Chapter 2

Posterior mandibular residual ridge resorption in patients with overdentures supported by two or four endosseous implants; a 10-year prospective study

This chapter is an edited version of the manuscript:

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Posterior mandibular residual ridge resorption in patients with overdentures supported by two or four endosseous implants in a 10-year prospective comparative study.
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Abstract

Purpose The aim of this study was to evaluate the effect of treatment with either two or four mandibular endosseous implants with an overdenture on the mandibular posterior residual ridge resorption over 10 years.

Materials and methods Sixty edentulous patients with a mandibular height of between 12 and 18 mm participated. Thirty patients were treated with an overdenture supported by two IMZ implants (two-implant group) and 30 patients were treated with an overdenture with four IMZ implants (four-implant group). Prior to and 10 years after treatment, panoramic radiographs were taken to calculate possible bone loss. Proportional area measurements were used to determine changes in the mandibular posterior residual ridge bilaterally.

Results There was a statistically significant difference in mandibular posterior residual ridge resorption between the two types of treatment. The Posterior Mandibular Ridge Ratio was reduced by a mean of 10% for the two-implant group and 6% for the four-implant group over 10 years. No correlation was shown between mandibular posterior residual ridge resorption and peri-implant marginal bone loss. The confounding factors marginal bone loss around the implants, age, gender, initial mandibular height and the number of years the patient had been edentulous failed to show a significant effect on the posterior mandibular ridge resorption.

Conclusions It can be concluded that slightly more posterior mandibular residual ridge resorption occurred in patients treated with a two-implant overdenture than in patients treated with a four-implant overdenture over a period of 10 years.
Introduction
Edentulous patients often experience difficulties with their dentures. Main problems are lack of retention and stability of the mandibular denture, and decreased chewing ability (Van Waas, 1990). These problems are aggravated by the loss of height of the mandibular residual ridge, a result of extensive remodelling following extraction of the teeth and the use of dentures (Carlsson & Persson, 1967). There is great individual variation in the rate of residual ridge resorption among different patients and even in the same person at different times and sites (Atwood, 1971; Xie et al., 1997). A 15-years and 25-years follow-up study on complete denture wearers revealed a continuing reduction of the mandibular ridge (Tallgren, 1972). In another study it was hypothesised that excessive alveolar bone resorption is caused by physiologically intolerable forces produced by complete dentures (Kelsey, 1971).

An implant-retained overdenture is a treatment possibility which improves function and comfort for edentulous patients and eliminates a substantial part of the problems which edentulous patients experience (Boerrigter et al., 1995). Implant-retained overdentures were already being studied in the 1980s and are still considered of great value in the rehabilitation of edentulous patients (van Steenberghe et al., 1985; Batenburg et al., 1998). Mandibular overdentures can be stabilised by a different number of implants (usually two or four) and by different attachment systems (usually bar systems, which connect the implants or solitary systems such as ball-attachment systems). Besides the improvement of retention and stability of the denture, it has been suggested that the stabilisation of the overdenture by implants will preserve the remaining residual bony ridge. Posterior ridge measurements can be done on panoramic radiographs. After tracing of the radiograph the surface of a proportional area is calculated. This method has been reported in several other studies (Wilding et al., 1987; Jacobs et al., 1992). Jacobs et al. suggested a threshold for the area index of 0.04 in the detection of bone resorption (Jacobs et al., 1992). Using this method, Kordatzis et al demonstrated significantly less posterior mandibular residual ridge resorption in patients with implant overdentures when compared to patients with conventional complete dentures (Kordatzis et al., 2003). In addition, Wright et al reported low rates of posterior mandibular residual ridge resorption for patients with overdentures stabilised by two implants (Wright & Watson, 1998). They compared overdentures stabilised by two implants connected by a parallel-sided bar (rigid joint) or connected by an oval bar.

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(resilient joint). They found no significant difference in posterior mandibular residual ridge resorption between a resilient joint and a rigid joint, although subsequent work showed the rigidity of some of the rigid joints was less than predicted (Setz et al., 2000). In a more recent study, Wright et al. compared patients wearing fixed implant prostheses with patients wearing implant-retained removable overdentures regarding posterior mandibular residual ridge resorption (Wright et al., 2002). They reported low rates of bone resorption for patients rehabilitated with an implant-retained removable overdenture and bone apposition in the posterior mandibular area in patients with a fixed prosthesis. There are no studies to date comparing mandibular overdentures supported by two or four implants with respect to the posterior mandibular residual ridge resorption.

For general application in the edentulous mandible, a treatment concept utilising two or four implants to stabilise a mandibular overdenture has been proposed (Batenburg et al., 1998). Both two implants and four implants to support an overdenture are placed in the interforaminal region of the mandible, however the bar superstructure design is different. In comparison with two implants, there is a less resilient joint in case of four implants. This could lead to fewer forces on the posterior mandibular ridge with a four-implant overdenture compared to a two-implant overdenture. Recent studies comparing the effects of mandibular overdentures supported by either two or four implants looked at outcome factors such as survival rate, condition of hard and soft peri-implant tissues, marginal bone loss, patient satisfaction, prosthetic aftercare, surgical aftercare and cost-effectiveness. Except for the initial costs, which were significantly higher for mandibular overdentures supported by four implants, there were no significant differences found (Stoker et al., 2007; Visser et al., 2009; Meijer et al., 2009). Although both treatment possibilities have been examined thoroughly by several study groups, there are no 10-year data comparing the posterior residual ridge resorption in the mandible of patients with mandibular overdentures stabilised by two or four implants.

Therefore, the aim of this study was to investigate posterior mandibular residual ridge resorption following the use of either two or four endosseous implants to stabilise complete overdentures over 10 years. Also various confounding factors will be reviewed. The working hypothesis was that there will be more posterior mandibular residual ridge resorption following treatment using two implants compared to four implants.
Materials and Methods

Patient selection and treatment

Sixty edentulous patients (39 women, 21 men, mean age 54.9 years, median 52 years, range 38-81 years) were selected. They were all referred by their dentist or general medical practitioner to the University Medical Center Groningen. All patients were suffering from reduced stability and insufficient retention of their mandibular denture. Inclusion criteria for the clinical trial were an edentulous period of at least two years and moderate resorption of the mandible (mandible height in the symphysis region between 12 and 18 mm), being class IV-VI according to the Cawood and Howell classification (Cawood & Howell, 1988). Patients with a history of radiotherapy in the head and neck region, a history of pre-prosthetic surgery or previous implant placement were excluded. The hospital ethical committee approved the study. The jawbone quality was scored according to the classification of Lekholm & Zarb (1985).

The patients were informed about the treatment options (overdenture on two or four endosseous implants) which were both appropriate in the patients included. Written informed consent was obtained from all patients. Treatment was randomly allocated by lot resulting in 30 patients (two-implant group) to be treated with two IMZ implants (titanium plasma-sprayed (TPS), Friedschfield AG, Mannheim, Germany) and 30 patients (four-implant group) to be treated with four IMZ implants. Table 1 shows that there were no significant differences in the baseline characteristics. Most patients mainly had 16 mm of bone height and type III bone.

All implants were inserted under local anaesthesia in the inter-foramina region according to the procedure described by Kirsch (1983). All implants were placed as a two-stage procedure.

Table 1. Characteristics of the groups at baseline.

<table>
<thead>
<tr>
<th>Group</th>
<th>two-implant</th>
<th>four-implant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Gender (m/f)</td>
<td>9/21</td>
<td>6/24</td>
</tr>
<tr>
<td>Age (years; mean/SD/range)</td>
<td>54.0/8.7/38-77</td>
<td>55.7/12.3/35-79</td>
</tr>
<tr>
<td>Edentulous period mandibular jaw (years; mean (SD))</td>
<td>21.0 (9.0)</td>
<td>21.8 (10.5)</td>
</tr>
<tr>
<td>Mandibular bone height (mm; mean (SD))</td>
<td>15.8 (2.3)</td>
<td>15.7 (2.7)</td>
</tr>
<tr>
<td>Bone quality (possible score 1-4; mean)</td>
<td>3.0</td>
<td>2.7</td>
</tr>
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</table>
by the same oral surgeon. In the ‘two-implant group’ the implants were placed in the canine region of the mandible, 10 millimetres left and right from the midline. In the ‘four-implant group’ there was equal distance between the four implants and the most lateral implants were placed 5 mm medially of the mental foramen. Position of the implants depends on the available space and the anterior curve of the mandible. No surgical stent was used. Standard postoperative treatment was composed of analgesics and chlorhexidine 0.2% mouth rinses, but no antibiotics.

Three months after the implant placement, second stage surgery (thinning of the peri-implant mucosa and placement of the abutment) was performed. Two weeks thereafter standard prosthetic treatment was provided being a new maxillary complete denture and a mandibular

![Figure 1.](image1.jpg)
Two implants with a bar superstructure in an edentulous mandible after 10 years in function.

![Figure 2.](image2.jpg)
Inner side of a two-implant mandibular overdenture.

![Figure 3.](image3.jpg)
Four implants with a bar superstructure in an edentulous mandible after 10 years in function.

![Figure 4.](image4.jpg)
Inner side of a four-implant mandibular overdenture.
overdenture supported by an individually made round bar with no distal extensions and clip attachments (Figures 1, 2, 3 and 4). None of the overdentures were reinforced with a pre-cast metal construction. All patients were treated by one experienced oral and maxillofacial surgeon and one experienced prosthodontist.

Figure 5.
Panoramic radiograph of the two-implant group used for tracing - 10 years.

Figure 6.
Panoramic radiograph of the four-implant group used for tracing - 10 years.

Figure 7.
The anatomical landmarks M, M’ (lower border of mental foramen); S, S’ (Sigmoid notch); G, G’ (gonion) were used to construct the triangles M-S-G and M’-S’-G’ with centres N and N’ respectively. Boundary lines were constructed as follows: M-G and M’-G’, A-L and A’-L’ (crest of residual ridge to lower border of mandible perpendicular to M-G and M’-G’), M-N and M’-N’, and G-P and G’-P’ (G-N and G’-N’ extended to the crest of the residual ridge at P and P’).
Radiographic analysis

Posterior residual ridge resorption

Panoramic radiographs were obtained from all patients immediately before and 10 years after treatment (Figures 5 and 6). The panoramic radiographs were throughout the evaluation period manufactured with the same orthopantomograph (Orthopos®, Siemens, Bernsheim, Germany) for standardisation with corresponding radiographs. The films were automatically processed in a Kodak RP® X-Omat M5 processor (Kodak, Rochester, NY). The landmarks were traced from the radiographs and digitised; areas were calculated with computer software.

The method consisted of proportional area measurements of the posterior mandible, similar to that used by Wright et al. (2002) Using proportions minimises errors related to magnification and distortion. For every radiograph a tracing was made on the mandible. Figures 7 and 8 show the areas that were traced. The anatomical landmarks M (lower border of mental foramen), S (sigmoid notch) and G (gonion) were used to construct the triangles on the right (M-S-G).

![Figure 8](image)

The areas were defined as follows: posterior bone area_{right} and posterior bone area_{left} by the crest of the residual ridge P-A and P'-A' and the boundary lines A-M and A'-M', M-G and M'-G', and G-P and G'-P', respectively; and the posterior reference area_{right} and posterior reference area_{left} by the triangles M-G-N and M'-G'-N', respectively. A ratio was calculated was calculated from (bone area_{right} / reference area_{right} + bone area_{left} / reference area_{left})/2.
and left (M’-S’-G’) side of the mandible with centre N (Figure 7). Boundaries were constructed by the following lines: the boundary line M-G, the boundary line A-L; a line from the crest of residual ridge (point A) to the lower border (point L) through M perpendicular to M-G, the boundary line M-N and boundary line G-P; the line G-N extended to the crest of the residual ridge through point P. The experimental bone area was eventually outlined by the area PAMG and the reference area by the triangle MGN (Figure 8). The Posterior Mandibular Ridge Ratio (PMandRR) was calculated by dividing the bone area by the reference area. The ratios for the right and left part in one patient were averaged.

To estimate the change in the height of the posterior mandibular residual ridge over ten years, not taking into account the magnification or distortion of the radiographs, the mean of the change in bone area bounded by the residual ridge was divided by the length of the crest of the residual ridge (Kordatzis et al., 2003).

Before starting the study a pilot was used to determine the reproducibility of measurements and if the quality of the radiograph was of any influence. Six radiographs were selected with varying quality of visibility of the tracing points. All radiographs were measured 10 times by one examiner using the method planned for the main study. The standard deviation and the coefficient of variation were calculated for each set of measurements. The coefficient of variation ranged between 0.88% and 2.72% where the lowest variation was associated with clear visibility of the tracing points. Therefore, only radiographs with clear visibility of the tracing points were included in the main study. If tracing points were clear, it was possible to compute the surface of the posterior area. The measuring procedure was carried out at the end of the study period. At that time it appeared that some tracing points were not clearly visible for actual measurements. It was found that patients could not be re-called for taking an extra radiograph.

Confounding factors

The following confounding factors were studied: peri-implant marginal bone loss, age, gender, initial mandibular height and the number of years the patient had been edentulous.

Data of peri-implant bone loss were obtained from the study of Meijer et al. (2009), which describes the same patient groups. In this study, standardised intra-oral radiographs, using a long cone technique, of each implant were obtained using a beam direction device (Meijer et
Baseline intraoral radiographs were made at time of implant loading. Analysis and calculation of changes was done on implant basis.

Statistical analyses
Since none of the data showed a normal distribution a Mann-Whitney non-parametric statistical analysis was used. To examine confounding factors, a multiple regression analysis using a backward stepwise procedure was adopted. The correlation was tested using a Kendall’s tau correlation test. In all tests, a significance level of 0.05 was chosen.

Results
Of the 30 patients in the two-implant group there was a drop out of seven patients: one patient died, in two patients the implants were removed, and the panoramic radiographs of four patients were unfit for use due to lack of clarity of the reference points. The four-implant group had a drop out of 12 patients: four patients died, three patients moved to another part of the country and the panoramic radiographs of five patients were unfit for use. This resulted in a group of 23 patients (5 male/18 female) for the two-implant group and 18 patients (6 male/12 female) for the four-implant group. The assumption was made that drop-out of patients (two-implant group: 23%, four-implant group: 40%) was not related to posterior ridge reduction. Before the study and at each annual check-up patients were asked about their medical condition. No particular diseases occurred that could be linked to bone resorption.

The change in PMandRR was calculated for each patient by subtracting the ratio value at 0 years from the ratio value at 10 years. Therefore, a negative difference indicated resorption, and a positive difference indicated an increase in area or apposition of bone. The results for both groups are shown in Table 2. There was a significant difference (p<0.05) in PmandRR between the groups. Reduction in bone height is easier to visualise than change in PmandRR.

It is possible to convert bone area data into bone height data, after the method of Kordatzis et al. (2003) This is however only an estimation. The approximate changes in height can be calculated by dividing the average initial area by the average length of the posterior residual ridge, which was approximately 40 mm. The estimated change in posterior mandibular residual ridge resorption over a period of 10 years was 1.44 mm for the two-implant group and 0.74 mm for the four-implant group.
Table 2. Change in Posterior Mandibular Ridge Ratio.

<table>
<thead>
<tr>
<th>Group</th>
<th>two-implant*</th>
<th>four-implant*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pairs of radiographs</td>
<td>23</td>
<td>18</td>
</tr>
<tr>
<td>Mean (SD) change PmandRR</td>
<td>-0.10 (0.07)</td>
<td>-0.06 (0.09)</td>
</tr>
<tr>
<td>Median change PmandRR</td>
<td>-0.09</td>
<td>-0.04</td>
</tr>
<tr>
<td>Minimum / Maximum change PmandRR</td>
<td>-0.33 / 0.01</td>
<td>-0.20 / 0.03</td>
</tr>
</tbody>
</table>

* Positive values indicated resorption and negative values indicated an increase in the area of posterior residual ridge or bone apposition.

Abbreviations: PmandRR = Posterior Mandibular Ridge Ratio.

The mean marginal bone loss around the implants was 1.4 mm in the two-implant group and 1.1 mm in four-implant group in 10 years, as described in the study of Meijer et al. (2009). No significant correlation was found between the mean marginal bone loss and posterior mandibular residual ridge resorption.

The other potential confounding factors, age, gender, initial height of the mandible, bone quality, years edentulous and marginal bone loss around the implants, failed to show a significant effect on the amount of posterior mandibular residual ridge resorption. This confirms the results of the non-parametric Mann-Whitney test.

Discussion

The mean change in Posterior Mandibular Ridge Ratio (PmandRR) was 0.10 in two-implant group (estimated mandibular ridge resorption was 1.44 mm in 10 years) and 0.06 in the four-implant group (estimated mandibular ridge resorption was 0.74 mm in 10 years). There was a significant difference in PmandRR between the groups. There was less resorption in patients treated with four-implant overdentures. The assumption was made that drop-out of patients was not related to posterior alveolar ridge reduction, because death of patients and moving to another part of the country were not implant-related. Moreover, the number of unclear panoramic radiographs was comparable between the groups. This makes the groups rather comparable. However, it cannot be excluded that loss of implants due to peri-implantitis (two-implant group: 2 patients) was not accompanied by some additional posterior ridge reduction. This is not likely, but even if it had occurred, the conclusion of this study would not have changed.
as such a condition would have lead to on average even more bone loss in the two-implant group. Inter-abutment distance can vary in the four-implant group. In a large jaw, with a large interforaminal space, a larger inter-abutment distance will be the consequence with possibly more forces on the implants. The authors feel, however, that this variable is not very relevant. Differences in inter-abutment distance are small and also other, not measured, variables can be of influence (e.g. chewing pattern, chewing force). The present study could be compared with the study of Wright et al. (1998), which compared a resilient joint with a rigid joint, both in mandibular overdentures. The groups had two implants with either a straight ovoid bar with a resilient joint or a parallel-sided bar and a rigid joint. It failed to show a significant difference between the two groups. This could be due to the small number of patients investigated in Wright’s study, or to the rigid joint being less rigid than predicted (Setz et al., 2000). In the present study the bar on four implants provided more posterior support than the bar on two implants. The posterior position of the axis of rotation and less resilience could be the cause of fewer forces on the posterior ridge and therefore causes less bone resorption. To explain the differences in mandibular posterior residual ridge resorption between the two and four implant overdenture patients, differences in loading patterns and movements of the denture, for both designs must be considered. Research shows that an implant-retained overdenture significantly improves the masticatory function in patients (Stellingsma et al., 2005; Fueki et al., 2007). However, little is known about the exact changes to the force and its distribution under the denture. Most studies focus on the force distribution on the implants and not on the posterior residual ridge. With a bar between two implants in the interforaminal region, free rotation of the denture around the bar is possible. This is the case with both round bars and ovoid bars. Rotation of the overdenture is more rigid with a bar on four implants in the interforaminal region, although rotation is still possible. With a fixed prosthesis on implants, there is no rotation and the posterior ridge will not be loaded. One would expect that the fewer forces on the posterior ridge, the less resorption will occur. An overdenture on two implants might result in an overall distribution of the masticatory forces, which could result in an increased resorption of the posterior ridge. Whereas, with the more rigid four implant design, with wider distribution of the implants, patients are more likely to center the masticatory forces over the implants where the denture is the most stable. Thus less resorption could occur which might explain the difference in resorption between the two groups.
A comparison can be made with the study of Wright et al. (2002) who used a similar method to study two groups of patients wearing different types of prostheses; a group with a mandibular overdenture stabilised by two implants connected by a bar and a group with fixed mandibular prostheses. With respect to the method of loading of the posterior ridges, the group with the overdenture on two implants can be compared with the two-implant group in the present study. In case of the fixed prosthesis, there is no loading of the posterior ridges and one would expect a lower mean change in Posterior Mandibular Ridge Ratio (called the Posterior Area Index in the study of Wright et al.) compared to the four-implant group in the present study, in which still some loading is possible. The annual change in the PmandRR of the fixed prostheses group was indeed lower than the change in ratio for the group with the four implants in the present study when translated in an annual rate of 0.006. The fixed prosthesis group even showed a positive annual change of +0.016, indicating slight bone apposition. The mean annual change in PmandRR for their two-implant stabilised overdenture group was 0.011, which is comparable with the result in our group with two implants, being 0.010.

The confounding factors marginal bone loss around the implants, age, gender, initial mandibular height and the number of years the patient had been edentulous failed to show a significant effect on the posterior mandibular ridge resorption.

Kordatzis et al. (2003) suggested that female gender is a risk factor for greater posterior residual ridge resorption. Kordatzis et al. (2003), Wright et al. (1998) and the present study found no interaction between prosthesis type and the variables of gender, age, years of edentulousness. In previous studies comparing two with four implants under overdentures, survival of the implants, clinical state, marginal bone loss, patient satisfaction and surgical / prosthetic aftercare have been compared with no significant differences detected (Stoker et al., 2007; Visser et al., 2009; Meijer et al., 2009). For cost-effectiveness reasons a two-implant overdenture is therefore advised. However, this study demonstrates a slight difference in posterior mandibular residual ridge resorption, so for preservation of the mandible a four-implant overdenture design might be indicated, especially for patients who present with a severely reduced posterior ridge. Further research must reveal whether this reduction is of clinical relevance.
Conclusion

It can be concluded that there is a slight difference in mandibular posterior residual ridge resorption between patients treated with either two or four implants stabilising an overdenture. No correlation was shown between mandibular posterior residual ridge resorption and peri-implant marginal bone loss. The confounding factors, age, gender, initial mandibular height and the number of years the patient had been edentulous failed to show a significant effect on the posterior ridge resorption.

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References


