With recent advances in implant dentistry, yttrium-stabilized zirconia, a chemically inert and biocompatible material, implants have been used to rehabilitate partially and completely edentulous individuals.\textsuperscript{1,2} In a recent prospective clinical trial, Borgonovo et al\textsuperscript{3} reported comparable crestal bone loss (CBL) around zirconia (ZrO\textsubscript{2}) implants from baseline up to 4 years of follow-up, with implant survival rates of up to 100%. Similarly, Brull et al\textsuperscript{4} showed a mean CBL of 0.1 mm around ZrO\textsubscript{2} implants at 3 years of follow-up with a mean implant survival rate (ISR) of 96.5%.

Although titanium (Ti) implants are commonly used to replace missing teeth and have shown promising outcomes (implant survival rates up to 99.7%),\textsuperscript{5-7} the occurrence of complications (infection) such as peri-implant mucositis and periimplantitis around Ti implants cannot be ignored.\textsuperscript{8,9} In comparison, ZrO\textsubscript{2} implants have shown low bacterial adherence and low potential for periimplant infection.\textsuperscript{10} Studies have also suggested that immune reactions as a result of sensitivities and allergies to Ti implants could lead to biologic complications.\textsuperscript{11-13} Moreover, the bluish-gray appearance of Ti implant

**ABSTRACT**

**Statement of problem.** Zirconia implants have been used for oral rehabilitation; however, evidence of their ability to maintain crestal bone and periimplant soft tissue health is not clear.

**Purpose.** The purpose of this systematic review was to evaluate crestal bone loss (CBL) around zirconia dental implants and clinical periimplant inflammatory parameters.

**Material and methods.** The focus question addressed was, “Do zirconia implants maintain crestal bone levels and periimplant soft tissue health?” Databases were searched for articles from 1977 through September 2014 with different combinations of the following MeSH terms: “dental implants,” “zirconium,” “alveolar bone loss,” “periodontal attachment loss,” “periodontal pocket,” “periodontal index.” Letters to the editor, case reports, commentaries, review articles, and articles published in languages other than English were excluded.

**Results.** Thirteen clinical studies were included. In 8 of the studies, the CBL around zirconia implants was comparable between baseline and follow-up. In the other 5 studies, the CBL around zirconia implants was significantly higher at follow-up. Among the studies that used titanium implants as controls, 2 studies showed significantly higher CBL around zirconia implants, and in 1 study, the CBL around zirconia and titanium implants was comparable. The reported implant survival rates for zirconia implants ranged between 67.6% and 100%. Eleven studies selectively reported the periimplant inflammatory parameters.

**Conclusions.** Because of the variations in study design and methodology, it was difficult to reach a consensus regarding the efficacy of zirconia implants in maintaining crestal bone levels and periimplant soft tissue health. (J Prosthet Dent 2015;\textsuperscript{1-3})
collars in areas of thin mucosa or mucosal recession compromises the esthetics of the definitive implant. These biologic and esthetic complications have led to the search for an alternative implant material to Ti.

In a recent systematic review, Depprich et al14 showed that the implant survival rates of ZrO2 implants ranged between 74% and 98% for up to 56 months of follow-up. However, a possible risk of bias in the studies assessed by Depprich et al14 cannot be disregarded. It is well known that the maintenance of crestal bone levels plays an important role in the long-term survival and success of dental implants.15–17 as does an inflammation-free peri-implant soft tissue environment.18,19 However, certain parameters such as plaque index (PLI), bleeding index (BI) bleeding on probing (BOP), periimplant pocket depth (PPD), and clinical attachment loss (CAL) were not addressed in the study.14

With this background, the purpose of the present study was to systematically review the crestal bone levels and clinical periimplant inflammatory parameters around ZrO2 dental implants.

**MATERIAL AND METHODS**

The focused question addressed was, “Do zirconia dental implants maintain crestal bone levels and periimplant soft tissue health?”

The following inclusion criteria were imposed: original studies, clinical studies with 12 months of follow-up, intervention recording crestal bone loss and periimplant inflammatory parameters around ZrO2 dental implants, and articles published only in English. Letters to the editor, historic reviews, commentaries, experimental (animal) studies, case-reports, and unpublished articles were excluded.

In order to identify studies relevant to the focused question, the MEDLINE database, the EMBASE database, the Cochrane Central Register of Controlled Trials (CENTRAL), Scopus, and the Web of Knowledge and Google-Scholar databases were electronically searched. Databases were searched for articles from 1977 through September 2014 with the following Medical Subject Headings (MeSH) terms: (1) dental implantation, (2) dental implants, (3) zirconium, (4) alveolar bone loss, (5) periodontal attachment loss, (6) periodontal pocket, (7) periodontal index, (8) dental plaque index, and the combinations 1 or 2 and 3; 1 or 2 and 3 and 4; 1 or 2 and 3 and 5; 1 or 2 and 3 and 5 or 6 or 7 or 8; and 1 or 2 and 3 and 4 and 5 or 6 or 7 or 8. Other relevant non-MeSH keywords were used in the search process to identify articles discussing periodontal inflammatory parameters around ZrO2 implants. These included “yttria-stabilized zirconia implants,” “zirconia,” “inflammation,” “bleeding index” and “bleeding on probing,” and “peri-implant pocket” and “clinical attachment loss.” The titles and abstracts of studies identified with the described protocol were screened by 3 authors (F.V., A.A.K., F.J.) and checked for agreement. The full texts of those studies judged by title and abstract to be relevant were read by authors (F.V., M.I.A., T.S.) for disagreement after discussion among the authors. Kappa scores (Cohen kappa coefficient) were used to determine the level of agreement between the 2 reviewers.20,21 Articles available online in electronic form ahead of print were considered eligible for inclusion.

**Figure 1. Literature search strategy using PRISMA flow diagram.**
according to the PRISMA guidelines. The research methodology of the present systematic review was adopted from previous published work, and the review pattern focused on summarizing the relevant data.22

The search yielded 55 studies. Overall, 42 studies were excluded (Appendix A, available online). In total, 13 studies were included and data analysis was performed (Fig. 1).

RESULTS

All the studies1,3,4,23-32 were performed either at universities or health care centers. The number of participants in the studies ranged between 5 and 74. Eleven studies1,3,4,23,24,26,27,29-32 reported the mean age of participants, which was between 38.5 years and 62 years (age range 18 to 80). Ten studies1,3,23,26-32 reported the percentage of female participants, which ranged between 6% and 57.5% (Table 1). In 3 studies,1,30,32 Ti implants were compared with ZrO2 implants. In 2 studies,4,26 smokers were included. In 5 studies,3,23,24,27,30 individuals smoking more than 10 cigarettes daily were excluded. In all studies,1,3,4,22-31 CBL was measured using conventional 2- dimensional radiographs. The follow-up period ranged from 12 months to 48 months.

The number of implants placed ranged between 14 and 150, with diameters between 3.5 mm and 6 mm and lengths between 6 mm and 16 mm. All implants had rough surfaces. In 11 studies,1,3,4,23,26,28,29-31 1-piece implants were used. In 3 studies,26,28,29 implants were placed using flapped and flapless surgical procedures. In 4 studies,4,26,28,29 implants were placed in fresh extraction sockets as well as in healed sites. In 6 studies,3,23,25,28,29 adjunct guided bone regeneration procedures were performed at the time of implant placement. In 2 studies,26,31 implants were loaded immediately after placement (Table 2).

In summary, there was a lack of homogeneity in the assessment of periimplant inflammatory parameters

### Table 1. Characteristics of studies that fulfilled eligibility criteria

<table>
<thead>
<tr>
<th>Author</th>
<th>Study Design</th>
<th>No. of Patients</th>
<th>Mean Age (y), range</th>
<th>Female, % (n)</th>
<th>Study Groups</th>
<th>Follow-up (mo)</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brull et al4</td>
<td>Retrospective</td>
<td>74</td>
<td>51 (18-72)</td>
<td>NA</td>
<td>Group 1: 55 1-piece ZrO2 implantsb Group 2: 62 2-piece ZrO2 implants</td>
<td>Up to 36</td>
<td>CBL around ZrO2 implants at baseline and follow-up was comparable (0.1 ±0.6 mm)</td>
</tr>
<tr>
<td>Cionca et al27</td>
<td>Prospective</td>
<td>32</td>
<td>51.9 (24-75)</td>
<td>56.2 (18)</td>
<td>49 ZrO2 implants</td>
<td>Up to 24</td>
<td>CBL around implants at baseline and follow-up was comparable</td>
</tr>
<tr>
<td>Payer et al32</td>
<td>Prospective</td>
<td>22</td>
<td>46 (24-77)</td>
<td>40.9 (9)</td>
<td>Group 1: 16 ZrO2 implants Group 2: 15 Ti implants</td>
<td>Up to 24</td>
<td>Both ZrO2 and Ti implant showed significant CBL at follow-up. Ti: 1.43 ±0.67 vs. ZrO2: 1.48 ±1.05 ZrO2 implant showed significantly higher CBL than Ti implants in mandible</td>
</tr>
<tr>
<td>Osman et al30a</td>
<td>Prospective</td>
<td>19</td>
<td>62 (46-80)</td>
<td>21.0 (4)</td>
<td>Group 1: 73 ZrO2 implants Group 2: 56 Ti implants</td>
<td>Up to 12</td>
<td>CBL around ZrO2 implants at baseline and follow-up was comparable (0.42 mm ±0.40)</td>
</tr>
<tr>
<td>Siddiqi et ala</td>
<td>Prospective</td>
<td>22</td>
<td>62 (50-79)</td>
<td>18.1 (4)</td>
<td>Group 1: 68 Alveolar ZrO2 implants Group 2: 30 alveolar Ti implants</td>
<td>Up to 12</td>
<td>CBL around ZrO2 and Ti implants at baseline and follow-up was comparable</td>
</tr>
<tr>
<td>Borgonovo et al3</td>
<td>Prospective</td>
<td>13</td>
<td>60 (38-75)</td>
<td>7.6 (1)</td>
<td>35 ZrO2 implants</td>
<td>Up to 48</td>
<td>CBL was comparable between baseline and follow-up</td>
</tr>
<tr>
<td>Kohal et al29</td>
<td>Prospective</td>
<td>28</td>
<td>55.7 (39-75)</td>
<td>39.2 (11)</td>
<td>56 ZrO2 implants</td>
<td>Up to 12</td>
<td>CBL was significantly higher than baseline. In 40% of subjects CBL was greater than 2 mm</td>
</tr>
<tr>
<td>Payer et al21</td>
<td>Prospective</td>
<td>20</td>
<td>44.4 (27-71)</td>
<td>45.0 (9)</td>
<td>20 ZrO2 implants</td>
<td>Up to 24</td>
<td>CBL was significantly higher at follow-up compared with baseline</td>
</tr>
<tr>
<td>Borgonova et al5</td>
<td>Prospective</td>
<td>6</td>
<td>NA</td>
<td>NA</td>
<td>14 ZrO2 implants</td>
<td>Up to 48</td>
<td>CBL was comparable between loading and follow-up</td>
</tr>
<tr>
<td>Borgonova et al6</td>
<td>Prospective</td>
<td>5</td>
<td>56.2 (50-65)</td>
<td>NA</td>
<td>29 ZrO2 implants</td>
<td>Up to 48</td>
<td>CBL (&lt;1.6 mm) was comparable between loading and follow-up</td>
</tr>
<tr>
<td>Kohal et al28</td>
<td>Prospective</td>
<td>65</td>
<td>38.4 (25)</td>
<td>66 ZrO2 implants</td>
<td>Up to 12</td>
<td>In 34% of subjects CBL was ≥ 2 mm</td>
<td></td>
</tr>
<tr>
<td>Borgonova et al23</td>
<td>Prospective</td>
<td>16</td>
<td>54 (36-72)</td>
<td>6.2 (1)</td>
<td>42 ZrO2 implants</td>
<td>Up to 24</td>
<td>CBL was comparable between baseline and follow-up. CBL was &gt;1.5 mm around one implant</td>
</tr>
<tr>
<td>Cannizzaro et al26</td>
<td>Prospective</td>
<td>40</td>
<td>38.5 (18-55)</td>
<td>57.5 (23)</td>
<td>Group 1: 20 non-occlusal ZrO2 implants Group 2: 20 occlusal ZrO2 implants</td>
<td>Up to 12</td>
<td>CBL was significantly higher at follow-up as compared to baseline in both test groups</td>
</tr>
</tbody>
</table>

CBL, crest bone loss; NA, not available; ZrO2, zirconia; Ti, titanium.

*Implants supporting complete overdentures.

1P-piece implants.
(plaque index [PLI], bleeding index [BI], bleeding on probing [BOP], periimplant pocket depth [PPD], and clinical attachment loss [CAL]) among the studies that fulfilled our eligibility criteria.1,3,4,23-32 In 5 studies,23,24,27,31,32 plaque scores in participants with ZrO₂ implants were expressed as a percentage of full-mouth sites, which ranged from 19% to 92%. However, in another 5 studies,1,3,25,28,29 BI ranged between 0 and 0.29 (Loe and Silness plaque index score) around ZrO₂ implants at follow-up. In 4 studies,1,25,28,29 BOP was reported, which ranged from 0.15% to 92%. The PPD around ZrO₂ implants was reported in 9 studies1,3,4,23-25,27,29 and ranged from 0.15% to 3.2 mm. CAL was reported in 2 studies28,29 and ranged from 2.84 mm to 3.24 mm at follow-up (12 months). Only 1 study1 reported the amount of keratinized mucosa around implants at baseline and follow-up, which was comparable. In 2 studies,26,30 not all periimplant inflammatory parameters were reported. These results are summarized in Table 3.

In 8 studies,1,3,4,23-25,27,30 the CBL around ZrO₂ implants was comparable between baseline (0.0 mm) and follow-up (0.66 to 7.82 mm) (up to 48 months). In 4 studies,26,28,29,31,32 the CBL around ZrO₂ implants was significantly higher at follow-up (0.83 to 2.75mm) (up to 24 months) compared with baseline (0.08 to 0.16 mm). Among the studies1,30,32 that used Ti implants as controls,
2 studies\textsuperscript{1,30} showed significantly higher CBL around ZrO\textsubscript{2} implants, and in 1 study,\textsuperscript{32} the CBL around ZrO\textsubscript{2} and Ti implants was comparable. In the study by Kohal et al,\textsuperscript{28} the CBL was greater or equal to 2 mm in 34\% of study participants. In the study by Borgonovo et al,\textsuperscript{23} more than 1.5 mm of CBL was found around 1 implant.

In the study by Siddiqi et al,\textsuperscript{1} bone level was measured from the top of the implant (head of ball) to the first crestal bone contact at the mesial and distal aspect of the implant. In the studies by Payer et al\textsuperscript{31} and Borgonova et al,\textsuperscript{24} bone level was measured from the implant shoulder to the crest. The use of these modified bone level assessment techniques resulted in a baseline bone level in excess of zero.

The survival rates for ZrO\textsubscript{2} implants ranged between 67.6\% and 100\%. In 3 studies\textsuperscript{1,30,32} in which Ti implants were compared with ZrO\textsubscript{2} implants, the survival rates were comparable. In the study by Siddiqi et al,\textsuperscript{1} the survival rate of ZrO\textsubscript{2} implants was 67.6\% and that of Ti implants was 66.7\%. The follow-up period in the studies included ranged from 12 to 48 months.\textsuperscript{1,3,4,23-32}

**DISCUSSION**

One of the most frequently reported criteria for the success of conventional osseointegrated Ti implants is CBL of greater than 1.5 mm/year (with no radiographic signs of pathology) during the first year of implant loading.\textsuperscript{33} Among the studies included in the present review,\textsuperscript{1,3,4,23-32} 11 studies\textsuperscript{1,3,4,23-32} reported CBL of greater than 1.5 mm up to 4 years of follow-up. It is therefore speculated that crestal bone levels with ZrO\textsubscript{2} and conventionally used Ti implants are comparable. However, in 9\textsuperscript{3,4,23-29} of the 11 studies\textsuperscript{1,3,4,23-32} that reported CBL greater than 1.5 mm around ZrO\textsubscript{2} implants, ZrO\textsubscript{2} implants were not compared with Ti implants. In an attempt to clarify whether ZrO\textsubscript{2} implants minimize CBL, these implants must be compared with Ti implants. From the studies included in the present systematic review, 3 studies\textsuperscript{1,30,32} compared CBL with ZrO\textsubscript{2} and Ti implants. The results of the studies by Osman et al\textsuperscript{30} and Siddiqi et al\textsuperscript{1} reported increased CBL around ZrO\textsubscript{2} implants compared with Ti implants, whereas, in the study by Payer et al,\textsuperscript{32} CBL was comparable around ZrO\textsubscript{2} and Ti implants. This may be explained by the markedly varied methodologies of these studies. For example, in the studies by Osman et al\textsuperscript{30} and Siddiqi et al,\textsuperscript{1} ZrO\textsubscript{2} and Ti implants were placed in edentulous jaws and were followed up for 12 months, whereas, in the study by Payer et al,\textsuperscript{32} implants were placed in partially dentate individuals and were followed up for 24 months. Moreover, the implant locations also varied among the studies. For instance, in the study by Payer et al,\textsuperscript{32} more than 75\% of implants were placed in the mandible compared with

<table>
<thead>
<tr>
<th>Author</th>
<th>PLI</th>
<th>BI</th>
<th>Implant: (%)</th>
<th>PPD (mm)</th>
<th>CAL (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brull et al\textsuperscript{4}</td>
<td>NA</td>
<td>NA</td>
<td>Implant: 4.1</td>
<td>Teeth: 7.2</td>
<td></td>
</tr>
<tr>
<td>Cionca et al\textsuperscript{27}</td>
<td>At loading: 7%</td>
<td>At loading: 6%</td>
<td>NA</td>
<td>At loading: 3.1 ±0.6</td>
<td>NA</td>
</tr>
<tr>
<td>Payer et al\textsuperscript{31}</td>
<td>ZrO\textsubscript{2} implants</td>
<td>At placement: 15.75% (2.72)</td>
<td>NA</td>
<td>ZrO\textsubscript{2} implants</td>
<td>NA</td>
</tr>
<tr>
<td>Payer et al\textsuperscript{32}</td>
<td>Ti implants</td>
<td>At placement: 19.38% (0.88)</td>
<td>NA</td>
<td>Ti implants</td>
<td>NA</td>
</tr>
<tr>
<td>Osman et al\textsuperscript{28}</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Siddiqi et al\textsuperscript{1}</td>
<td>ZrO\textsubscript{2} implants</td>
<td>At loading: 0.37 (0.45)</td>
<td>NA</td>
<td>At loading: 1.59 (0.61)</td>
<td>NA</td>
</tr>
<tr>
<td>Borgonova et al\textsuperscript{7}</td>
<td>At loading: 1</td>
<td>At 48 mo: 0.15</td>
<td>NA</td>
<td>At loading: 3.0</td>
<td>NA</td>
</tr>
<tr>
<td>Kohal et al\textsuperscript{25}</td>
<td>At loading: 0.51 (0.49)</td>
<td>At 12 mo: 0.09 (0.16)</td>
<td>NA</td>
<td>At loading: 2.85 (0.73)</td>
<td>At 12 mo: 3.14</td>
</tr>
<tr>
<td>Payer et al\textsuperscript{11}</td>
<td>At loading: 27% (5.3)</td>
<td>At 24 mo: 22% (6.4)</td>
<td>NA</td>
<td>At loading: 25 (5.6)</td>
<td>NA</td>
</tr>
<tr>
<td>Borgonova et al\textsuperscript{25}</td>
<td>At 48 mo:0.29 (0.47)</td>
<td>At 48 mo: 0.57 (0.51)</td>
<td>NA</td>
<td>At 48 mo: 3.13 (0.87)</td>
<td>NA</td>
</tr>
<tr>
<td>Borgonova et al\textsuperscript{24}</td>
<td>At 6 mo: 50%</td>
<td>NA</td>
<td>At 6 mo: 50</td>
<td>At 6 mo: 2.85 (1.85-2.1)</td>
<td>NA</td>
</tr>
<tr>
<td>Kohal et al\textsuperscript{28}</td>
<td>At loading: 0.26 (0.35)</td>
<td>At 12 mo: 0.11 (0.23)</td>
<td>At loading: 0.36 (0.50)</td>
<td>At 12 mo: 2.75 (0.75)</td>
<td>At 12 mo: 8.4 (1.19)</td>
</tr>
<tr>
<td>Borgonova et al\textsuperscript{23}</td>
<td>At 12 mo: 92.3%</td>
<td>At 12 mo: 92.3</td>
<td>At 12 mo: &lt; 5mm</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Cannizzaro et al\textsuperscript{4}</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>

PLI, plaque index; BI, bleeding index; BOP, bleeding on probing; PPD, periimplant probing depth; CAL, clinical attachment loss; NA, not available; Gp, group; mm, millimeters; ZrO\textsubscript{2}, zirconia; Ti, titanium.
50% in the studies by both Osman et al.[10] and Siddiqi et al.1 Furthermore, in 2 studies,1,30 1-piece implants were used to support implant overdentures, but 2-piece implants were used to retain crowns and partially fixed dental prostheses in the study by Payer et al.32 One-piece implants may minimize bone loss by avoiding the implant abutment microgap and micromovements. Therefore, implant design, implant location, and coronal implant-supported restorations could have influenced the crestal bone levels around the implants reported in the studies comparing ZrO2 and Ti implants.1,30-32 Further long-term studies should focus on crestal bone levels around ZrO2 and Ti implants using standardized protocols.

In the present review, 38% of studies showed significant CBL around ZrO2 implants at follow-up; however, in nearly 62% of the studies,1,3,4,23-25,27,30 CBL around ZrO2 implants at baseline and follow-up was comparable. Multiple factors can explain the variability in these results. Alveolar bone remodeling is known to vary in immediate and conventionally placed implants.24-30 From the literature reviewed, in 3628,29,31,32 of the 5 studies that showed significant bone loss around ZrO2 implants, the implants were placed in healed sites as well as fresh extraction sockets, making it difficult to estimate the precise amount of CBL that occurred around ZrO2 implants. Further studies focusing on ZrO2 implants placed in either healed sites or fresh extraction sockets are warranted to determine the extent of CBL around ZrO2 implants. Other factors that could have biased the outcomes of the reported studies include smoking and the use of guided bone regeneration. In the studies in which smokers were not included,3,4,23,24,26,27,30 the duration of the habit was not reported. Smoking jeopardizes the outcome of the oral surgical procedure and increases CBL.31 In more than 45% of studies,24,25,26,30 bone augmentation procedures were performed to enhance new bone formation around ZrO2 implants. This is a potential source of bias, in that new bone formation as a result of guided bone regenerative protocols would most likely mask the contribution of dental implants (regardless of their type, ZrO2 or Ti) in maintaining crestal bone heights.35,36 Assessing whether ZrO2 implants are able to maintain crestal bone levels in a manner similar to traditional Ti implants would have been possible if ZrO2 and Ti implants had been assessed exclusively in nonsmokers without the adjunct use of guided bone regeneration.

The biologic response of periimplant soft tissue is favorable for ZrO2 implants because of the low bacterial adherence of ZrO2.11 With regard to clinical periimplant inflammatory parameters, periimplant inflammatory parameters remained uninvestigated in 2 studies.26,30 However, in the remaining studies,1,3,4,23-25,27,29,31,32 only selective clinical periimplant inflammatory parameters were investigated. For example, in the study by Brull et al.,4 BOP and PPD were assessed around ZrO2 implants, whereas PPD and BI remained uninvestigated in the study by Payer et al.32 Likewise, CAL (a critical factor in the assessment of periodontal/periimplant disease) was assessed in only 2 studies.28,29 In order to assess the influence of ZrO2 on periimplant inflammatory parameters, studies with standardized protocols are required.

CONCLUSIONS

The variations in study design and methodology make a consensus difficult regarding the efficacy of ZrO2 implants in maintaining crestal bone levels and periimplant soft tissue health. Further long-term, randomized controlled trials with a standard methodology are needed.

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