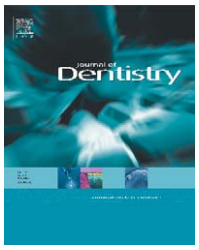
JOURNAL OF DENTISTRY 38 (2010) 899–907

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/jden



Does mandibular edentulous bone height affect prosthetic treatment success?☆

Shaoxia Pan[a], *Marie Dagenais*[b], *J. Mark Thomason*[b,c], *Manal Awad*[d], *Elham Emami*[b,e], *Suguru Kimoto*[f], *Stephanie D. Wollin*[b], *Jocelyne S. Feine*[b,g,h,*]

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

ARTICLE INFO

Article history:
Received 7 July 2010
Received in revised form
1 August 2010
Accepted 3 August 2010

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

ABSTRACT

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.

☆ The clinical trial registration number: ISRCTN24273915.

* *Corresponding author at*: Faculty of Dentistry, McGill University, 3550 University Street, Suite 101, Montreal, Quebec, H3A 2A7, Canada. Tel.: +1 514 398 7203x00052; fax: +1 514 398 7220.
E-mail address: jocelyne.feine@mcgill.ca (J.S. Feine).

0300-5712/$ – see front matter
doi:10.1016/j.jdent.2010.08.002

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.[1] Bone loss leads to a decrease in the size of the denture-bearing area, thereby reducing denture stability,[2] 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.[3]

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.[4–6] Mandibular overdentures on 2 implants are more retentive, and patients report that it is easier to chew and to speak with implant overdentures.[7] 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.[8]

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.[9]

2.1. *Clinical procedure*

Detailed descriptions of the RCT study design and methods have been previously reported.[9,10] 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

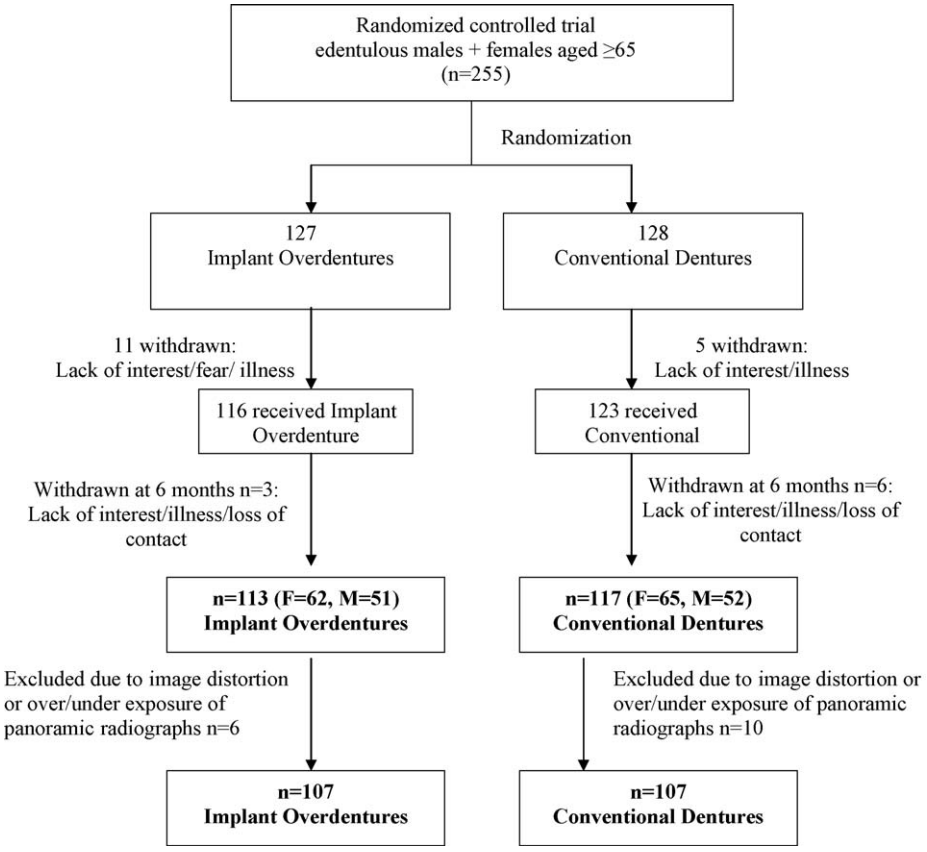


Fig. 1 – Study flow chart.

Table 1 – Classifications used in mandible bone height assessment.

Classification	Anatomic landmark	Classification	
American College of Prosthodontics (ACP)	Least height	I: ≥21 mm II: 16 mm < *H* < 20 mm III: 11 mm < *H*< 15 mm IV: ≤10 mm	
Cawood & Howell	Anterior: midline Posterior: mental foramen	Anterior I: ≥25 mm II: <25 mm	Posterior I: ≥16 mm II: <16 mm
Wical & Swoope	Mental foramen	I: 1/3 height loss II: 1/3–2/3 height loss III: ≥2/3 height loss	
Xie	Mental foramen and mandibular canal	Grade 0: The crest of the residual ridge above both the mental foramen and the mandibular canal 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 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 Grade III: The superior border of the mandibular canal partially resorbed and the borders of the mental foramen totally resorbed	

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 $(25)^2$.[6] 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 & Swoope[15] and Xie[16]) 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).

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,[13,14] measurements were conducted at five positions on each panoramic radiograph.[17] The five positions were: midline, least height on both sides of the mandible and on both mental foramina (Fig. 2). At each of those 5 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.

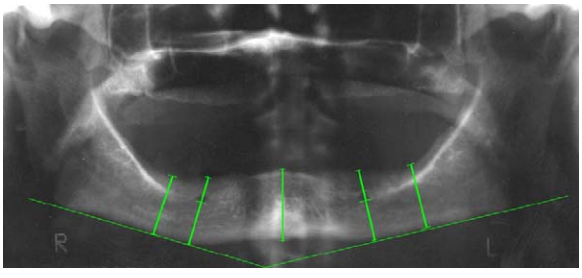


Fig. 2 – Five positions of mandibular bone height assessment.

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 I classification ($\geq$21 mm) was combined with the category II (>16 mm to <21 mm; Table 2a). The majority of the study participants (79.1% of CD group and 85.6% of IOD group) fit into categories III (11–16 mm) and IV ($\leq$10 mm).

Table 2a – Distributions of patients' mandibular bone height according to treatment received by using modified ACP classification, Cawood & Howell classification, Wical & Swoope classification and Xie classification.

		CD		IOD	
		Frequency	Valid percent (%)	Frequency	Valid percent (%)
Modified ACP classification[a]	≥16 mm	22	21.0	15	14.4
	11–16 mm	53	50.5	50	48.1
	≤11 mm	30	28.6	39	37.5
	Unreadable	2		3	
Cawood & Howell	≥16 mm	46	50	38	44.2
	<16 mm	46	50	48	55.8
	Unreadable	15		21	
Wical & Swoope	1/3 height loss	11	12.0	7	8.1
	1/3–2/3 height loss	65	70.7	66	76.7
	≥2/3 height loss	16	17.4	13	15.1
	Unreadable	15		21	
Xie	Grade 0	52	51.5	50	48.1
	Grade 1	24	23.8	16	15.4
	Grade 2	11	10.9	22	21.2
	Grade 3	14	13.9	16	15.4
	Unreadable	6		3	

[a] In ACP classification, first two categories were combined due to insufficient patients number in first category (least bone height ≥21 mm).

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.

Table 2b – Distributions of patients' maxillo-mandibular relationship, mandibular ridge form and soft tissue quality according to treatment received.

		CD		IOD	
		Frequency	Valid percent (%)	Frequency	Valid percent (%)
Maxillo-mandibular relationship	Class I	67	70.5	74	79.6
	Class III	28	29.5	19	20.4
	Missing	12		14	

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

Variable	Mandibular least bone height ≥16 mm²		Mandibular least bone height 11–16 mm²		Mandibular least bone height ≤11 mm²	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
General satisfaction	28**	11,45	19***	9,29	19**	7,31
Comfort	30**	12,48	18***	8,28	25**	11,39
Stability	26*	6,45	16**	6,27	16*	2,30
Speech	12*	0.4,23	9*	1,16	7	−4,19
Ability to clean	5	−11,21	1	−5,7	0	−9,10
Esthetics	19*	3,35	8*	1,16	5	−8,18
General ability to chew	20*	4,37	17**	7,27	21**	8,34
Bread	20*	3,37	7	−3,18	13*	1,25
Cheese	18*	4,31	18***	8,27	17**	5,29
Carrot	22*	0.01,45	32***	19,45	37***	23,51
Salami	33***	16,50	24***	10,37	28***	14,42
Steak	27**	10,44	21***	10,33	34***	19,48
Apple	29*	6,51	32***	21,42	28***	14,43
Lettuce	34***	17,50	16**	6,25	21**	8,34

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

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.[18–20]

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.[21] 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] However, the results of our study demonstrate that patients with more mandibular ridge resorption are not necessary less satisfied with their new prostheses than those with less resorption. However, this could change with time with additional bone resorption and loss of initial prosthesis retention. Long term follow-up on satisfaction data will help to clarify this issue.

4.2. *Sex differences and denture satisfaction*

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.[17] 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.[22,23]

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.

4.3. *Differences between treatment groups*

No matter what the mandibular condition, differences in satisfaction and function ratings were found only between the

Table 4 – Regression analysis of relationship between patients' ratings of satisfaction and function at 6 months follow-up visit and type of treatment, adjusted for mandibular bone height, maxillo-mandibular relationship, sex, pretreatment ratings and interaction of sex and type of prosthesis.

Patients ratings	Variable	Coefficient	*p*-Value	95% CI for coefficient
General satisfaction	Type of prostheses[a]	23.7	<0.001	13.4,33.9
	Gender[b]	13.3	0.017	2.4,24.2
	Gender/type of prostheses interaction	−8.3	0.281	−23.5,6.9
	Mandible height[c] ≥16 mm	−7.0	0.224	−18.3,4.3
	Mandible height 11–16 mm	−5.2	0.237	−13.9,3.5
	Mandible height ≤11 mm[d]			
	Maxillo-mandibular relationship	0.47	0.919	−8.7,9.6
	General satisfaction at baseline	0.091	0.171	−0.04,0.22
Ability to chew	Type of prostheses	25.7	<0.001	16.2,35.2
	Gender	19.2	<0.001	9.0,29.3
	Gender/type of prostheses interaction	−19.3	0.008	−33.4,−5.01
	Mandible height ≥16 mm	−4.4	0.408	−15.0,6.1
	Mandible height 11–16 mm	−4.8	0.247	−13.0,3.4
	Mandible height ≤11 mm			
	Maxillo-mandibular relationship	−3.5	0.423	−12.0,5.0
	Ability to chew at baseline	0.132	0.029	0.014,0.251
Comfort	Type of prostheses	28.0	<0.001	17.5,38.6
	Gender	16.5	0.004	5.3,27.8
	Gender/type of prostheses interaction	−15.5	0.053	−31.2,0.2
	Mandible height ≥16 mm	−4.9	0.406	−16.7,6.8
	Mandible height 11–16 mm	0.2	0.966	−8.8,9.2
	Mandible height ≤11 mm			
	Maxillo-mandibular relationship	0.136	0.955	−4.6,4.9
	Comfort at baseline	0.112	0.087	−4.6,4.9
Stability	Type of prostheses	22.8	<0.001	11.6,30.1
	Gender	12.1	0.048	0.102,24.0
	Gender/type of prostheses interaction	−12.0	0.162	−28.8,4.9
	Mandible height ≥16 mm	−7.7	0.222	−20.1,4.7
	Mandible height 11–16 mm	−3.1	0.516	−12.6,6.4
	Mandible height ≤11 mm			
	Maxillo-mandibular relationship	1.5	0.770	−8.5,11.5
	Stability at baseline	0.17	0.023	0.023,0.31
Ability to speak	Type of prostheses	10.1	0.01	2.4,17.8
	Gender	8.4	0.048	0.09,16.7
	Gender/type of prostheses interaction	−6.4	0.268	−17.9,5.0
	Mandible height ≥16 mm	−0.9	0.834	−9.5,7.6
	Mandible height 11–16 mm	0.31	0.925	−6.2,6.8
	Mandible height ≤11 mm			
	Maxillo-mandibular relationship	−0.46	0.796	−4.0,3.0
	Ability to speak at baseline	0.113	0.02	0.02,0.20
Aesthetic	Type of prostheses	14.3	0.001	5.8,22.9
	Gender	15.0	0.001	5.9,24.1
	Gender/type of prostheses interaction	−15.4	0.017	−28.1,−2.8
	Mandible height ≥16 mm	−7.5	0.125	−17.1,2.1
	Mandible height 11–16 mm	0.341	0.926	−6.9,7.6
	Mandible height ≤11 mm			
	Maxillo-mandibular relationship	−2.5	0.202	−6.4,1.4
	Aesthetic at baseline	0.202	<0.001	0.103,0.301

[a] 0: CD; 1: IOD.
[b] 0: female; 1: male.
[c] According to modified ACP classification, mandible were classified as higher (≥16 mm), medium (11–16 mm), lower (≤11 mm).
[d] Reference category.

two treatment groups, with higher ratings assigned to the implant overdentures than to the conventional dentures. This finding supports those from other investigations,[4–6] 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.

REFERENCES

1. Allen PF, McMillan AS. A review of the functional and psychosocial outcomes of edentulousness treated with complete replacement dentures. *Journal of the Canadian Dental Association* 2003;**69**. 662a–d.
2. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed-longitudinal study covering 25 years. *Journal of Prosthetic Dentistry* 1972;**27**:120–32.
3. Stellingsma C, Vissink A, Meijer HJ, Kuiper C, Raghoebar GM. Implantology and the severely resorbed edentulous mandible. *Critical Reviews in Oral Biology & Medicine* 2004;**15**:240–8.
4. Wismeijer D, Van Waas MA, Vermeeren JI, Mulder J, Kalk W. Patient satisfaction with implant-supported mandibular overdentures. A comparison of three treatment strategies with ITI-dental implants. *International Journal of Oral and Maxillofacial Surgery* 1997;**26**:263–7.
5. Geertman ME, Boerrigter EM, Van't Hof MA, Van Waas MA, van Oort RP, Boering G, *et al*. Two-center clinical trial of implant-retained mandibular overdentures versus complete dentures-chewing ability. *Community Dentistry and Oral Epidemiology* 1996;**24**:79–84.
6. Awad MA, Lund JP, Shapiro SH, Locker D, Klemetti E, Chehade A, *et al*. Oral health status and treatment satisfaction with mandibular implant overdentures and conventional dentures: a randomized clinical trial in a senior population. *International Journal of Prosthodontics* 2003;**16**:390–6.
7. Thomason JM, Lund JP, Chehade A, Feine JS. Patient satisfaction with mandibular implant overdentures and conventional dentures 6 months after delivery. *International Journal of Prosthodontics* 2003;**16**:467–73.
8. Guckes AD, Scurria MS, Shugars DA. A conceptual framework for understanding outcomes of oral implant therapy. *Journal of Prosthetic Dentistry* 1996;**75**:633–9.
9. Pan S, Awad M, Thomason JM, Dufresne E, Kobayashi T, Kimoto S, *et al*. Sex differences in denture satisfaction. *Journal of Dentistry* 2008;**36**:301–8.
10. Emami E, de Grandmont P, Rompre PH, Barbeau J, Pan S, Feine JS. Favoring trauma as an etiological factor in denture stomatitis. *Journal of Dental Research* 2008;**87**:440–4.
11. Heydecke G, Klemetti E, Awad MA, Lund JP, Feine JS. Relationship between prosthodontic evaluation and patient ratings of mandibular conventional and implant prostheses. *International Journal of Prosthodontics* 2003;**16**:307–12.
12. Awad MA, Feine JS. Measuring patient satisfaction with mandibular prostheses. *Community Dentistry and Oral Epidemiology* 1998;**26**:400–5.
13. Cawood JI, Howell RA. A classification of the edentulous jaws. *International Journal of Oral and Maxillofacial Surgery* 1988;**17**:232–6.
14. McGarry TJ, Nimmo A, Skiba JF, Ahlstrom RH, Smith CR, Koumjian JH. Classification system for complete edentulism. The American College of Prosthodontics. *Journal of Prosthodontics* 1999;**8**:27–39.
15. Wical KE, Swoope CC. Studies of residual ridge resorption. I. Use of panoramic radiographs for evaluation and classification of mandibular resorption. *Journal of Prosthetic Dentistry* 1974;**32**:7–12.
16. Xie Q, Wolf J, Tilvis R, Ainamo A. Resorption of mandibular canal wall in the edentulous aged population. *Journal of Prosthetic Dentistry* 1997;**77**:596–600.
17. Guler AU, Sumer M, Sumer P, Bicer I. The evaluation of vertical heights of maxillary and mandibular bones and the location of anatomic landmarks in panoramic radiographs of edentulous patients for implant dentistry. *Journal of Oral Rehabilitation* 2005;**32**:741–6.
18. Narhi TO, Ettinger RL, Lam EW. Radiographic findings, ridge resorption, and subjective complaints of complete denture patients. *International Journal of Prosthodontics* 1997;**10**:183–9.
19. van Waas MA. The influence of clinical variables on patients' satisfaction with complete dentures. *Journal of Prosthetic Dentistry* 1990;**63**:307–10.

20. Carlsson GE. Clinical morbidity and sequelae of treatment with complete dentures. *Journal of Prosthetic Dentistry* 1998;**79**:17–23.
21. Kimoto K, Garrett NR. Effect of mandibular ridge height on patients' perceptions with mandibular conventional and implant-assisted overdentures. *The International Journal of Oral & Maxillofacial Implants* 2005;**20**:762–8.
22. Fenlon MR, Sherriff M, Walter JD. Agreement between clinical measures of quality and patients' rating of fit of existing and new complete dentures. *Journal of Dentistry* 2002;**30**:135–9.
23. Fontijn-Tekamp FA, Slagter AP, Van Der Bilt A, Van THMA, Witter DJ, Kalk W, *et al*. Biting and chewing in overdentures, full dentures, and natural dentitions. *Journal Dental Research* 2000;**79**:1519–24.