Clinical, Technical, and Radiologic Outcomes of 182 Implant-Supported Zirconia Single Crowns Using Titanium-Base Abutments: A Retrospective Study

Mustafa Baris Guncu, DDS, PhD
Guliz Aktas, DDS, PhD
Department of Prosthodontics, School of Dentistry, Hacettepe University, Ankara, Turkey.

Guliz N. Guncu, DDS, PhD
Department of Prosthodontics, School of Dentistry, Hacettepe University, Ankara, Turkey.

Duygu Anıl, PhD
Department of Prosthodontics, School of Dentistry, Hacettepe University, Ankara, Turkey.

Ilser Turkyilmaz, DMD, PhD
Lisa R. Antonoff, BS, DDS
Department of Prosthodontics, New York University College of Dentistry, New York, New York, USA.

**Purpose:** To evaluate the biologic, technical, and radiographic outcomes of CAD/CAM–milled bilayer and monolithic zirconia crowns using implants and Ti-base abutments with up to 5 years of follow-up. **Materials and Methods:** A total of 182 implant-supported “screw-mentable” (hybrid screw/cement retention) single crowns were evaluated in 118 patients. Ti-base abutments were selected according to the chimney (3.5 or 5 mm) and gingival (1, 2, or 3 mm) heights in the virtual model. Zirconia crowns were designed using CAD/CAM software and then milled from partially stabilized zirconia blocks. After all crowns were cemented onto Ti-base abutments, they were clinically screwed onto the implants. Both implants and crowns were followed up for up to 5 years, and their clinical, technical, and radiologic results were recorded. **Results:** A total of 118 patients (86 women and 32 men) who received 182 implant-supported screw-mentable crowns were included in this study. The mean follow-up period was 32 ± 18 months (range: 24 to 60 months) for all implants and crowns. No implant was lost during the follow-up period, yielding a cumulative implant survival rate of 100%. Two technical complications were observed in two bruxer patients, yielding a cumulative restoration survival rate of 98.9%. The marginal bone loss was 0.7 ± 0.5 mm from the baseline radiograph to the radiograph taken at the final recall visit. No implants were diagnosed with peri-implantitis. **Conclusion:** The outcomes of this study suggest that Ti-base abutments are a feasible and affordable alternative to CAD/CAM abutments and that they can successfully support single zirconia crowns.

Dental implants are a predictable therapeutic choice for replacing missing teeth, and several reports showing successful outcomes with this treatment modality have been published. Therefore, implant-supported single crowns have been very popular in the last 20 years.1–4 Single crowns or fixed dental prostheses can be retained on implants via cement or screws.5–7 The type of retention between the implant and restoration has been one of the biggest controversies among practitioners.8–10 Several characteristics, such as esthetics, retrievability, retention, passivity, and occlusion, are associated with screw- and cement-retained implant restorations. Retrievability, use in limited interocclusal space, and no need for cement can be listed as the main advantages of screw-retained restorations, while the need for ideal implant positions and higher cost can be listed as the main disadvantages.8–10

Correspondence to:
Dr Ilser Turkyilmaz
Department of Prosthodontics
New York University College of Dentistry
380 Second Avenue, Suite 302,
New York, NY 10010
Email: ilserturkyilmaz@yahoo.com
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Flexibility in implant position, better control of occlusion, and easier achievement of passivity are considered the main advantages of cement-retained restorations, while difficulty removing excess cement and unpredictable retrievability are considered the main disadvantages.8–10

Retrievability is the most valuable benefit with the use of screw-retained restorations, especially for full-arch fixed restorations supported by multiple implants, as the prosthesis can be retrieved without damage to the restoration or implants for maintenance or repairs.11–13 Peri-implant tissue inflammation due to residual cement may be the most common complication with the use of cement-retained restorations, especially if the abutment-crown junction is located very subgingivally.11–13 Therefore, it is vital to remove all residual cement at the time of crown placement; otherwise, peri-implant loss will occur, which may ultimately cause implant failure. In fact, peri-implant soft tissue responses seem to be more favorable with screw-retained restorations compared to cement-retained restorations.11–13

CAD/CAM technology has dramatically ameliorated both surgical and restorative aspects of implant dentistry.14–17 CAD/CAM fabrication of abutments, crowns, and frameworks has resulted in the elimination of distortion, better fit, fewer fabrication steps, and faster turnaround time.18–20 Thus, titanium-base (Ti-base) abutments have recently been popular as a platform for milling custom-made ceramic restorations that are cementedchairside to the Ti-base abutments and eventually screwed onto the implant.21–24 This hybrid retention modality (“screw-mentable”) with Ti-base abutments offers some advantages, such as retrievability, a tailored emergence profile to reestablish soft tissue contours, cementation under controlled laboratory environments, and the elimination of the risk of residual cement.21–24

CAD/CAM technology allows the fabrication of high-strength restorations with acceptable esthetics by using new dental materials such as monolithic zirconia.25–28 Crowns made of monolithic zirconia can withstand masticatory loads greater than the average maximal posterior occlusal forces. With their mechanical advantages, monolithic zirconia crowns have become an alternative to conventional metal-ceramic crowns.

There are a limited number of clinical studies regarding the short-term outcomes of CAD/CAM–fabricated zirconia crowns using implants and Ti-base abutments in the literature.29,30 However, to the best of the authors’ knowledge, information about the long-term outcomes of zirconia crowns using implants and Ti-base abutments is lacking. Hence, the aim of this study was to evaluate the biologic, technical, and radiographic outcomes of CAD/CAM–milled bilayer and monolithic zirconia crowns using Ti-base abutments and implants for up to 5 years of follow-up. This was a retrospective study based on a chart review.

MATERIALS AND METHODS

Study Design

The clinical and technical outcomes of 182 implant-supported screw-mentable crowns were evaluated in 118 healthy patients (86 women and 32 men). This retrospective study is based on data collected from dental records between January 2016 and January 2021 with approval from the internal review board of Hacettepe University (project no.: GO 18/373-31).

Prosthodontic Procedures

All patients included in the study presented with at least one missing tooth and had received a bone-level dental implant (3.3 NC, 4.1 RC, or 4.8 RC Bone Level Tapered Implants, Straumann). After healing periods of 2 to 4 months, final impressions were made with a polyvinyl siloxane impression material (Elite HD, Zhermack) and a closed-tray technique. After the impressions were poured, an implant-level scan body was seated on the implant replica, and digital scans were performed (Dental Wings, Straumann). Ti-base abutments (Variobase Abutment, Straumann) were selected according to the chimney (3.5 or 5 mm) and gingival (1, 2, or 3 mm) heights in the virtual model. Zirconia suprastructures were designed in full contour or as copings using the given software and then milled from partially stabilized zirconia blocks (Katana Zirconia HT, Kuraray Noritake). Sintering of the suprastructures was performed according to the manufacturer guidelines. If the zirconia suprastructure was designed as bilayer, the coping was veneered (Initial, GC), except for the area in contact with the soft tissue.

Cementation Procedure and Delivery

After try-in was performed and the patient’s approval obtained, glazing (bilayer zirconia) or polishing (monolithic zirconia) procedures were completed. Then, cementation was performed with adhesive cement. First, the restoration and Ti-base abutment were ultrasonically cleaned in alcohol for 5 minutes and dried. Next, the Ti-base abutment was screwed onto the implant analog, and the screw access hole of the Ti-base abutment was filled with polytetrafluoroethylene (PTFE) tape, also known as Teflon tape. The Ti-base abutment’s emergence profile was coated with glycerin gel, and the Ti-base abutment platform was airborne particle–abraded with 50-μm Al₂O₃ at a pressure of 2 bar until a matte surface was obtained. Finally, the abutment was cleaned ultrasonically in distilled water for 5 minutes.

The inner surface of the zirconia crown was airborne particle–abraded with 50-μm Al₂O₃ for 20 seconds at a pressure of 1 bar from a 10-mm distance. Then, the chimney, Ti-base abutment platform, and inner surface of the zirconia crown were coated with primer (Monobond Plus, Ivoclar Vivadent). Self-curing luting composite
(Multilink Hybrid Abutment, Ivoclar Vivadent) was applied to the titanium surface, and the crown was gently seated on the abutment. The parts were maintained in position throughout polymerization.

Excess cement was removed with a bonding brush, and the margin of the Ti-base abutment was coated with glycerin gel. After polymerization for 7 minutes, the PTFE tape in the access hole was removed, and the Ti-base abutment-crown assembly was unscrewed. The emergence profile of the abutment was checked for cement remnants under a clinical microscope at x10 magnification, the remnants removed, and the abutment cleaned and polished.

Next, the screw-mentable crown was screwed onto the implant intraorally and torqued with a manual torque wrench until 35 Ncm, as recommended by the manufacturer. The screw access hole was filled with a PTFE band and restored with a photopolymerized composite resin material.

Data Collection
A single examiner recorded the parameters for each implant studied, which included the chimney (3.5 mm, 5.5 mm) and gingival (1, 2, 3 mm) heights of the Ti-base abutments, the treated arch (maxilla, mandible), the implant location (anterior, premolar, molar), and the crown material (bilayer zirconia, monolithic zirconia) (M.B.G.). Also, the opposing dentition and the presence of wear facets with a history of parafunction or the use of a nightguard (noninstrumental approaches for assessing bruxism) were documented.

Clinical and Radiologic Follow-up
Following crown delivery, clinical follow-up visits were scheduled at 6 and 12 months and annually after the first year. The International Team for Implantology (ITI) Complication Criteria parameters were used to evaluate any mechanical and technical complications. All clinical parameters were assessed by an independent examiner (G.N.G.).

Implant loss, fracture of an abutment or abutment screw, fracture of a monolithic crown, or chipping of the veneering porcelain that required the remake of a crown were considered failures and used to calculate the cumulative survival rate. Conversely, the cumulative success rate was calculated based on complications such as abutment screw loosening, debonding of the zirconia suprastructure, and chipping of the veneering porcelain (smaller than 1 mm) where the porcelain could be reshaped and polished.

Furthermore, digital periapical radiographs were obtained immediately after delivering the crowns and at annual recalls after the first year. Evaluation of the digitally recorded radiographs was performed with radiologic software using an integrated millimeter calibration tool. The implant-abutment junction was used as a reference for bone-level measurements. The marginal bone levels were determined using the periapical radiographs at implant placement and the final follow-up visit.

Peri-implant soft tissues were assessed using a periodontal probe, the Modified Bleeding Index (mBIL), and the Modified Plaque Index (mPLI). The peri-implant probing depth (PPD), amount of keratinized tissue, mBIL, and mPLI were recorded at 6 months, 12 months, and at annual follow-up visits after delivery of the single crowns. According to these parameters and the periapical radiographs, dental implants were classified as peri-implant health, peri-implant mucositis, or peri-implantitis during the follow-up periods.

The classification of peri-implant diseases presented in the 2018 consensus report was used for the evaluation of these data. Briefly, peri-implant health was characterized by the absence of erythema, bleeding on probing, swelling, and suppuration. Peri-implant mucositis was characterized by bleeding on gentle probing, as well as erythema, swelling, and/or suppuration. Peri-implantitis was characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone.

Statistical Analysis
The data for the 182 screw-mentable crowns were subjected to statistical analysis, and SPSS version 25 (IBM) software was used for all analyses. For each crown, the time to failure and the complications were recorded. The survival of the restorations or subsets of restorations grouped by the variables chimney height, location, prosthesis material, and bruxism was displayed using Kaplan-Meier survival curves. Significant differences between survival curves were determined with log-rank test, and $P$ values < .05 were considered statistically significant.

RESULTS
A total of 118 patients (86 women and 32 men) with a mean age of 42 ± 12 years (range: 22 to 74 years), in whom 182 implant-supported screw-mentable crowns were placed, were included in this clinical study. The mean follow-up period was 32 ± 18 months (range: 24 to 60 months) for all implants and crowns. Information about the patients, types of abutments, and restorations is presented in Table 1.

No implant was lost during the follow-up period, yielding a cumulative implant survival rate of 100%. Two technical complications were observed in two bruxer patients; one Ti-base abutment (3.5-mm chimney height) fracture and one fracture in the internal surface of a monolithic zirconia single crown (5.5-mm chimney height; Figs 1 and 2), yielding a cumulative restorative survival rate of 98.9%.
DISCUSSION

Marginal bone loss in the present study was 0.7 ± 0.5 mm, and the implant and restoration survival rates were 100% and 98.9%, respectively. The present findings are comparable to those reported in previous studies. A study by Asgeirsson et al. evaluated the clinical performance of 24 veneered single zirconia crowns with Ti-base abutments for 1 year. The all-zirconia crowns were screwed onto the implants after extraoral cementation on the Ti-base abutments. The authors analyzed both implants and crowns at 6 and 12 months after delivery of the crowns and noted that the mean marginal bone levels were 0.54 ± 0.39 mm at baseline and 0.54 ± 0.45 mm at 1 year. One implant was lost, resulting in a 95.8% survival rate, and four technical complications occurred, indicating a complication-free rate of 83.3%. The lower percentages in the present study may be due to patient-related factors (eg, occlusion, opposing arch, bruxism), different types of restorative procedures/materials, and/or the strict maintenance protocol adhered to in recall appointments.

Weigl et al. compared the clinical performance of screw-retained monolithic zirconia and cement-retained porcelain-fused-to-metal (PFM) implant crowns. They placed 44 implants in 22 patients. No implant was lost during the follow-up period of 1 year. They noticed that the peri-implant bone resorption was 0.26 mm in the test (screw-retained) group and 0.22 mm in the control (cement-retained) group after 1 year. The following restorative problems were reported: chipping of the ceramic in two patients; decementation in two patients with cemented crowns, screw loosening in one patient; and replacement of the filling material of the screw hole in two patients.

Several factors influence the retention of cement-retained restorations, including the chimney height. For cement-retained restorations, the acceptable chimney height was reported as a minimum of 4 mm. In the present study, it was observed that abutments with a chimney height of 3.5 mm were as successful as abutments with a chimney height of 5.5 mm. In an in vitro study, Zahoui et al. investigated the retention of zirconia crowns fabricated on two different Ti-base abutment heights (2.5 and 4 mm) and noted higher retention values with the taller abutments than the shorter abutments. The contrast between the findings of Zahoui et al. and the present study may be explained by the bond strength between the luting agent and the abutment surface tested, as the bonding surface is determined by the abutment height and also the strength of the mechanical interlocking chemical bonds and surface roughness.

Moreover, this unique feature of Ti-base abutments may have a role in the success of the 3.5-mm abutments in the present study. According to the manufacturer's recommendations, the Ti-base abutment surface to be bonded should be airborne-particle-abraded with 50-µm alumina particles. Some studies investigated the bond strength between all-ceramic copings and Ti-base abutments and presented conflicting recommendations. While some investigators recommend airborne-particle abrasion,

### Table 1 Data Collected at Clinical Follow-up

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Gender</strong></td>
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<tr>
<td>Female</td>
<td>86</td>
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<tr>
<td>Male</td>
<td>32</td>
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<td>Anterior</td>
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<td>Premolar</td>
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<tr>
<td>Molar</td>
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<tr>
<td>Bilayer zirconia</td>
<td>80</td>
<td>44</td>
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<tr>
<td>Monolithic zirconia</td>
<td>102</td>
<td>56</td>
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<tr>
<td><strong>Gingival height, mm</strong></td>
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<td></td>
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<tr>
<td>1</td>
<td>173</td>
<td>95.1</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>4.9</td>
</tr>
<tr>
<td><strong>Platform height, mm</strong></td>
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<td></td>
</tr>
<tr>
<td>3.5</td>
<td>78</td>
<td>43</td>
</tr>
<tr>
<td>5.5</td>
<td>104</td>
<td>57</td>
</tr>
<tr>
<td><strong>Opposing dentition</strong></td>
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<td></td>
</tr>
<tr>
<td>Natural dentition</td>
<td>136</td>
<td>74.7</td>
</tr>
<tr>
<td>Metal-ceramic crown on tooth</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Bilayer zirconia on tooth</td>
<td>18</td>
<td>9.9</td>
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<tr>
<td>Bilayer zirconia on dental implants</td>
<td>8</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>Bruxism</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>43</td>
<td>36.4</td>
</tr>
<tr>
<td>Not present</td>
<td>75</td>
<td>63.6</td>
</tr>
</tbody>
</table>

Analysis of the digital periapical radiographs with radiologic software incorporating a millimeter calibration tool indicated the marginal bone loss was 0.7 ± 0.5 mm from the baseline radiograph to the radiograph taken at the final recall visit (32 ± 18 months). No implants were diagnosed with peri-implantitis. However, 19 dental implants located in the molar regions were diagnosed with peri-implant mucositis and were successfully treated using nonsurgical methods.

When all 182 implant-supported single crowns using Ti-base abutments were considered, Kaplan-Meier analysis indicated that the mean survival period was 58.28 ± 1.08 months (95% CI: 56.16 to 60.4 months). Kaplan-Meier survival analysis was also performed separately for four different risk factors (chimney height, location, crown material, and bruxism). The results are presented in Table 2.
Table 2  Kaplan-Meier Analysis Showing the Mean Survival of Crowns

<table>
<thead>
<tr>
<th></th>
<th>Mean survival, mo</th>
<th>SE</th>
<th>Lower bound</th>
<th>Upper bound</th>
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</thead>
<tbody>
<tr>
<td><strong>Platform height, mm</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>58.22</td>
<td>1.63</td>
<td>55.03</td>
<td>61.41</td>
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<tr>
<td>5.5</td>
<td>58.27</td>
<td>1.43</td>
<td>55.58</td>
<td>61.18</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>61.12<strong>a</strong></td>
<td>0.86</td>
<td>59.43</td>
<td>62.81</td>
</tr>
<tr>
<td>Premolar</td>
<td>58.99<strong>b</strong></td>
<td>2.08</td>
<td>54.91</td>
<td>63.07</td>
</tr>
<tr>
<td>Molar</td>
<td>54.28<strong>c</strong></td>
<td>1.08</td>
<td>50.86</td>
<td>58.87</td>
</tr>
<tr>
<td>Overall</td>
<td>58.28</td>
<td>1.08</td>
<td>56.16</td>
<td>60.4</td>
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<tr>
<td><strong>Type of crown material</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monolithic zirconia</td>
<td>56.1<strong>d</strong></td>
<td>1.77</td>
<td>52.63</td>
<td>59.56</td>
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<tr>
<td>Bilayer zirconia</td>
<td>61.5<strong>e</strong></td>
<td>0.48</td>
<td>60.55</td>
<td>62.45</td>
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<td><strong>Bruxism</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>58.09</td>
<td>1.88</td>
<td>54.41</td>
<td>61.77</td>
</tr>
<tr>
<td>Not present</td>
<td>58.24</td>
<td>1.37</td>
<td>55.55</td>
<td>60.93</td>
</tr>
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</table>

Different lowercase superscript letters indicate statistically significant differences (P < .05).
abrasion with alumina,\textsuperscript{21} others suggest that airborne-particle abrasion decreases retention forces due to the increase in the cement gap area.\textsuperscript{36,37} When the studies that do not recommend airborne-particle abrasion with alumina particles were examined in detail, it was noteworthy that abutments with microgrooves were used and that airborne-particle abrasion damaged the microgrooves. Although differences exist among brands, several existing Ti-base abutments contain macroretentive features. The combination of mechanical and chemical pretreatment of the Ti-base abutments may result in greater retention values.\textsuperscript{38} Airborne-particle abrasion removes the surface oxide layer mechanically, and a new thin, stable oxide film is formed on the titanium surface.

In the present study, ceramic chipping did not occur in the bilayer zirconia group, but two technical failures requiring crown replacement occurred in the monolithic zirconia group. The monolithic zirconia restorations showed higher fatigue resistance compared to the veneered zirconia under cyclic loading.\textsuperscript{39} If there is an overload on the restoration, debonding may occur, separating the Ti-base abutment and the crown. The cement is the weak link and will fail before the restoration or abutment screw.

Bruxism is prevalent in all age groups, social classes, and cultures. While manufacturers recommend monolithic zirconia restorations for this indication, patients presenting high occlusal stress were examined in a few studies.\textsuperscript{40} In the present study, no statistical difference was observed regarding the success rates of single crowns in individuals with and without symptoms of bruxism. However, it is noteworthy to mention that the two complications that required crown replacement, affecting the prosthetic survival rate, occurred in bruxer patients. Thus, it can be interpreted that patients with high parafunction have a higher risk of restoration failure.

In the present protocol, abutments with 1- and 2-mm gingival heights were used. Also, an extraoral cementation procedure was completed to avoid the cement’s toxic effects, as mentioned previously in the literature. In a systematic review,\textsuperscript{41} the mean prevalences of peri-implant mucositis and peri-implantitis were reported as 43% and 22%, respectively. However, no peri-implantitis was detected in the present study, and the peri-implant mucositis prevalence was 10.4%. The lower percentages of peri-implant mucositis and peri-implantitis may be due to the strict adherence to the maintenance protocol in all recall appointments and the fact that cementation was completed in the laboratory. Another reason might be the preservation of keratinized gingiva around implants, which was one of the main goals during implant placement in the present study. It has been reported\textsuperscript{42} that the presence of keratinized gingiva is required to keep peri-implant tissue healthy and for the long-term success of implant treatment.

It should be kept in mind that the present study is a retrospective chart review. Although findings of retrospective studies can form the basis for prospective studies, they have some limitations owing to their design. Some information may be missing, as they were originally not designed to gather data for research. Selection and recall biases may also influence the results and reasons for differences in treatment between patients. Therefore, researchers should avoid overgeneralization of results and be careful in claiming cause-effect relationships in retrospective studies.

**CONCLUSIONS**

Screw-mentable restorations offer retrievability, an emergence profile that reestablishes soft tissue contours, and the elimination of residual cement and its inherent risks. Ti-base abutments are a feasible and affordable alternative to CAD/CAM abutments. They can successfully support single zirconia crowns. Implant-supported screw-mentable zirconia single crowns are a viable option for treating missing teeth.

**ACKNOWLEDGMENTS**

The authors report no conflicts of interest.

**REFERENCES**


