogel lenses worn either in a daily wear fashion or extended wear fashion [2,12]. Many investigators have shown that more bacteria will adhere to unworn contact lens materials than to worn lenses [9–11]. It is possible that since RGP lens materials are smaller in diameter and thus do not cover the limbus, which is a vascular area, that there is a reduced risk of infection. They reside on the cornea in most patients. Standard hydrogel contact lenses cover all of the cornea and rest on the limbus thereby allowing the edge of the lens to come into direct contact with an area rich in vascularization. Clearly, the relationship between bacterial adhesion to contact lenses and bacterial infections in the eye requires further investigation.

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