Surgical site infections are the most common type of nosocomial infection,
and they can have a significant effect on patient outcomes and the
costs of health care. Surgical site infections can increase both length of stay and antibiotic use, require follow-up surgery, and delay wound healing. The additional costs associated with treating patients with surgical site infections can increase the cost of surgery up to 5 times.

Several patient characteristics have been linked to increased risk of surgical site infection, including age, sex, and socioeconomic status. Although the evidence linking race to increased risk of surgical site infection is conflicting, it has been suggested that African Americans are more susceptible to surgical site infection. Further, African American race has been identified specifically as a risk factor for incisional surgical site infection.

Many microbial, procedural, and patient-related methods are used to reduce the risk of surgical site infection, including cleaning the area of incision with a surgical preparatory agent. Chlorhexidine gluconate has antibacterial and antifungal
properties and has been used for more than 50 years as an effective surgical preparatory agent.\textsuperscript{10} Preoperative application of chlorhexidine gluconate solution has been shown to decrease the risk of surgical site infection, likely by preventing colonization of the area by pathogenic bacteria.\textsuperscript{11}

At the study institution, chlorhexidine gluconate and isopropyl alcohol (ChloraPrep; Becton, Dickinson & Co, Franklin Lakes, New Jersey) is used as the preparatory solution for cleansing the patient’s skin before surgery. This surgical preparatory solution is available in clear as well as in teal (Scrub Teal) and orange (Hi-Lite Orange) tints. Tinted surgical preparations increase visualization of the prepared area of skin.\textsuperscript{12}

Concerns have been raised about the visibility of ChloraPrep on skin with darker pigmentation.\textsuperscript{13,14} Inability to see the solution on the skin could lead to inadequate preparation of the skin before surgery and increase the risk of surgical site infection. The goal of this study was to determine whether different tints of ChloraPrep and different skin pigmentation categories affect the ability of orthopedic surgeons to determine the adequacy of skin preparation.

**Materials and Methods**

Four volunteers were divided into 1 of 4 skin pigmentation categories (fair, medium-fair, medium-dark, and dark) (Figure 1). Volunteers had no major scars, tattoos, or other disruptions of pigmentation or identifiable markings on the forearm. Participation was entirely voluntary, and participants could withdraw at any point without repercussions.

The applicator provided with the solution was used to apply ChloraPrep in either the Scrub Teal or Hi-Lite Orange tint to the forearm of each volunteer. Each of the 4 volunteers had 1 forearm prepared first “inadequately” and then “adequately” with ChloraPrep in the Scrub Teal and then the Hi-Lite Orange tint. Each volunteer underwent a total of 4 preparations on 1 forearm. All preparations were conducted by the same individual (C.M.M.), according to the manufacturer’s recommended application procedure of repeated strokes backward and forward for a period of 30 seconds. Between preparations, the skin of the forearm was washed with soap and water to remove traces of the ChloraPrep tint and was allowed to dry before application of the next preparation. For inadequately prepared applications, ChloraPrep was applied so that small streaks of the forearm, approximately 5 cm long and 1 cm wide, were not covered by the forward and backward application of the preoperative chlorhexidine solution. For adequately prepared applications, there was no unprotected skin on the forearm. For both adequately prepared and inadequately prepared applications, the solutions were allowed to dry for 3 minutes before being recorded with a video camera.

Short videos of approximately 10 seconds (Figures 2-3) were recorded of the entire length of the forearm with a Canon Vixia HF R62 video camera (Canon USA, Inc, Melville, New York). Videos were taken under lighting conditions comparable to those in the operating room. No flash was used, and the video camera was placed at a fixed distance from the subjects on a tripod. No postproduction editing of the videos, including correction of color or exposure, was performed.

Videos of adequately and inadequately prepared skin of all 4 pigmentation preparations with both Scrub Teal and Hi-Lite Orange were compiled into a web-based survey in an order randomly determined by algorithm, for a total of 16 videos. The survey was distributed to 54 orthopedic surgeons in the Washington, DC, area. Participants were instructed to watch each video and then to state whether they believed that the skin was adequately prepared for surgery. Results from the study were first analyzed with Student’s $t$ test to determine the significance of identification rates separately for skin pigmentation and ChloraPrep tint. A chi-square test was used to analyze the degree of independence between identification rates by skin pigmentation and ChloraPrep tint.
RESULTS

Of the 54 orthopedic surgeons who were asked to complete the survey, 83.3% (n=45) responded. Without controlling for ChloraPrep tint, surgeons significantly correctly identified the adequacy of skin preparation only in fair (69.3%±4.9%, P<0.0001) and medium-fair skin pigmentation categories (54.9%±7.2%, P=.23) (Table 1). When the 4 skin pigmentation categories were aggregated, surgeons significantly correctly identified skin preparation with the Scrub Teal tint 55.8% of the time (±4.6%, P=.044) and with the Hi-Lite Orange tint 61.7% of the time (±4.3%, P=.00045) (Table 2). No statistically significant difference was found between identification rates of skin preparation, with Hi-Lite Orange and Scrub Teal without controlling for skin pigmentation (Table 3).

Without controlling for ChloraPrep tint, respondents identified the adequacy of skin preparation accurately only for the fair and medium-fair skin pigmentation categories (chi-square, 2.21; P=.14). For all 4 skin pigmentation categories, a significant difference was noted between the Scrub Teal tint and the Hi-Lite Orange tint in respondents’ ability to identify the adequacy of skin preparation (Table 3). The adequacy of skin preparation with the Hi-Lite Orange tint was significantly easier to identify in fair (chi-square, 7.79; P=.0053) and medium-fair skin pigmentation categories (chi-square, 19.33; P=.000011), whereas the adequacy of skin preparation with the Scrub Teal tint was significantly easier to identify in medium-dark (chi-square, 4.09; P=.043) and dark skin pigmentation categories (chi-square, 4.03; P=.045).

DISCUSSION

Previous studies raised concerns about the visibility of preoperative skin preparation, but none investigated the role of skin pigmentation or preparation tint on visibility. Failure to determine the field of prepared skin adequately would likely lead to an increased risk of surgical site infection. Thus, the ability of surgeons to determine the preparation of the skin adequately is a crucial component of anti-infection precautions.

In the United States, ChloraPrep is a widely used preoperative surgical preparation, and the chlorhexidine gluconate and isopropyl alcohol formulation was shown to reduce the rate of surgical site infection compared with iodine-based products. The addition of food coloring dye to clear chlorhexidine gluconate and isopropyl alcohol formulations significantly decreases the antimicrobial efficacy of the skin preparation, thus limiting tint options to those formulated with sterile food, drug, and cosmetic dyes used in ChloraPrep, namely, Scrub Teal and Hi-Lite Orange.

For all skin pigmentation categories, surgeons identified the adequacy of skin preparation with the use of either the Scrub Teal tint or the Hi-Lite Orange tint, suggesting that there is no difference between the tints. However, when not controlling for ChloraPrep tint, respondents identified the adequacy of skin preparation accurately only for the fair and medium-fair skin pigmentation categories. This finding supports the hypothesis that skin pigmentation and preparation tint play a role in the visibility of prepared skin and should guide the choice of preoperative skin preparation to minimize the risk of surgical site infection.

Although determining the adequacy of skin preparation is possible in the fair and medium-fair skin pigmentation categories without controlling for ChloraPrep tint, because Hi-Lite Orange is significantly easier to identify than Scrub Teal in these 2 categories, surgeons should use Hi-Lite Orange tint for patients with fair or medium-fair skin pigmentation (Figure 4). Although it is not possible to determine the adequacy of skin preparation accurately for the medium-dark and dark skin pigmentation categories, surgeons should use Hi-Lite Orange tint for patients with medium-dark and dark skin pigmentation.
skin pigmentation categories when not controlling for ChloraPrep tint, it is possible to do so with Scrub Teal (Figure 4), albeit at identification rates of approximately 60%. The authors recommend that surgeons consider using Scrub Teal tint for patients with medium-dark and dark skin pigmentation.

**Limitations**

This study had several limitations. The videos used for the survey were prepared under conditions simulating those of an operating room, but it is possible that determining the adequacy of skin preparation from a video is appreciably different from doing so in the clinical setting. Additionally, although the same individual prepared the forearms of the volunteers, some unavoidable variation occurred in the streaking of the skin preparation for forearms that were considered inadequately prepared, and this variation could have affected the survey results. Finally, although the survey yielded statistically significant results, a considerable number of surgeons did not correctly identify the adequacy of skin preparation, regardless of skin pigmentation and preparation tint. This could limit the extent to which the use of an appropriate preparation tint would reduce the risk of surgical site infection.

Further investigations should examine the visibility of skin preparation tint in the clinical setting, including prospective tracking of the surgical site infection rate among patients undergoing orthopedic surgery according to ChloraPrep tint and skin pigmentation category.

**Conclusion**

To reduce the risk of surgical site infection, surgeons should consider using Hi-Lite Orange tint for patients with fair and medium-fair skin pigmentation and Scrub Teal tint for patients with medium-dark and dark skin pigmentation. A large number of surgeons did not identify the adequacy of skin preparation, regardless of preparation tint and skin pigmentation, and so a second application of the appropriate tint for the patient’s skin color may be warranted to ensure adequacy of

<table>
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<tr>
<th>Skin Pigmentation</th>
<th>Correctly Identified</th>
<th>Incorrectly Identified</th>
<th>Chi-square</th>
<th>P</th>
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<td><strong>by ChloraPrep Tint</strong></td>
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<td></td>
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<tr>
<td>Fair</td>
<td>Hi-Lite Orange</td>
<td>79.5% (±4.6%; n=62)</td>
<td>20.5% (±17.8%; n=16)</td>
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<td>58.7% (±9.4%; n=44)</td>
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<td>Medium-fair</td>
<td>Hi-Lite Orange</td>
<td>78.9% (±4.8%; n=60)</td>
<td>21.1% (±17.9%; n=16)</td>
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<td>43.5% (±13.4%; n=30)</td>
<td>56.5% (±10.3%; n=39)</td>
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<td>Medium-dark</td>
<td>Hi-Lite Orange</td>
<td>40.5% (±13.6%; n=30)</td>
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<td>43.2% (±12.4%; n=35)</td>
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<td>Hi-Lite Orange</td>
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<td>37.2% (±14.0%; n=29)</td>
<td>4.03</td>
</tr>
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b Significant at P<.01.

c Significant at P<.001.

d Significant at P<.05.

**Figure 4:** Correct identification of skin preparation by skin pigmentation and ChloraPrep (Becton, Dickinson & Co, Franklin Lakes, New Jersey) tint.
coverage. However, this practice must be weighed against concerns about lengthening the preoperative period and increasing the cost of skin preparation.

REFERENCES