Effects of dental implants on hard and soft tissues
Tymstra, Nynke

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Anterior maxillary residual ridge resorption and posterior residual ridge resorption in patients with an implant-retained mandibular overdenture compared to patients with a conventional mandibular denture; a 10-year prospective study

This chapter is an edited version of the manuscript:

Tymstra N, Raghoebear GM, Vissink A, Meijer HJA. Anterior maxillary residual ridge resorption and posterior residual ridge resorption in patients with an implant-retained mandibular overdenture compared to patients with a conventional mandibular denture. A 10-year prospective study. Submitted
Abstract

Aim The purpose of this study was to compare the effect of an implant-retained mandibular overdenture on 2 or 4 dental implants with the effect of a conventional denture on resorption of the residual ridge of the anterior maxilla and posterior mandible over a period of 10 years.

Material and methods In total 120 patients, 30 patients treated with an overdenture on 2 implants (two-implant group), 30 patients with an overdenture on 4 implants (four-implant group) and 60 patients treated with a conventional full denture (conventional group), participated in this study. All patients had a conventional maxillary denture. On panoramic radiographs, made before and 10 years after treatment, proportional area measurements were applied to determine changes in bone height.

Results After 10 years, a statistically significant amount of bone resorption had occurred in the anterior maxilla in the two-implant group and in the four-implant group (p=0.003 and p=0.004 respectively). A significant amount of bone resorption had occurred in the posterior mandible in all three groups (two-implant group: p<0.001, four-implant group: p=0.006, conventional group: p=0.011). There were no statistically significant differences between the groups in both areas. Patients presented large individual differences. No correlation was found between resorption of the residual ridge of the anterior maxilla and posterior mandible.

Conclusions Patients rehabilitated with implant-retained mandibular overdentures are not subjected to more residual ridge resorption in the anterior maxilla when compared to patients wearing a conventional full denture. Regarding the mandibular posterior residual ridge, resorption was irrespective of wearing an implant-retained mandibular overdenture or a conventional mandibular denture.
Introduction

Edentulous patients often experience problems with their dentures. Main complaints are lack of stability and retention of their dentures, together with a decreased chewing ability (Van Waas, 1990). An implant-retained overdenture is a treatment possibility which improves oral function, chewing force and comfort for edentulous patients and eliminates a substantial part of the problems which edentulous patients experience (Boerrigter et al., 1995; Fontijn-Tekamp et al., 1998). Although implant-retained mandibular overdentures as treatment possibility have been examined thoroughly by several study groups, most articles predominantly focus on the effect of treatment on the mandible and only a few articles focus on the effect of treatment on the resorption patterns in the maxilla (Barber et al., 1990; Jacobs et al., 1993; Lechner & Mammen, 1996; Narhi et al., 2000; Kreisler et al., 2003).

In previous studies it was suggested that the chance of developing the so-called combination syndrome, as observed in patients with an edentulous maxilla opposing a shortened dental arch in combination with a prosthetic device in the mandible, increases in persons wearing mandibular implant-retained overdentures (Barber et al., 1990; Jacobs et al., 1992; Lechner & Mammen, 1996). The five symptoms that commonly occur in the combination syndrome are (1) loss of bone from the anterior part of the maxillary ridge, (2) development of fibrous or bony enlargements of the tuberosities, (3) papillary hyperplasia of the hard palate, (4) extrusion of the mandibular anterior teeth and (5) reduction of mandibular bone beneath a mandibular distal extension of a removable partial denture. Saunders et al. (1979) have posed that the combination syndrome starts with resorption of the posterior mandibular residual ridge. Consequently, this resorption is thought to gradually result in a loss of posterior occlusal load and an increase in anterior occlusal load. This increased anterior loading may result in resorption of the anterior maxillary residual ridge. Similar oral changes also may occur in patients wearing an implant-retained mandibular overdenture. As a result of a built-in possibility of rotation in the implant-retained mandibular overdenture a similar unfavourable distribution of occlusal load of the posterior mandible and anterior maxilla might exist. Kordatzis et al. (2003) refuted this hypothesis in their study investigating the degree of resorption of the posterior mandibular residual ridge under conventional dentures and mandibular overdentures supported by 2 implants. Their results showed that they observed less resorption under an overdenture than under a conventional overdenture. Similarly, Wright et al. (2002) reported
low rates of posterior mandibular ridge resorption for patients rehabilitated with a stabilised removable prosthesis and even bone apposition in the posterior mandibular area in patients with a fixed prosthesis. Studies focusing on the maxilla show contradicting results. Nähri et al. (2000) concluded that the decrease in the width of the maxillary residual ridge is small and independent of the type of mandibular denture, being an implant-supported overdenture on 5 implants, an implant-mucosa-supported overdenture and a conventional denture. Other studies demonstrated a higher annual maxillary residual ridge resorption in patients wearing a conventional denture than in patients wearing an implant-retained mandibular overdenture (Jacobs et al., 1993; Abd El-Dayem et al., 2007), or reported on significant vertical bone loss in the anterior maxilla in patients wearing an implant-retained mandibular overdenture (Barber et al., 1990; Kreisler et al., 2003). Finally, from a systematic review it was concluded that, although the literature is very limited, there was no evidence that maxillary ridge resorption was accelerated with implant-retained mandibular overdenture on 2 implants (Rutkunas et al., 2008).

There are no studies to date, however, comparing resorption of the residual ridge of the anterior maxilla and posterior mandible in patients treated with either implant-retained mandibular overdentures on two or four dental implants, or conventional mandibular dentures. Therefore, the purpose of this study was to assess the effect of an implant-retained mandibular overdenture on two or four dental implants and a conventional denture on resorption of the residual ridge of the anterior maxilla and posterior mandible over a period of 10 years.

Materials and Methods

Patient selection

For this study, panoramic radiographs (Orthopos, Siemens, Bensheim, Germany) that had been made according to protocol before and 10 years after prosthodontic treatment were available of 3 groups of patients that were enrolled from 2 previous prospective studies. The studies had been performed by the department of Oral and Maxillofacial Surgery at the University Medical Center Groningen and encompassed 30 patients treated with a mandibular overdenture on 2 IMZ implants (Friedrichsfeld, Mannheim, Germany) and a maxillary denture (two-implant group) (Batenburg et al., 1998); 30 patients treated with a mandibular overdenture on 4 IMZ implants (Friedrichsfeld, Mannheim, Germany) and a maxillary denture (four-implant group).
(Batenburg et al., 1998), and 60 patients treated with conventional maxillary and mandibular dentures (conventional group) (Meijer et al., 1999). The patients in both studies had been selected on the basis of the following inclusion criteria: edentulous maxilla and mandible for at least 1 year, problems with retention and stability of the mandibular denture, a mandibular bone height between 8 and 25 mm as measured at the mandibular symphysis region on a lateral cephalometric radiograph and no history of former preprosthetic surgery or contraindications for a surgical procedure.

The patients treated within these studies had been informed about the different treatment options, possible risks and the method employed for assignment to the treatment groups. Patients in the conventional group were given the option to change to an implant-retained overdenture after 1 year if they were not satisfied with their conventional denture. Informed consent was obtained from all participants. Both studies were approved by the medical ethical committee of the university medical center. Baseline characteristics of the three groups are listed in Table 1.

Table 1. Characteristics of the groups at baseline.

<table>
<thead>
<tr>
<th>Group</th>
<th>two-implant</th>
<th>four-implant</th>
<th>conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>30</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Gender (m/f)</td>
<td>9/21</td>
<td>6/24</td>
<td>19/41</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>
<td>56.9/11.6/34-84</td>
</tr>
<tr>
<td>Edentulous period mandibular jaw (years; mean (SD))</td>
<td>21.0 (9.0)</td>
<td>21.8 (10.5)</td>
<td>22.7 (9.6)</td>
</tr>
<tr>
<td>Mandibular bone height (mm; mean (SD))</td>
<td>15.8 (2.3)</td>
<td>15.7 (2.7)</td>
<td>17.0 (4.8)</td>
</tr>
</tbody>
</table>

**Surgical and prosthetic procedures**

All patients were treated in the same department (Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, Groningen, the Netherlands) by two experienced oral-maxillofacial surgeons and/or two experienced prosthodontists. In the two-implant group, two implants were placed in the canine region of the mandible, about
1 cm left and right from the midline. In the four-implant group, there was an equal distance between the four implants and the most lateral implants were placed at least 5 mm medially of the mental foramen. Standard postoperative treatment was composed of analgesics and chlorhexidine 0.2% mouth rinses (Corsodyl, GlaxoSmithKline Consumer Healthcare BV, Utrecht, The Netherlands), 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 overdenture supported by an individually made round bar with a clip attachment system (Ackermann, Preat Corporation, Santa Ynez, CA). No distal bar extensions were used. None of the overdentures were reinforced with a pre-cast metal construction.

The conventional group was treated with a new conventional denture in the maxilla and mandible jaw. A uniform prosthetic procedure for all patients was performed. A balanced occlusion and monoplane articulation was used in all three groups.

**Radiographic analysis**

**Anterior maxillary ridge resorption**

Maxillary bone resorption was evaluated using a previously described method based on proportional area measurements (Kreisler et al., 2000). The radiographs were digitised by scanning. In cooperation with the department Biomaterials of the University Medical Center Groningen a computer program was developed. With this software the sizes of the anatomic and reference areas were determined by outlining reference points and lines (described below) with a cursor. The following reference points were used for the investigation (Figure 1). The anterior nasal spine $S$ and the two lowermost bony margins of the orbit $O_{\text{right}}$ and $O_{\text{left}}$ form the ‘central triangle’. The line $o$ joins $O_{\text{right}}$ and $O_{\text{left}}$. The intersection between $o$ and $p$, a line perpendicular to $o$ through $S$, is point $P$. The point $R$ divides the distance $[PO]$ into two thirds and one third. This value was determined experimentally so as to divide the maxilla in anterior and posterior regions. $r$ is a line perpendicular to $o$ through $R$. $u$ is a line parallel to $o$ through $S$. $u$ and $r$ meet at the point $U$. $P'$ was marked by measuring the distance $[UR]$ starting from $S$. $R'$ was marked by measuring the distance $[UR]$ starting from $U$ the line $i$ connects $R'_{\text{right}}$ and $R'_{\text{left}}$. $1$ is the intersection of the alveolar crest with $p$, $2$ is the intersection of the alveolar crest with $r$. 
In the anterior region the experimental area is outlined by the area $S_{12U}$ and the reference area by the area $SP'R'U$. Anatomic and reference areas on the right and left sides were averaged, and a ratio (Anterior Maxillary Ridge Ratio) for the anterior maxillary bone area was calculated by dividing the anatomic bone area by the reference area. The change in Anterior Maxillary Ridge Ratio (AMaxRR) was calculated by subtracting the ratio at 0 years from the ratio at 10 years.

**Posterior mandibular residual ridge resorption**

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 2 and 3 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 ($M$-$S$-$G$) and left ($M'$-$S'$-$G'$) side of the mandible with centre $N$ (Figure 2). Boundaries were constructed by the...
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’).

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. The Posterior Mandibular Ridge Ratio was calculated from (bone area right / reference area right + bone area left / reference area left) / 2.

Reproducibility of measurements.

Before starting the study, a pilot study was performed 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.

**Panoramic radiographs selection**

Panoramic radiographs were obtained from all patients immediately before and 10 years after treatment. Radiographs were only included if the reference points used for both methods were distinct and if there were no gross distortion of the images. Patients were included if both the preoperative radiograph and the 10 years radiograph satisfied the two selection criteria.

**Statistical analysis**

For description of the data the mean values, standard deviations, minimum and maximum were calculated for the change in residual ridge resorption. Since the data for the change in anterior maxillary residual ridge ratio (AMaxRR) and the posterior mandibular residual ridge ratio (PMandRR) both violated the assumptions of a normal distribution, differences between the three groups were analysed using the Kruskal-Wallis test. Differences between the 0 year data and the 10 year data within the groups were analysed using the Wilcoxon matched-pairs test. Correlation between posterior mandibular residual ridge ratio and the anterior maxillary residual ridge ratio within the groups and for the patients altogether was calculated with the Spearman correlation test. For all tests, a significance level of 0.05 was chosen.

**Results**

**Patients**

Of the 30 patients in the two-implant group at baseline, there was a drop out of six patients at the 10-years evaluation: 2 patients had died, 3 patients did not attend the 10-years evaluation and 1 patient didn’t want a 10-years radiograph to be taken. Of the 24 patients left, 8 radiographs had to be excluded because of unclear reference points or gross distortion. Leaving panoramic radiographs (0 and 10 years) of 16 patients available for further analysis in the two-implant group. The four-implant group had a drop out of 10 patients: 6 patients had died and 4 patients did not attend the 10-years evaluation. Another 6 radiographs had to be excluded because of unclear reference points. Leaving panoramic radiographs of 14 patients available for further analysis in the four-implant group. The conventional group had a drop
out of 42 patients: 22 patients had meanwhile chosen for an implant-supported overdenture because they were not satisfied with their conventional denture, 10 patients had died and 10 patients did not attend the 10-years evaluation. Of the 18 patients left, 3 radiographs had to be excluded because of unclear reference points. Leaving panoramic radiographs available for further analysis of 15 patients in the conventional group (Table 2).

Table 2. Characteristics of the groups at the ten years evaluation.

<table>
<thead>
<tr>
<th>Group</th>
<th>two-implant</th>
<th>four-implant</th>
<th>conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>16</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Gender (m/f)</td>
<td>3/13</td>
<td>4/10</td>
<td>3/12</td>
</tr>
<tr>
<td>Age (years; mean/SD/range)</td>
<td>54.2/8.0/38-70</td>
<td>52.1/8.7/38-69</td>
<td>58.0/7.6/47-70</td>
</tr>
<tr>
<td>Edentulous period mandibular jaw (years; mean (SD))</td>
<td>20.2 (8.9)</td>
<td>19.8 (8.3)</td>
<td>22.7 (10.3)</td>
</tr>
<tr>
<td>Mandibular bone height (mm; mean (SD))</td>
<td>15.7 (2.9)</td>
<td>15.0 (2.3)</td>
<td>16.8 (4.0)</td>
</tr>
</tbody>
</table>

Reasons for not attending the evaluations were mainly sickness, old age and not being able to trace a patient because he or she had moved without leaving a new address. The assumption was made that drop-out of patients was not related to resorption of the mandibular or maxillary ridge. Moreover, 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, also not in the patients that had dropped out during the 10 years evaluation period (no relevant issues in their medical condition had occurred until their last recall visit.

Assessment of resorption

The change in AMaxRR and 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. Table 3 indicates that on average bone resorption had occurred in the anterior maxilla in patients from all three groups at the 10 years evaluation. This bone loss in the anterior residual ridge between 0 and 10 years was statistically different for the two-implant group and the four-implant group,
but not for the conventional group. There were no significant differences between the groups. Regarding the posterior mandibular residual ridge resorption, in all groups significant resorption had occurred between 0 and 10 years (Table 4), but the extent of resorption (PMandRR) was not different between the groups. Moreover, there was no correlation between the PMandRR and AMaxRR.

Table 3. Change in anterior maxillary residual ridge resorption (AMaxRR) over ten years.

<table>
<thead>
<tr>
<th>Group</th>
<th>two-implant*</th>
<th>four-implant*</th>
<th>conventional*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>16</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Mean (SD) AMaxRR</td>
<td>-0.12 (0.14)</td>
<td>-0.11 (0.10)</td>
<td>-0.04 (0.11)</td>
</tr>
<tr>
<td>Minimum AMaxRR</td>
<td>-0.51</td>
<td>-0.29</td>
<td>-0.30</td>
</tr>
<tr>
<td>Maximum AMaxRR</td>
<td>0.12</td>
<td>0.05</td>
<td>0.11</td>
</tr>
</tbody>
</table>

* Negative values indicated resorption and positive values indicated an increase in the area of anterior maxillary residual ridge or bone apposition. Kruskal Wallis test showed no significant differences in residual ridge reduction between the groups. Wilcoxon matched-pairs test showed significant differences between 0 and 10 years of the two-implant group (p = 0.003) and the four-implant group (p = 0.004).

Table 4. Change in posterior mandibular residual ridge resorption (PMandRR) over ten years.

<table>
<thead>
<tr>
<th>Group</th>
<th>two-implant*</th>
<th>four-implant*</th>
<th>conventional*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>16</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Mean (SD) PMandRR</td>
<td>-0.11 (0.07)</td>
<td>-0.07 (0.08)</td>
<td>-0.08 (0.11)</td>
</tr>
<tr>
<td>Minimum PMandRR</td>
<td>-0.33</td>
<td>-0.20</td>
<td>-0.36</td>
</tr>
<tr>
<td>Maximum PMandRR</td>
<td>-0.02</td>
<td>0.03</td>
<td>0.10</td>
</tr>
</tbody>
</table>

* Negative values indicated resorption and positive values indicated an increase in the area of posterior mandibular residual ridge or bone apposition. Wilcoxon matched-pairs test showed significant differences between 0 and 10 years of the two-implant group (p < 0.001), the four-implant group (p = 0.006) and the conventional group (p = 0.011). Kruskal Wallis test showed no significant differences in residual ridge reduction between the groups.
Discussion

Mean reduction of the measured proportional areas in the anterior maxilla was 0.12 in the two-implant group, 0.11 in the four-implant group and 0.04 in the conventional group. These results revealed that in the mandibular overdenture groups, ongoing resorption of the anterior maxilla had occurred during the 10 years evaluation period, which was significant for both the two-implant and four-implant groups. However, patients presented large individual differences. These observations are in line with the findings of other authors who showed gradual maxillary ridge resorption in patients wearing implant-retained overdentures (Saunders et al., 1979; Lechner & Mammen, 1996; Kreisler et al., 2003). In contrast to the present study, these studies did not include a control group, which can be considered an omission as the present study showed that resorption patterns were rather similar between patients treated with an implant-retained overdenture and patients treated with a conventional denture. Although the differences between the groups were not significant, there seemed to be a tendency of slightly more maxillary residual ridge resorption in patients treated with a two-implant and four-implant mandibular overdenture. On the other hand, some studies concluded that the maxillary ridge resorption was more pronounced in patients wearing a conventional denture in comparison with patients wearing an overdenture or a fixed prosthesis (Jacobs et al., 1993; Abd El-Dayem et al., 2007). These authors attributed these findings to the instability of the complete dentures, which contributed to an unfavourable stress distribution among the denture-bearing areas. The patients included in the present study received special attention regarding the prosthetic aftercare, including routine recall visits every year checking denture fit and the occlusion. If necessary, the dentures were relined as to accomplish optimal fit and therefore a more balanced stress distribution (Meijer et al., 1999; Visser et al., 2009). The minimal change in resorption for the conventional full denture wearers of this study could be the result of less chewing forces (Fontijn-Tekamp et al., 1998). The results in the present study seem to correspond with the findings of Nähri et al (2000) who found significant reduction of the maxillary residual ridge. Their changes were small and not associated with the type of prosthetic restoration in the mandible (conventional denture or overdenture).

Mean reduction of the measured proportional areas in the posterior mandible was 0.11 in the two-implant group, 0.07 in the four-implant group and 0.08 in the conventional group. Regarding posterior residual ridge resorption of the mandible, minimal resorption was observed.
for all three groups. Although the differences between the groups were not significant, there
seemed to be a tendency of slightly more posterior residual ridge resorption in patients treated
with two implants in comparison to patients treated with four implants or a conventional
denture.

Jacobs et al. (1992) reported higher posterior mandibular residual ridge resorption in patients
wearing a two-implant mandibular overdenture in comparison with patients wearing a
conventional denture or a fixed prosthesis. Importantly, the latter authors also reported
in their study that when patients were edentulous for more than ten years the differences
between the groups disappeared, which is in agreement with our results. In the present study,
the patients had been edentulous for, on average, 20 years (Table 1).
The interindividual variability of the resorption ratios for both the maxilla and the mandible
were high, but comparable to earlier studies and could be related to the multifactorial
aetiology of bone resorption (Tallgren, 1972; Jacobs et al., 1993; Kordatzis et al., 2003; Kreisler
et al., 2003). In several studies it was suggested that the chance of developing conditions
of the combination syndrome increases in persons wearing mandibular implant-retained
overdentures. The anterior maxillary ridge resorption was suggested to be a result of the
posterior mandibular ridge resorption, both conditions being symptoms of the combination
syndrome. However, the present study found no correlation between the posterior mandibular
residual ridge resorption and the anterior maxillary residual ridge resorption. There was
indeed posterior mandibular residual ridge resorption in all groups but this resorption was
slight and there was not significant more posterior mandibular bone loss in patients wearing
mandibular implant overdentures. Furthermore, there were no significant differences in the
maxillary residual ridge resorption. The results of the present study could not confirm the
suggestion that the combination syndrome also may occur in conventional maxillary dentures
opposed by an implant-retained mandibular overdenture. Several factors could contribute to
these findings. Firstly, all patients in the present study were treated with a balanced occlusion
and monoplane articulation concept to avoid too much anterior pressure. This concept with
no anterior teeth contact has also been recommended for implant-retained mandibular
overdentures to preserve anterior maxillary bone (Lang & Razzooq, 1992; Narhi et al., 2000).
Secondly, optimal denture fit and therefore a more balanced stress distribution of the denture
was achieved by giving special attention with regard to the prosthetic aftercare (Meijer et al., 2003; Visser et al., 2009). Finally, it could be that the long edentulous period (on average 20 years) of the described patients affects the residual ridge resorption. Possibly, most resorption takes place in an earlier stage after tooth extraction and resorption becomes less pronounced in years. Although treatment with implant-retained mandibular overdentures resulted in higher chewing forces and improved masticatory function (Fontijn-Tekamp et al., 1998), this improved oral function did apparently not result in increased resorption of the residual ridge in the posterior mandible and anterior maxilla.

Conclusions

Within the limitations of the present study, it can be concluded that there was no difference in anterior maxillary residual ridge resorption between patients rehabilitated with an implant-retained mandibular overdenture when compared to patients wearing a conventional full denture. Regarding the mandibular posterior residual ridge, resorption was irrespective of wearing an implant-retained mandibular overdenture or a conventional mandibular denture.

Acknowledgements

The investigators express their gratitude to Mr. J. de Vries (Biomedical Engineering, University Medical Center Groningen) for his valuable help in developing the software for the radiographic measurements.
References


