Bone Loss in the Posterior Edentulous Mandible with Implant-Supported Overdentures vs Complete Dentures: A Systematic Review and Meta-Analysis

Won-suk Oh, DDS, MS
Berna Saglik, DDS, MS
Sun-Yung Bak, DDS
Department of Biologic and Materials Sciences and Prosthodontics, University of Michigan School of Dentistry, Ann Arbor, Michigan, USA.

**Purpose:** To analyze the current evidence on bone loss in the posterior edentulous mandible restored with complete dentures (CDs), two-implant–supported overdentures (2-IODs), or four-implant–supported overdentures (4-IODs).

**Materials and Methods:** A search was conducted in the Ovid MEDLINE, Embase, Web of Science, CINAHL, and Cochrane databases for clinical studies comparing bone loss in posterior edentulous mandibles restored with CDs, 2-IODs, or 4-IODs. A meta-analysis was performed using statistical software to estimate the mean differences in bone loss with 95% CI. The level of significance was set at $P < .05$.

**Results:** The search strategy identified 2,806 articles, of which 14 met the inclusion criteria. The meta-analysis included 7 two-arm studies comparing CDs vs 2-IODs or 2-IODs vs 4-IODs. No statistically significant difference was found in bone loss between 2-IODs and CDs (mean difference $-0.25$ [95% CI $-0.85$ to $0.36$]; $P = .43$), whereas bone loss was significantly lower with 4-IODs than with 2-IODs (mean difference $-0.96$ [95% CI $-1.86$ to $-0.06$]; $P = .04$). Overall, the data were highly heterogeneous ($I^2 > 74\%$).

**Conclusion:** 4-IODs can benefit the patient by decreasing bone loss in the posterior edentulous mandible. However, 2-IODs may not be superior to CDs in reducing bone loss in the posterior mandible. A validation of these results is needed through well-designed RCTs.


Bone loss in the posterior edentulous mandible is a result of a combination of anatomical, biologic, and prosthetic effects. This process is irreversible and occurs as a consequence of remodeling of alveolar bone following the loss of periodontal ligament and tooth loss. When this process is accelerated, the stability of the denture base is compromised, risking the success of prosthodontic treatment.

The ridge mucosa is deformed under compressive loading delivered by means of a denture base. When loading is excessive, the mucosa can lose blood supply for a prolonged period of time because of the viscoelastic nature of tissue recovery. The mucosa can consequently experience deficiency of nutrients and metabolites needed for maintaining the cellular activities of mandibular bone. The mandible may lose height and rotate in the forward and upward directions, producing a pronounced Class III skeletal pattern, particularly in elderly individuals demonstrating atrophic mucosa.

Dental implants can assist the function of the denture base by enhancing support and stability. When designing mandibular two-implant–supported overdentures (2-IODs), the implants are commonly placed in the canine region anterior to the mental foramen. The base is secured to the implants by means of transmucosal abutments and transmits the stress of loading to the implant in the mandible. The ridge mucosa of the anterior mandible is spared from the loading delivered by the denture base; however, the base may rotate along the axis of rotation created by the implants and exert pressure against the posterior edentulous mandible.
Bone loss can increase as a function of the masticatory forces delivered by the base—30—the higher the forces, the greater the loss in the mandible. Patients with complete dentures (CDs) may generate approximately 25% of the occlusal forces compared to individuals retaining natural dentition. In contrast, individuals wearing 2-IODs generate significantly higher occlusal forces than individuals wearing CDs. Previous research has found contradictory results on bone loss in the posterior edentulous mandible restored with removable prostheses, and others have shown opposite results or no significant difference. Alternatively, additional placement of dental implants has been proposed to reduce bone loss; however, there is a lack of current evidence on the effect of implant support with regard to preserving the posterior edentulous mandible.

The objective of this study was to systematically review the current evidence on bone loss in the posterior edentulous mandible associated with CDs, 2-IODs, and 4-IODs. The null hypothesis assumed no significant differences between 2-IODs and CDs or between 4-IODs and 2-IODs regarding bone loss in the posterior edentulous mandible.

**MATERIALS AND METHODS**

A bibliographic search was conducted using the Ovid MEDLINE, Embase, Web of Science, CINAHL, and Cochrane databases (Table 1). The search was limited to English-language peer-reviewed articles published up to April 2019. In addition, the search terms were used on the Google search engine, followed by a manual search to identify articles relevant to the topic of bone loss in the posterior edentulous mandible.

The search was done to include randomized controlled trials and retrospective and prospective clinical studies according to the following inclusion criteria: full-text articles written in English focusing on bone loss in the posterior edentulous mandible restored with CDs, 2-IODs, or 4-IODs. The articles were identified from the electronic databases and exported to EndNote to eliminate the duplicate publications. Titles and abstracts of all the articles were screened and read by three authors (W.O., B.S.), and irrelevant studies were excluded. The exclusion criteria were as follows: abstracts; case reports; articles that dealt only with discussing bone loss with denture use; articles related to abnormal conditions, such as maxillofacial defects or treatment for systemic disease; and articles related to maxillary IODs. In addition, experimental laboratory studies, animal studies, and articles in which the main topic was unrelated to denture use and bone loss were excluded from the review.

Full-text articles pertaining to the selection criteria were included for data extraction. Each article was checked for inclusion and exclusion criteria; type of intervention; allocation concealment; balanced allocation to test and control groups; and follow-ups. Two authors (W.O., B.S.) independently reviewed all articles and extracted data from each study, including year of publication; study design; sample population; type of publication; implant support; retention mechanism; antagonist arch; follow-up; method of measurement; sociodemographic environment; funding source; and conflicts of interest. An agreement was obtained by consensus between the two reviewers. When there was a disagreement, a third reviewer (S.B.) was consulted for the final decision.

The search strategy for this systematic review was based on a Population, Intervention, Comparison, and Outcome (PICO) framework with the
Fig 1  Flowchart of study design.

following question: Do mandibular IODs induce greater bone loss in the posterior edentulous mandible in comparison to mandibular CDs? To analyze the reviewed articles in a standardized manner, the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist was used. The studies presenting at least 15 of the 22 criteria were classified as having a high methodologic quality; those presenting 8 to 14 of the criteria were classified as having moderate methodologic quality; and those presenting with less than 7 criteria were of low methodologic quality.

The data from individual studies were pooled quantitatively to perform meta-analyses using R statistical software (version 3.6.0; R Foundation for Statistical Computing). Random-effects models were used to analyze the treatment effect of bone loss with weighted mean difference and 95% confidence interval (CI) for each individual study. The effect size was calculated using chi-square test, including I² statistics to assess statistical heterogeneity. The level of significance was set at \( P < .05 \).

RESULTS

The details of selection and elimination of publications are summarized in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) study flow chart (Fig 1). A total of 22 articles pertaining to the selection criteria were identified for full-text reading. One study was unavailable, and 7 studies did not meet the inclusion criteria. Therefore, 14 studies were chosen for data extraction (Tables 2 and 3); 9 studies conducted in Europe, in Asia, 24,27 2 in Africa, and 1 in North America. The details of mean values of bone loss with standard deviation (SD) for each treatment modality of CDs, 2-IODs, and 4-IODs are summarized in Table 4.

Two studies found significantly greater bone loss in the posterior edentulous mandible with 2-IODs than with CDs, whereas two studies reported the opposite results and one study found no significant difference. Bone loss was significantly lower with 4-IODs than with 2-IODs in all three studies.

Seven studies were excluded from meta-analysis because six had only one arm for 2-IODs and one had two arms for comparing different designs of 2-IODs. Five two-arm studies were included in the meta-analysis for comparing 2-IODs and CDs, 2-IODs, and 4-IODs and one study had two subgroups with different mandibular bone heights at baseline. Three studies were compiled to analyze the effects of 4-IODs compared to 2-IODs in a meta-analysis. One study had three groups of patients for CDs, 2-IODs, and 4-IODs, and thus these data were divided into two subsets for 2-IODs vs CDs and 4-IODs vs 2-IODs.

No statistically significant difference (\( P = .43 \)) was found regarding bone loss between 2-IODs and CDs. The overall treatment effect of 2-IODs on bone loss was similar to CDs; however, the data were highly heterogenous, with a wide range of variables. The estimated amount of heterogeneity (I²) was 0.44, with 79.84% total heterogeneity (I²) based on chi-square statistics.
(χ² = 21.17, degrees of freedom [df] = 5, P = .0008). The total estimate of bone loss (weighted mean difference in bone loss between 2-IODs and CDs) was –0.25 mm, with a 95% CI of –0.85 to 0.36. The estimates of the overall results are summarized and graphically illustrated using a forest plot for visual assessment of the variation between the studies (Fig 2).

Bone loss in the posterior edentulous mandible was significantly lower with 4-IODs than with 2-IODs (P = .04). The overall treatment effect was in favor of 4-IODs over 2-IODs; however, the data were heterogeneous. The estimated amount of heterogeneity (τ²) was 0.46, with 74.02% total heterogeneity (τ²), based on chi-square statistics (χ² = 6.37, df = 2, P = .04). The total estimate of bone loss was –0.96 mm, with a 95% CI of –1.86 to –0.06 (Fig 3).

None of the 14 selected studies were classified as having low methodological quality as described by the STROBE checklist. Eight studies (57.1%) were found to be of moderate methodological quality,6,7,18,21,24,25,27,29 and 6 studies (42.9%) were of high methodological quality.19,20,22,23,26,28 Overall compliance with the STROBE checklist was 63.1% (Range: 36% to 73%, SD 11.4%).

**DISCUSSION**

CDs may induce relatively low and uniform compressive loading along the posterior edentulous mandible, whereas the mandible may be subjected to higher stresses when loaded by means of 2-IODs, in particular occlusally in the molar region and lingually in the premolar areas.24 According to Ahmad et al,24 bone loss in the posterior edentulous mandible was almost double when the mandible was restored with 2-IODs compared to CDs. There was a correlation between bone loss and stress distribution, in that the maximum bite force was nearly twice that with 2-IODs than with CDs.

Compressive loading was relatively low and uniform along the posterior edentulous mandible with CDs,10,24 whereas the mandible was subject to higher stresses when loaded by means of a 2-IOD, in particular occlusally in the molar region and lingually in the premolar areas.11,24 CDs rely entirely on the edentulous ridge for support and may lead to greater bone loss than 2-IODs.4–9 In one study, bone loss in the posterior edentulous mandible was 7.8% greater with CDs than with 2-IODs.27 Over a 5-year period, bone loss in the posterior mandible was estimated to be 2.4 times greater with CDs than with 2-IODs.20 Nevertheless, the pattern of bone loss was relatively uniform at all locations with CDs, unlike with 2-IODs.27 These results may partly relate to different mechanisms of support and retention for CDs compared to 2-IODs.10,11 CDs and 2-IODs may be similar in inducing bone loss in the posterior edentulous mandible.23 The estimated mean difference between the prostheses was statistically insignificant (P = .43). However, the range of the mean difference was wide, with a 95% CI of –0.85 to 0.36. There was a high variability of bone loss, especially

### Table 2 Summary of Studies Selected for Systematic Review and Meta-Analysis for Complete Dentures (CDs)

<table>
<thead>
<tr>
<th>Study</th>
<th>Study design</th>
<th>No. of patients</th>
<th>Mean age, y (range)</th>
<th>Edentulous period, y (range)</th>
<th>Mandibular height, mm</th>
<th>Antagonist arch</th>
<th>Follow-up, y (range)</th>
<th>Method</th>
<th>Measurement unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuncay et al, 1984</td>
<td>R</td>
<td>37 (17 men, 20 women)</td>
<td>53 (30–65)</td>
<td>13.5 (1–30)</td>
<td>NR</td>
<td>CD</td>
<td>10</td>
<td>Cephalometric</td>
<td>Loss of height (mm)</td>
</tr>
<tr>
<td>Sennery et al, 1988</td>
<td>R</td>
<td>15 (6 men, 9 women)</td>
<td>43.8</td>
<td>NA</td>
<td>NR</td>
<td>CD</td>
<td>21</td>
<td>Cephalometric</td>
<td>Loss of height (mm)</td>
</tr>
<tr>
<td>Jacobs et al, 1992</td>
<td>R</td>
<td>85 (16 men, 69 women)</td>
<td>59 (26–69)</td>
<td>13 (0.5–34)</td>
<td>NR</td>
<td>CD (77%), matural dentition (18%), implant-fixed prosthesis (5%)</td>
<td>1 (0.25–7.5)</td>
<td>Panoramic</td>
<td>Area index (annual loss)</td>
</tr>
<tr>
<td>Kordatzis et al, 2003</td>
<td>P</td>
<td>8 (2 men, 6 women)</td>
<td>60 (49–69)</td>
<td>29 (19–36)</td>
<td>&lt; 15</td>
<td>CD</td>
<td>5</td>
<td>Panoramic</td>
<td>Area index</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 (6 men, 5 women)</td>
<td>49 (35–60)</td>
<td>19 (2–33)</td>
<td>&gt; 15 and &lt; 25</td>
<td>CD</td>
<td>10</td>
<td>Panoramic</td>
<td>Area index</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 (8 men, 7 women)</td>
<td>55 (36–70)</td>
<td>21 (5–39)</td>
<td>&gt; 15 and &lt; 25 (with vestibuloplasty)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tymstra et al, 2011</td>
<td>P</td>
<td>15 (3 men, 12 women)</td>
<td>58 (47–70)</td>
<td>22.7 (± 10.3)</td>
<td>17.0 (4.8)</td>
<td>CD</td>
<td>10</td>
<td>Panoramic</td>
<td>Area index</td>
</tr>
<tr>
<td>Ahmad et al, 2015</td>
<td>P</td>
<td>9 (6 men, 3 women)</td>
<td>NR</td>
<td>&gt; 0.5</td>
<td>NR</td>
<td>CD</td>
<td>1</td>
<td>CBCT</td>
<td>Loss of volume (%)</td>
</tr>
<tr>
<td>Khuder et al, 2017</td>
<td>P</td>
<td>23 (12 men, 11 women)</td>
<td>64.9 (± 9.7)</td>
<td>6.1 (± 6.1)</td>
<td>NR</td>
<td>CD</td>
<td>1–7</td>
<td>Panoramic</td>
<td>Area index</td>
</tr>
</tbody>
</table>

R = retrospective; P = prospective; M = men; NR = not reported; CBCT = cone beam computed tomography.
Table 3  Summary of Studies Selected for Systematic Review and Meta-Analysis for Implant-Supported Overdentures (IODs)

<table>
<thead>
<tr>
<th>Study</th>
<th>Study design</th>
<th>No. of patients</th>
<th>Age, y (range)</th>
<th>Edentulous period, y (range)</th>
<th>Mandibular height, mm</th>
<th>No. of implants</th>
<th>Implant location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jacobs et al, 199218</td>
<td>R</td>
<td>30 (9 men, 21 women)</td>
<td>54 (38–68)</td>
<td>10 (0.5–36)</td>
<td>NR</td>
<td>2</td>
<td>Between mental foramina</td>
</tr>
<tr>
<td>Wright et al, 200219</td>
<td>P</td>
<td>21 (1 man, 20 women)</td>
<td>53(29–93)</td>
<td>14.7 (2–32)</td>
<td>NR</td>
<td>2</td>
<td>NR</td>
</tr>
<tr>
<td>Kordatzis et al, 200320</td>
<td>P</td>
<td>18 (2 men, 16 women)</td>
<td>52 (36–72)</td>
<td>23 (5–38)</td>
<td>&lt; 15</td>
<td>2</td>
<td>Between mental foramina</td>
</tr>
<tr>
<td>de Jong et al, 201021</td>
<td>P</td>
<td>23 (NR)</td>
<td>54 (38–77)</td>
<td>21 (9)</td>
<td>15.8 (2.3)</td>
<td>2</td>
<td>Canine</td>
</tr>
<tr>
<td>Tymstra et al, 201123</td>
<td>R</td>
<td>16 (3 men, 13 women)</td>
<td>54.2 (38–70)</td>
<td>20.2 (8.9)</td>
<td>15.7 (2.9)</td>
<td>2</td>
<td>Canine</td>
</tr>
<tr>
<td>Ahmad et al, 201524</td>
<td>P</td>
<td>20 (8 men, 12 women)</td>
<td>NA</td>
<td>&gt; 0.5</td>
<td>NR</td>
<td>2</td>
<td>Canine</td>
</tr>
<tr>
<td>Mosnegutu et al, 201525</td>
<td>R</td>
<td>82 (NR)</td>
<td>54.7 (35–79)</td>
<td>21.8 (10.5)</td>
<td>15.7 (2.7)</td>
<td>2</td>
<td>Canine</td>
</tr>
<tr>
<td>Raedel et al, 201526</td>
<td>R</td>
<td>23 (8 men, 15 women)</td>
<td>61.4 (8.82)</td>
<td>19.8 (8.3)</td>
<td>15.0 (2.3)</td>
<td>2</td>
<td>Canine</td>
</tr>
<tr>
<td>Khuder et al, 201727</td>
<td>R</td>
<td>23 (6 men, 17 women)</td>
<td>66.2 (8.4)</td>
<td>5.4 (5.9)</td>
<td>NR</td>
<td>2</td>
<td>Parasympysis</td>
</tr>
<tr>
<td>Elysad et al, 201728</td>
<td>P</td>
<td>10 (7 men, 3 women)</td>
<td>58.33 (3.51)</td>
<td>2.16 (1.04)</td>
<td>31.99 (2.86)</td>
<td>2</td>
<td>Canine</td>
</tr>
<tr>
<td>Elysad et al, 201729</td>
<td>R</td>
<td>9 (NR)</td>
<td>62.1</td>
<td>14.2</td>
<td>20</td>
<td>2</td>
<td>Canine</td>
</tr>
</tbody>
</table>

R = retrospective; P = prospective; NR = not reported; CD = complete denture; RPD = removable partial denture; CBCT = cone beam computed tomography.

Table 4  Mean and Standard Deviation (SD) Values of Bone Loss with Complete Dentures (CDs), 2-Implant–Supported Overdentures (2-IODs), or 4-Implant–Supported Overdentures (4-IODs)

<table>
<thead>
<tr>
<th>Study</th>
<th>CD</th>
<th>Mandibular height/retention mechanism</th>
<th>No. of patients</th>
<th>Mean bone loss</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jacobs et al, 199218</td>
<td>CD</td>
<td>R</td>
<td>37</td>
<td>2.14 mm</td>
<td>0.19 mm</td>
</tr>
<tr>
<td>Sennerby et al, 19887</td>
<td>CD</td>
<td>P</td>
<td>15</td>
<td>22.3%</td>
<td>NA</td>
</tr>
<tr>
<td>Wright et al, 200219</td>
<td>CD</td>
<td>R</td>
<td>85</td>
<td>0.1</td>
<td>0.19</td>
</tr>
<tr>
<td>Kordatzis et al, 200320</td>
<td>CD</td>
<td>R</td>
<td>8</td>
<td>0.11</td>
<td>0.06</td>
</tr>
<tr>
<td>de Jong et al, 201022</td>
<td>CD</td>
<td>R</td>
<td>15</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>Tymstra et al, 201123</td>
<td>CD</td>
<td>P</td>
<td>9</td>
<td>1.9%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Mosnegutu et al, 201525</td>
<td>CD</td>
<td>R</td>
<td>23</td>
<td>0.123</td>
<td>0.116</td>
</tr>
<tr>
<td>Raedel et al, 201526</td>
<td>CD</td>
<td>R</td>
<td>15</td>
<td>0.16</td>
<td>0.09</td>
</tr>
<tr>
<td>Khuder et al, 201727</td>
<td>CD</td>
<td>R</td>
<td>23</td>
<td>0.123</td>
<td>0.116</td>
</tr>
<tr>
<td>Elysad et al, 201728</td>
<td>CD</td>
<td>R</td>
<td>9</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Elysad et al, 201729</td>
<td>CD</td>
<td>R</td>
<td>23</td>
<td>0.123</td>
<td>0.116</td>
</tr>
</tbody>
</table>

© 2020 BY QUINTESSENCE PUBLISHING CO, INC. PRINTING OF THIS DOCUMENT IS RESTRICTED TO PERSONAL USE ONLY. NO PART MAY BE REPRODUCED OR TRANSMITTED IN ANY FORM WITHOUT WRITTEN PERMISSION FROM THE PUBLISHER.
Bone loss was mostly measured radiographically to quantify the changes in the posterior edentulous mandible. Bone loss in the posterior edentulous mandible decreased with an increase in the patient’s age. Patients who presented with greater volume of alveolar bone were more liable to suffer bone loss than those who displayed a more resorbed and compact mandible. The atrophic mandible commonly found in elderly individuals displayed little or no residual alveolar bone prior to initiation of the study.
However, the effect of age on bone loss was statistically insignificant.\textsuperscript{18–20,22} Women appear to have greater risk of bone loss than men wearing CDs or 2-IODs.\textsuperscript{1,9,18} Bone loss was more than 3 times the threshold level (4%) in 21% of women compared to 8% of men.\textsuperscript{18} Overall, bone loss was 7.5% less in men (0.9 mm less over 5 years) than in women regardless of the baseline height of the mandible and edentulous period.\textsuperscript{20} However, the data were statistically insignificant between men and women.\textsuperscript{19,20,22}

The antagonist teeth/arch may have a significant effect on bone loss in the posterior edentulous mandible.\textsuperscript{9,18,35} Bone loss was greater in the posterior mandible when opposing maxillary CDs than when opposing natural dentition.\textsuperscript{18,35} This result is interesting because the occlusal force is lower when opposing CDs.\textsuperscript{30} The posterior mandible, however, may be subject to greater stresses when the maxillary denture rotates with the pronounced incising action of 2-IODs.\textsuperscript{11,13,14} According to Colaiuzzi et al,\textsuperscript{36} the mandible displays a greater degree of the lateral component of the masticatory cycle with CDs than with natural dentition.

Bone loss of the posterior edentulous mandible was significantly lower with 4-IODs than with 2-IODs.\textsuperscript{22,23,28} This finding was consistent in all three studies, which indicates the significance of additional implant placement in the posterior mandible.\textsuperscript{22,23,28} Some of the posterior implants were placed anterior to the mental foramen and connected with anterior implants by means of an implant-connecting bar,\textsuperscript{22,23} and others were located at the first molar sites and received healing abutments.\textsuperscript{28} With the addition of posterior implants, the axis of rotation may shift to a more posterior direction, subjecting less stress to the posterior mandible.

The denture base should be designed to cover the retromolar region. This anatomical landmark was shown to demonstrate the least amount of bone loss and should serve as a stable posterior reference structure for the design of the denture base.\textsuperscript{7,37} The anterior edentulous mandible was least stable; bone loss was 3.3 times higher than the retromolar region.\textsuperscript{7} However, no bone loss was detected in the anterior mandible, where the implants were placed to support 2-IODs.\textsuperscript{18}

The limitations of this study include variations in effect size with methods of data collection and patient sampling across the studies. Most studies collected data based on panoramic,\textsuperscript{18–20,22,23,25–29} cephalometric,\textsuperscript{6,7} or CBCT radiographic images,\textsuperscript{24} and one study used cast models.\textsuperscript{21} The follow-ups were inconsistent and ranged from 1 to 24 years of bone loss measured in different units. Some studies measured the loss of height,\textsuperscript{6,7} and others reported the loss of volume\textsuperscript{24} or percentile loss of area compared to a reference.\textsuperscript{18–23,25–29} Other variables included variations in implant location, retention mechanism, and antagonist arch. The search for publications was thorough to select the articles conforming...
to the inclusion criteria; however, publication bias could not be excluded because of inaccessibility to unpublished studies.

CONCLUSIONS

Within the limitations of the current systematic review and meta-analysis, the following conclusions were drawn:

- Bone loss in the posterior edentulous mandible was lower when the mandible was restored with 4-IODs rather than with 2-IODs.
- Bone loss in the posterior edentulous mandible was similar when the mandible was restored with 2-IODs and CDs.

REFERENCES