Does mandibular edentulous bone height affect prosthetic treatment success?

Shaoxia Pan, Marie Dagenais, J. Mark Thomason, Manal Awad, Elham Emami, Suguru Kimoto, Stephanie D. Wollin, Jocelyne S. Feine

Department of Prosthodontics, Peking University, School and Hospital of Stomatology, Beijing, China
Faculty of Dentistry, McGill University, Montreal, Canada
School of Dental Sciences, Newcastle University, Newcastle upon Tyne, UK
College of Dentistry, Department of Clinical and Specialist Dental Practice, University of Sharjah, United Arab Emirates
Faculty of Dentistry, Université de Montréal, Montreal, Canada
Department of Gnatho-Oral Prosthodontic Rehabilitation, Nihon University School of Dentistry at Matsudo, Mastudo, Chiba, Japan
Department of Epidemiology and Biostatistics, Faculty of Medicine, McGill University, Canada
Department of Oncology, Faculty of Medicine, McGill University, Canada

A B S T R A C T

Objectives: The aim of this study is to determine whether mandibular bone height affects patients' ratings of satisfaction and function with mandibular 2-implant overdentures (IODs) and conventional dentures (CDs).

Methods: 214 edentulous elders were randomly allocated into 2 groups and treated with maxillary CDs and either mandibular CDs or IODs. Classifications of mandibular bone height were carried out on panoramic radiographs using 4 published methods. At baseline and 6 months after delivery, all participants rated their satisfaction with their prostheses using the McGill Denture Satisfaction Instrument. Independent t-tests and a linear multivariable regression model were used for statistical analyses.

Results: Mandibular bone height has no effect on patients' ratings of general satisfaction, nor on ratings of ability to chew, stability, comfort, aesthetics and ability to speak at 6 months (p > 0.05, linear regression). There were significant between treatment differences in ratings of general satisfaction, comfort, stability and ability to chew from all mandibular bone height categories, with higher ratings assigned to IODs (p < 0.01, t-tests). Linear regression analyses confirmed that, for general satisfaction, as well as ability to chew, stability, comfort, aesthetics and ability to speak, treatment with IODs contributes to higher satisfaction ratings (p < 0.001), while mandibular bone height does not.

Conclusions: The evidence demonstrates that mandibular bone height has no effect on patients' satisfaction with the function, chewing ability and comfort of their prostheses. Furthermore, no matter how much mandibular bone, these results suggest that edentulous elders will benefit more from mandibular IODs than from CDs.

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Keywords:
Conventional denture
Implant overdenture
Mandibular ridge resorption
Bone height
Satisfaction
Chewing ability
Elders
1. Introduction

It is generally accepted that residual ridge resorption is a major factor in the failure of traditional oral rehabilitation for edentulous patients. The volume of the alveolar process is thought to be key for retention and stability of dentures. The greater the vertical height of the alveolar ridge, the greater the surface area of the vestibular and sublingual regions, on which the denture rests. Bone loss leads to a decrease in the size of the denture-bearing area, thereby reducing denture stability, which causes insufficient retention of the lower denture, difficulties with eating and speech and altered facial appearance. These problems are a great challenge for clinicians who attempt to provide a satisfactory solution for their patients’ oral health problems.

Implants are used to retain or support dentures in edentulous patients, and mandibular 2-implant overdentures (IOD) have been shown to be superior to conventional dentures (CD) in randomized clinical trials. Mandibular overdentures on 2 implants are more retentive, and patients report that it is easier to chew and to speak with implant overdentures. Some authors have suggested that the volume of the available bone to support an implant prosthesis may play a role in the amount of benefit it will provide. They have suggested that mandibular bone volume should be controlled for in evaluations of implant prosthesis efficacy.

Therefore, we wished to know what impact the mandibular bone height has on the success of both conventional and implant overdentures.

The primary hypothesis in this study is:
Patients’ ratings of their general satisfaction, chewing ability and comfort with their mandibular conventional dentures and 2-implant overdentures are positively correlated with mandibular bone height.

2. Materials and methods

Data for this study were collected in a randomized controlled clinical trial (RCT) comparing mandibular conventional dentures and implant overdentures among 255 edentulous participants between the ages of 65 and 87 years (Fig. 1). All signed an informed consent that was approved with the study protocol by the Institutional Review Board of McGill University. Due to the loss of 25 participants who withdrew from the RCT following randomization, data from 230 participants were included in this study.

2.1. Clinical procedure

Detailed descriptions of the RCT study design and methods have been previously reported. One hundred forty one females and 114 males were recruited to participate in a randomized controlled clinical trial (RCT). In general, advertisements for subjects willing to participate in a clinical trial of mandibular conventional dentures or 2-implant overdentures were placed in local French and English newspapers, as well as in a monthly periodical for retired people. Respondents who

Fig. 1 – Study flow chart.
met the requirements in a telephone screening \((n = 730)\) were invited to an information session, in which the research assistant explained all aspects of the treatment and the study. Those interested in participating were then given a clinical examination to confirm that they had adequate bone for 2 implants to be placed in the anterior mandible. People meeting the inclusion criteria (Table 1) were then individually asked if they wished to participate and, if so, were invited to sign and confirm informed consent. The McGill University Institutional Review Board approved the protocol and the consent form. Treatment was randomly assigned using an offsite data management company, and patients were stratified by sex and the presence of type II diabetes to reduce potential selection bias.

Patients were randomly allocated into 2 groups and treated either with maxillary conventional dentures and mandibular overdentures supported by two implants with ball attachments or with maxillary and mandibular conventional dentures. Standard surgical and prosthodontic procedures were followed, as in previous RCTs conducted by this group.6,7

The maxillo-mandibular relationship was recorded for each patient by the examining clinician at the start of the RCT, according to the protocol from the previous study.11

### 2.2 Ratings of denture satisfaction

Prior to the provision of treatment and at 6 months after delivery of the prostheses, all subjects were asked to rate their satisfaction with their new prostheses using the McGill Denture Satisfaction Instrument.12 That is, for each of the outcomes, participants were asked to rate on 100-mm visual analogue scales (VAS), their satisfaction with their mandibular prostheses, for which higher ratings indicate greater satisfaction. Using the same scale, level of comfort, stability and ability to chew, as well as ease of cleaning, speech and aesthetics were also assessed.

### 2.3 Sample size

The primary outcome for this RCT was designed to evaluate the nutritional state of the patients in the different treatment groups at 6 and 12 months post delivery. In this report, we present findings on the secondary outcome, treatment satisfaction. It was estimated that 30 edentulous subjects per treatment group would provide 80% power with a type I error of 0.05, for a clinical meaningful difference of 20 mm in general satisfaction measured on a 100 mm VAS and variance \(\sigma^2\). With over 100 edentulous participants in each treatment group, this study is sufficiently powered to assess ratings of satisfaction according to treatment received.

### 2.4 Choice of classification methods

Several methods have been described previously to classify the characteristics of the mandible.13–16 Four of these (Cawood & Howell,13 American College of Prosthodontics,14 Wical & Swoope15 and Xie16) were used in this study to rate mandibular bone height or alveolar resorption on panoramic radiographs. We used all four methods as they have been previously published and accepted.

Anatomic landmarks used and rating criteria of these four classification methods are different (Table 1).

### Table 1 - Classifications used in mandible bone height assessment.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Anatomic landmark</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>American College of Prosthodontics (ACP)</td>
<td>Least height</td>
<td>I: (\geq 21) mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>II: (16 &lt; H &lt; 20) mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>III: (11 &lt; H &lt; 15) mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IV: (\leq 10) mm</td>
</tr>
<tr>
<td>Cawood &amp; Howell</td>
<td>Anterior: midline</td>
<td>Anterior</td>
</tr>
<tr>
<td></td>
<td>Posterior: mental foramen</td>
<td>Posterior</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I: (\geq 25) mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>II: (\leq 25) mm</td>
</tr>
<tr>
<td>Wical &amp; Swoope</td>
<td>Mental foramen</td>
<td>I: (\leq 1/3) height loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>II: (1/3–2/3) height loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>III: (\geq 2/3) height loss</td>
</tr>
<tr>
<td>Xie</td>
<td>Mental foramen and mandibular canal</td>
<td>Grade 0: The crest of the residual ridge above both the mental foramen and the mandibular canal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grade I: The crest of the residual ridge above the mandibular canal and the mental foramen at the top of the residual ridge with or without a partially resorbed border</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grade II: The superior border of the mandibular canal at the top of the residual ridge and the mental foramen with or without a partially resorbed border</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grade III: The superior border of the mandibular canal partially resorbed and the borders of the mental foramen totally resorbed</td>
</tr>
</tbody>
</table>

Here we list the American College of Prosthodontics (ACP) method of classification as follows:

a. Type I: Residual bone height of 21 mm or greater measured at the least vertical height of the mandible;
b. Type II: Residual bone height of 16–20 mm measured at the least vertical height of the mandible;
c. Type III: Residual alveolar bone height of 11–15 mm measured at the least vertical height of the mandible;
d. Type IV: Residual vertical bone height of 10 mm or less measured at the least vertical height of the mandible.

The other classifications can be found in Table 1.

2.5. Assessment of mandibular bone height from panoramic radiographs

The study protocol for this RCT stipulated that standard panoramic radiographs of all patients were to be used to evaluate mandibular bone height. All panoramic radiographs were screened by an experienced professional radiologist (MD), and any with distortion or over/under exposure was excluded from this study. All included radiographs were assessed using all four methods.

One examiner, who had previously been trained to measure bone height, was calibrated with the professional oral radiologist using 10% of the radiographs. The examiner then measured mandibular bone height for all patients. Intra-examiner differences were tested by a reassessment of all of the radiographs at an interval of 1 month. To show the reliability of the 4 methods when used by different prosthodontists, and to confirm inter-examiner reliability, half of the radiographs were also measured by another calibrated one.

Each radiograph was viewed on a standard light box. A light gathering magnifier (Magnabrite 4’, Visual Aid lab, Inc.) was used to ensure clear observation of the details of each image. According to the four classification methods used in the study, measurements were conducted at five positions on each panoramic radiograph. The five positions were: midline, least height on both sides of the mandible and on both mental foramina (Fig. 2). At each of those five positions a vertical line was drawn to make a 90° intersection with a horizontal line traced tangentially from the most inferior points on the mandibular angle through the lowest points of the mandibular body (Fig. 2). The magnification ratio of each panoramic radiograph was considered in the classification.

All cases were then classified according to specific criteria for each of the classification methods (Table 1). In Cawood’s, ACP’s and Wical’s classifications, mandibular bone height was graded using the data measured from the panoramic radiographs, while in Xie’s classification, mandibular ridge resorption was evaluated by visually rating the resorption of mental foramina and the wall of the mandibular canal.

2.6. Statistical analyses

Statistical analyses were conducted using SPSS14.0. Independent t-tests were used to compare mean differences between the two treatment groups for different categories of mandibular bone height. Multivariable linear regression analyses were carried out to explore the relationship between patients’ ratings of each of the dependent variables (general satisfaction, stability, chewing ability, comfort, aesthetics and speech) and treatment group (CD and IOD), adjusting for mandibular bone height, sex, maxillo-mandibular relationship, pretreatment satisfaction, and we also tested the interaction term between type of treatment and sex.

3. Results

Of 230 participants, 16 were excluded because of image distortion and/or over/under exposure of their panoramic radiographs. The remaining participants (n = 214) represented 107 subjects in the CD group and 107 subjects in the IOD group (Fig. 1). The mean age of the study population was 72.1 ± 4.5 years (range from 65 to 87 years, composed of 116 females and 98 males).

3.1. Mandibular bone height

The distribution of the participants’ mandibular bone heights according to the four classification methods are shown in Table 2a. Distributions of the participants’ maxillo-mandibular relationships according to treatment received are shown in Table 2b.

Both the Conventional Denture group and the Implant Overdenture Group were equivalent in bone height distribution, as well as in distribution of maxillo-mandibular relationships.

Inter-examiner reliability of the four classification methods of mandibular bone height were Kappa = 0.70–0.90, and those for intra-examiner reliability were Kappa values ranged from 0.85 to 0.96.

All classification methods of mandibular bone height yielded similar results, so only the results from American College of Prosthodontists (ACP) Classification System for Complete Edentulism will be discussed in detail.

Using the ACP system, participants were classified into four categories. Since only a few participants in our study group (n = 6) fit into the mandibular bone height category I classification, we used a modified ACP classification, i.e., the category 1 classification (>21 mm) was combined with the category II (>16 mm to <21 mm; Table 2a). The majority of the study participants (79.1% of CD group and 85.6% of IOD group) fit into categories III (11–16 mm) and IV (<10 mm).

Fig. 2 – Five positions of mandibular bone height assessment.
3.2. Satisfaction with post-treatment prostheses

Six months after delivery of the prostheses, participants in the IOD group rated their general satisfaction, as well as comfort, stability, ability to chew, speech and aesthetics with their prostheses significantly higher than those in the CD group ($p's < 0.01$, t-test).

In each mandibular bone height ACP category, significant between treatment differences in ratings of general satisfaction were observed ($P's < 0.01$, t-test; Table 3). These differences were also seen for patients' ratings of comfort, stability and ability to chew ($p < 0.01$, t-test). Irrespective of mandibular bone height, participants in the IOD group reported significantly less difficulty in chewing all the different foods except bread than did those in the CD group ($p < 0.05$, t-test).

3.3. Satisfaction and mandibular bone height

No significant differences were found in ratings of general satisfaction, function, comfort, stability and aesthetics in either treatment between the different bone height categories ($p > 0.05$, two-way ANOVA).

3.4. Final model

Multivariate linear regression analyses models were used to analyze the relationship between participants’ ratings of their prostheses 6 months after delivery and type of treatment received, adjusting for mandibular bone height, maxillo-mandibular relationship, sex, pretreatment ratings of satisfaction and interaction between sex and type of prosthesis.

For general satisfaction, as well as ability to chew, stability, comfort, aesthetics and ability to speak, results confirm that at 6 months after delivery, treatment with implant overdentures and being male are favourable factors that contribute to higher satisfaction (Table 4).

Mandibular bone height has no effect on ratings of satisfaction with the prostheses, nor on ratings of function at 6 months following delivery (Table 4).

The interaction term between sex and type of prosthesis was significant ($p = 0.008$), indicating that the relationship between ratings of chewing ability and prosthesis is different for males than for females.

4. Discussion

There is a common belief that the condition of the edentulous mandible will have an impact on the success of prosthetic treatment. In this study, we tested the effect of mandibular bone height on patients’ ratings of their satisfaction and function with new mandibular conventional dentures and 2-implant overdentures.
4.1. Mandibular bone height and satisfaction

One would presume that bone height is associated with satisfaction and function for conventional dentures, if not for implant overdentures. Surprisingly, no differences in patients’ ratings of satisfaction and chewing ability were associated with their various mandibular bone heights, no matter which prosthesis the patient was wearing. Furthermore, we found that, for both treatments, ratings of denture satisfaction and function were not related to patients’ maxillo-mandibular relationship.

Our results agree with those of previous studies on conventional dentures, in which no correlation was found between patients’ ratings of satisfaction and the condition of the edentulous jaws.\(^1\)\(^8\)–\(^2\)\(^0\)

One research group found that both types of mandibular prostheses (IOD and CD) were rated equally by patients with low, moderate and high ridge heights.\(^2\)\(^1\) Their finding, that there is no ridge height effect on patients’ ratings of satisfaction, agrees with the findings in this study. However, the lack of differences in ratings of satisfaction between treatment groups in that study could have been due to inadequate power for the assessment. The larger sample size in the present study and the fact that significance was found for other factors, suggests that this study has adequate power to conclude that there is no effect.

It has been reported that advanced residual ridge resorption results in problems with conventional lower dentures, such as insufficient retention and difficulties with eating and speech.\(^2\)\(^\) In our previous study,\(^9\) we found that females were less satisfied than males with their new conventional dentures. This sex difference was not detected in those who received implant overdentures.\(^9\)

In this study, the association between treatment received and chewing ability is different for males and females. In general, males rated their chewing abilities higher than females, irrespective of treatment received. However, the negative coefficient for the interaction term of treatment and sex indicates that males tend to rate their chewing abilities with implant overdentures significantly lower than females. Alternatively, it appears that edentulous females’ chewing abilities significantly improve with the provision of implant overdentures relative to males. It has been suggested that differences in the amount of remaining alveolar bone could be an important factor affecting denture support, retention, stability and masticatory function.\(^1\)\(^7\) Engstrom et al. has shown that females have relatively less alveolar bone height than males. Other studies have shown that conventional denture wearers who have greater vertical bone height perform better in chewing efficiency tests than those who have less bone height.\(^2\)\(^2\)\(^,\)\(^2\)\(^3\)

However, we found in this study that, although sex is a contributing factor to patients’ satisfaction, mandibular bone height did not contribute to these differences. Therefore, if sex differences are not related to mandibular physical condition, perhaps psychological factors, which were not measured in this study, may be a contributing factor to sex differences in denture satisfaction.

4.2. Sex differences and denture satisfaction

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mandibular least bone height ≥16 mm²</th>
<th>Mandibular least bone height 11–16 mm²</th>
<th>Mandibular least bone height ≤11 mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>General satisfaction</td>
<td>Mean: 28** 95% CI: 11.45</td>
<td>Mean: 19** 95% CI: 9.29</td>
<td>Mean: 19** 95% CI: 7.31</td>
</tr>
<tr>
<td>Comfort</td>
<td>Mean: 30** 95% CI: 12.48</td>
<td>Mean: 18** 95% CI: 8.28</td>
<td>Mean: 25** 95% CI: 11.39</td>
</tr>
<tr>
<td>Stability</td>
<td>Mean: 26 95% CI: 6.45</td>
<td>Mean: 16** 95% CI: 6.27</td>
<td>Mean: 16 95% CI: 2.30</td>
</tr>
<tr>
<td>Speech</td>
<td>Mean: 12 95% CI: 0.42,3</td>
<td>Mean: 9 95% CI: 1.16</td>
<td>Mean: 7 95% CI: 4.19</td>
</tr>
<tr>
<td>Ability to clean</td>
<td>Mean: 5 95% CI: −11.21</td>
<td>Mean: 1 95% CI: −5.7</td>
<td>Mean: 0 95% CI: −9.10</td>
</tr>
<tr>
<td>Esthetics</td>
<td>Mean: 19 95% CI: 3.35</td>
<td>Mean: 8 95% CI: 1.16</td>
<td>Mean: 5 95% CI: 8.18</td>
</tr>
<tr>
<td>General ability to chew</td>
<td>Mean: 20 95% CI: 4.37</td>
<td>Mean: 17** 95% CI: 7.27</td>
<td>Mean: 21** 95% CI: 8.34</td>
</tr>
<tr>
<td>Bread</td>
<td>Mean: 20 95% CI: 3.37</td>
<td>Mean: 7 95% CI: 3.18</td>
<td>Mean: 13 95% CI: 1.25</td>
</tr>
<tr>
<td>Cheese</td>
<td>Mean: 18 95% CI: 4.31</td>
<td>Mean: 18** 95% CI: 8.27</td>
<td>Mean: 17** 95% CI: 5.29</td>
</tr>
<tr>
<td>Carrot</td>
<td>Mean: 22 95% CI: 0.01,45</td>
<td>Mean: 32** 95% CI: 19.45</td>
<td>Mean: 37** 95% CI: 23.51</td>
</tr>
<tr>
<td>Salami</td>
<td>Mean: 23 95% CI: 16.50</td>
<td>Mean: 24** 95% CI: 10.37</td>
<td>Mean: 28** 95% CI: 14.42</td>
</tr>
<tr>
<td>Steak</td>
<td>Mean: 27** 95% CI: 10.44</td>
<td>Mean: 21** 95% CI: 10.33</td>
<td>Mean: 34** 95% CI: 19.48</td>
</tr>
<tr>
<td>Apple</td>
<td>Mean: 29 95% CI: 6.51</td>
<td>Mean: 32** 95% CI: 21.42</td>
<td>Mean: 28** 95% CI: 14.43</td>
</tr>
<tr>
<td>Lettuce</td>
<td>Mean: 34** 95% CI: 17.50</td>
<td>Mean: 16** 95% CI: 6.25</td>
<td>Mean: 21** 95% CI: 8.34</td>
</tr>
</tbody>
</table>

a Based on independent t-test.
*p < 0.05.
**p < 0.01.
***p < 0.001.

Table 3 – Mean difference and 95% confidence interval (CI) between CD and IOD satisfaction scores.\(^a\) according to ACP classification (6 months).

4.3. Differences between treatment groups

No matter what the mandibular condition, differences in satisfaction and function ratings were found only between the
two treatment groups, with higher ratings assigned to the implant overdentures than to the conventional dentures. This finding supports those from other investigations,\(^4\)\(^5\) in which researchers found that the IOD group scored significantly better than the CD group with respect to chewing ability,\(^5\) and simple implant treatment such as an overdenture retained by two ball attachments is sufficient for edentulous patients with atrophic mandibles.\(^4\)
4.4. Four methods of classification of bone height

Four bone height classification methods were used in this study.13–16 We found that, no matter which method was used, patients’ ratings of satisfaction were unrelated to mandibular bone height.

According to the Cawood and Howell classification method, half of the participants in this study had higher and half had lower mandibular bone height. Similarly, Xie’s classification assigned half into the good bone height category. However, both the ACP and the Wical and Swoope classification methods indicated that the majority of our study participants had moderate to poor bone height.

The discrepancies amongst these methods should be noted. However, each focuses on different aspects of the mandible. Of the four methods, those from the ACP are the easiest to use and most clearly identified on almost all of the panoramic radiographs. For the Cawood & Howell and Wical & Swoope classification methods, identification of the mental foramen was difficult on some radiographs, and measures could not be taken on 17% of the panoramic radiographs. Xie’s method is different from the others, because the classification is determined from an overview of the radiograph, instead of from direct measurement. This method focuses mainly on the involvement of the mandibular mental foramen and canal in residual ridge resorption. Because of this, Xie’s method may be more useful in studies of denture-related discomfort and pain.

5. Conclusion

The evidence from this study demonstrates that mandibular bone height has no effect on patients’ satisfaction of their function, chewing ability and comfort with mandibular prostheses. In fact, no matter how high the mandibular bone, these results suggest that edentulous elders will benefit more from mandibular implant prostheses than from conventional dentures.

Acknowledgements

The authors are very grateful to all of the participants in this trial, as well as to Mr. Nicolas Drolet for data collection. This study was funded by Grant no. UCR-36052 from the Canadian Institutes of Health Research (CIHR) and Straumann Canada, Limited. Dr. Shaoxia Pan is supported by the China Scholarship Council and by the McGill University Faculty of Dentistry Hong Kong Fellowship.

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