Effect of Implant Support on Distal-Extension Removable Partial Dentures: In Vivo Assessment

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Purpose: *The use of a limited number of implants for support of a removable partial denture (RPD) changes a Kennedy Class I or II situation to that of a Class III. This in vivo pilot study evaluated implant-supported distal-extension removable partial dentures (RPD) in 5 partially edentulous patients.* ***Materials and Methods:*** *Two implants (Brånemark TU MK III, Nobel Biocare) were placed in a mandibular Kennedy Class I arch. To fabricate an implant-supported RPD (ISRPD), a conventional RPD base was fitted to the healing abutment with autopolymerizing acrylic resin (Uni-fast II, GC) to support the posterior aspect of the RPD. By changing the healing abutment to a healing cap, there was no connection between the denture base and implant, and the ISRPD became a conventional RPD (CRPD). Using a crossover study design, the masticatory movements (mandibular movements during mastication) of both dentures were measured using a commercially available tracking device (BioPACK, Bioresearch, Japan). The occlusal force and contact area were also measured using pressure-sensitive sheets and an image scanner (T-scan system). Using a visual analog scale (VAS), the 4 criteria of comfort, chewing, retention, and stability were evaluated. All the data obtained were analyzed using Wilcoxen signed rank tests (α = .05).* ***Results:*** *There were no significant differences (P > .05) in masticatory movements between the ISRPD and the CRPD (5 patients: 4 women, 1 man). However, the ISRPD had significantly greater force and greater area than the CRPD (P = .043). The center of occlusal force of the ISRPD tended to move more distally compared to the CRPD. All the patients preferred the ISRPD for comfort, chewing, retention, and stability.* ***Conclusions:*** *One implant per edentulous area and a simple attachment technique yielded a stable distal extension RPD.* Int J Oral Maxillofac Implants 2008;23: 1095–1101

Key words: *implant-supported removable partial dentures, masticatory movements, occlusal force, visual analog scale*

In a distal-extension removable partial denture (RPD), the occlusal force tends to cause the base to move in a tissueward direction, since the sink of the posterior denture teeth is not protected by an abutment tooth on the distal of the base.[1,2] The rotational movements of the RPD can produce terminal torquing forces against the abutment teeth and the soft tissue.[3,4] Ill-fitting retainers, occlusal disharmony, and pain in the soft tissues under the connector or denture base are frequently observed after long-term use.[5–8] In addition, the resorption of the edentulous ridge gradually continues because of constant pressure from the denture base.[9,10] However, these denture movements and ridge resorption can be solved by the placement of fewer implants.[11–15]

In 1993, Keltjens et al[12] reported on a clinical trial with 2 patients in which implants were placed beneath the distal-extension denture base of the RPD to obtain stable and durable occlusion. Brudvik[15] also stated that implant placement in the distal edentulous ridge (ideally in the second molar region) would effectively change the Kennedy Class I or II situation to Class III. The clinical observations of 10 cases of implant-supported RPDs indicated no changes in the implant and residual ridge. An implant

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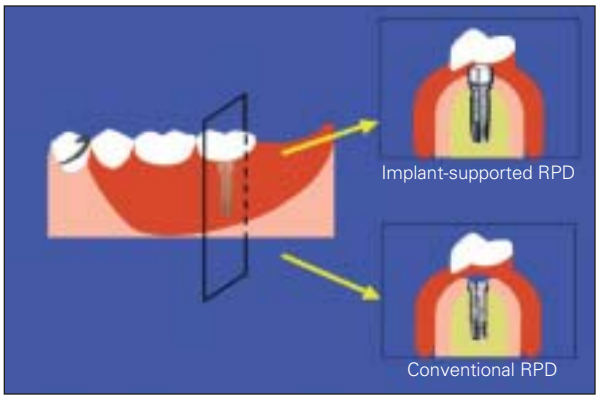


Fig 1 Due to the exchange of the healing abutment and healing cap, an ISRPD and CRPD were produced for comparison of both dentures.

placed posteriorly virtually eliminates the clinical problems often associated with a tooth- and tissue-supported distal-extension RPD.

Kihara et al[16] confirmed in vitro the effectiveness of implant-supported RPDs (ISRPDs). Conventional RPDs (CRPDs) had a greater vertical displacement and bending moment compared to ISRPDs. Ohkubo et al[17] also measured in vitro the differences in the denture displacement and burden on the soft tissues under the denture base between distal-extension RPDs with and without implant support. There was less pressure on both thin and thick soft tissues from the ISRPDs than from the CRPDs. Denture displacement of the ISRPDs was significantly less than for the CRPDs. It was verified that implant support could prevent the displacement of distal-extension RPDs and decrease the pressure on the soft tissues. However, there has been no in vivo assessment of ISRPDs. The purpose of this in vivo pilot study was to evaluate the implant-supported distal-extension RPDs in 5 partially edentulous patients using measurements of masticatory movement, occlusal force, and the summative area of the actual contact points.

MATERIALS AND METHODS

The study participants were selected from the patients visiting the Division of Maxillofacial Implantology, Tsurumi University Hospital, between June 2002 and December 2003. The criteria for patient selection included the absence of any systemic contraindications for implant surgery. Implant-supported fixed partial dentures were not placed because of patients' budgetary problems or lack of sufficient bone for implant-supported fixed prostheses (less than 12 mm length) distal to the mental foramina. All the patients included in the study expressed a desire for a more stable denture that would function in an acceptable manner and agreed to treatment with ISRPDs. The approval of the Ethical Committee for Human Clinical Research (No. 127) at the Tsurumi University School of Dental Medicine was procured, and a signed informed consent form was obtained from all patients before this in vivo assessment began.

Using a surgical guide, 2 osseointegrated implants (Brånemark MKIII TU 3.75 mm in diameter × 8.5 to 11.5 mm in length, Nobel Biocare, Göteborg, Sweden) were placed following the manufacturer's recommendations in or around the area of the second molar (Class II and Class I, respectively). In a second surgical procedure performed after a healing period, a healing abutment was placed on the implant so that 1 to 2 mm of the abutment protruded from the soft tissue. An impression was made using silicone impression materials (Exafine, GC, Japan), and the maxillary and mandibular relationship was registered with occlusion rims. A cobalt-chromium framework RPD with a lingual bar or plate was designed and fabricated conventionally. After the RPD was inserted and adjusted, it was worn for 2 to 3 weeks. If there were no problems, the RPD was fitted to the healing abutment by relining the basal surface with autopolymerizing acrylic resin (Uni-fast, GC) into the denture base under occlusal force. After the acrylic resin was polymerized and excess resin was trimmed, the ISRPD was completed.

A single-blind randomized crossover study was designed to compare the RPD functions with and without implants to support the posterior aspects of the RPD. After removing the healing abutments, a healing cap was placed so that the implants were not connected to the denture base. This situation simulated a CRPD. By changing the healing abutments to the healing caps, both the ISRPD situation and the CRPD situation were produced for purposes of comparison (Fig 1). The measurements of both the ISRPD and CRPD were made 2 to 3 weeks after the ISRPD was completed.

The mandibular jaw movements during mastication were measured with a commercially available tracking device (BioPACK, Bioresearch, Japan). A small magnet (13 × 6 × 4 mm) was attached to the labial surface of the incisors of the mandible. A piece of fresh gummy candy (approximately 4 g) was used as test food.[18] All chewing was performed on the side preferred by each patient at the patient's own pace until swallowing. This process was repeated 3 times per denture. The data were analyzed utilizing the BioPACK system.

Ten strokes from the initial 10 to 19 strokes in the chewing cycle were selected to compare the mastica-

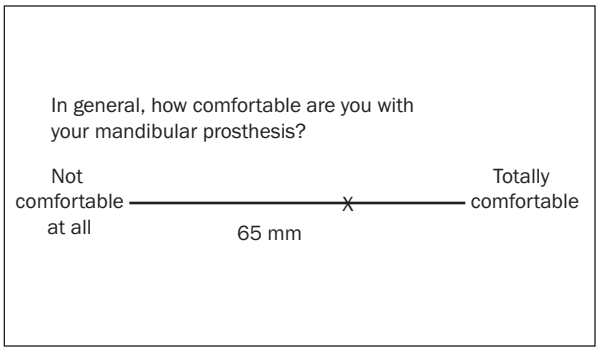


Fig 2 Example of a visual analog scale (VAS) translated into English. After using both RPDs, the patient marked the scale. The distance from the end of the horizontal line on the left to the "X" marked by the subject was measured in millimeters.

Table 1 Characteristics of the Patients Participating in this Study

No.	Age	Gender	Maxillary missing teeth	Mandibular missing teeth
1	50	Female	1(18) to 4(15) 6(13) to 13(25) 15(27)	17(38) to 20(35) 28(44) to 32(48)
2	57	Female	1(18) to 11(23)	17(38) to 20(35) 29(45) to 32(48)
3	59	Female	4(15), 10(22), 11(24)	17(38) to 20(35) 29(45) to 32(48)
4	60	Male	4(15) to 12(24)	17(38) to 20(35) 29(45) to 32(48)
5	63	Female	2(17) to 5(14) 8(11) to 16(28)	17(38) to 21(34) 29(45) to 32(48)

tory movements of the ISRPD and CRPD.[19] Each individual activity was identified, and the mean time (seconds) and standard deviation of each phase (ie, the opening phase, closing phase, and occluding phase) were measured. A coefficient of variation (%) for each individual activity and each phase was then calculated from the standard deviation divided by the mean.

After placement of a thin white pressure-sensitive sheet (Dental Prescale 50H type R 5-120 MPa, Fuji Photo Film, Tokyo, Japan) between the maxillary and mandibular teeth, the patients were instructed to bite strongly. The contact points between the maxillary and mandibular teeth caused by biting were indicated in shades of red (dark red represented strong contact). An image scanner (Occluzer FPD 703, Fuji Photo Film) analyzed the color of the contact points, thereby measuring and displaying the occlusal force and a summative area of the actual contact points as the occlusal area in the RPD area and in the full dental arch.[20,21] The center of occlusal force was also calculated by this system. This measurement was repeated 3 times per ISRPD and CRPD situation.

After the masticatory movements and occlusal force were measured, all the patients completed a questionnaire about the comfort of wearing the ISRPD and CRPD. This questionnaire, which followed the 100-mm visual analog scale (VAS) method,[22] assessed the patients' personal opinion based on 4 factors (retention, comfort, chewing, and stability; Fig 2).

All the data obtained were directly analyzed with the SPSS statistical package (Version 10.0, SPSS, Chicago, IL, USA). Wilcoxon signed rank tests were used to compare the ISRPDs and CRPDs at a significance level of $\alpha = .05$.

RESULTS

Five healthy patients (4 female, 1 male; mean age 60.5 years) with missing bilateral (Class I) mandibular premolars and molars voluntarily participated in this study (Table 1). The mean time and coefficient of variation of masticatory movements for each ISRPD and CRPD while gummy candy was chewed are shown in Figs 3a and 3b, respectively. Figure 4a displays the total occlusal force in the RPD area and in the full dental arch. The contact area of each type of RPD during strong biting in the RPD area and in the full dental arch is also shown in Fig 4b. Figure 4c indicates the changes of the contact points and the center of occlusal force. The patients' preferences for the 4 criteria are exhibited in Fig 5.

There were no significant differences in either the mean time or coefficient of variation between the ISRPDs and CRPDs (Mean time—opening: $Z = -1.753$, $P = .080$; closing: $Z = -0.405$, $P = .686$; occlusal: $Z = -0.944$, $P = .345$; cycle: $Z = -0.405$, $P = .686$. Coefficient of variation—opening: $Z = -1.753$, $P = .080$; closing: $Z = -0.135$, $P = .893$; occlusal: $Z = -0.674$, $P = .50$; cycle: $Z = -1.753$, $P = .080$). However, both the mean time and coefficient of variation for the ISRPDs were less than for the CRPDs with no significant differences, except for the coefficient of variation of the "opening" phase (Figs 3a and 3b).

The ISRPDs had greater force and greater contact area than the CRPDs (Figs 4a and 4b) both in the RPD area and in the full dental arch ($Z = -2.023$, $P = .043$). There were significant differences in the contact area between both dentures ($Z = -2.023$, $P = .043$) in the RPD area. In all patients, the center of occlusal force of

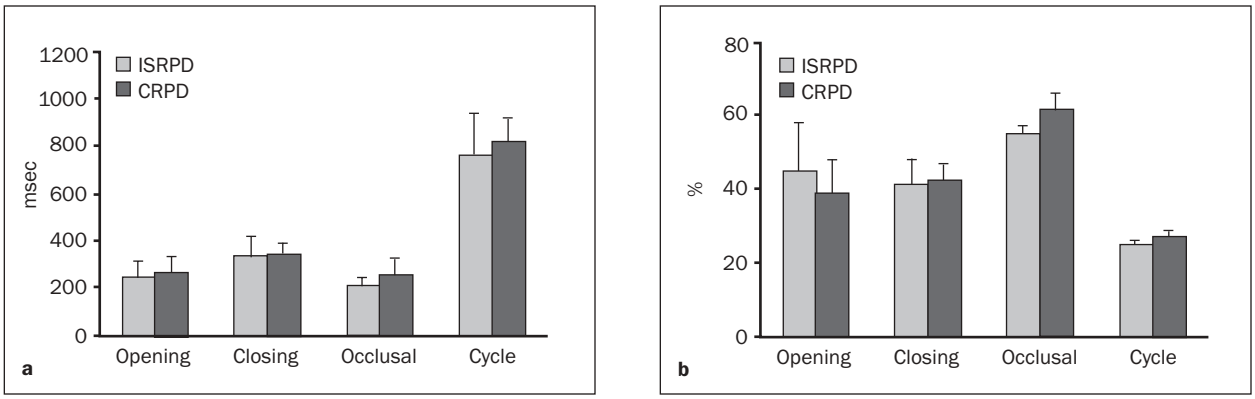
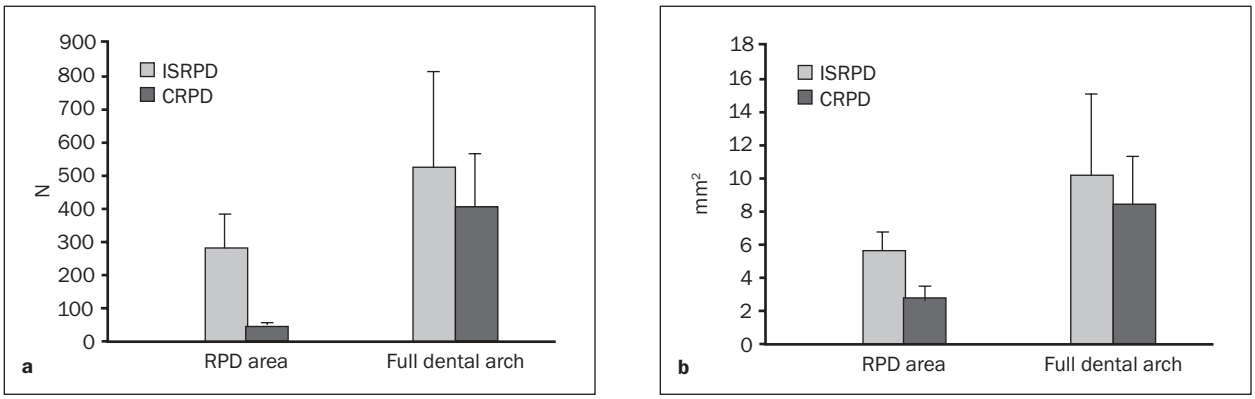


Fig 3 Mean time (a) and coefficient of variation (b) of masticatory movements while gummy candy was chewed using ISRPDs and CRPDs.



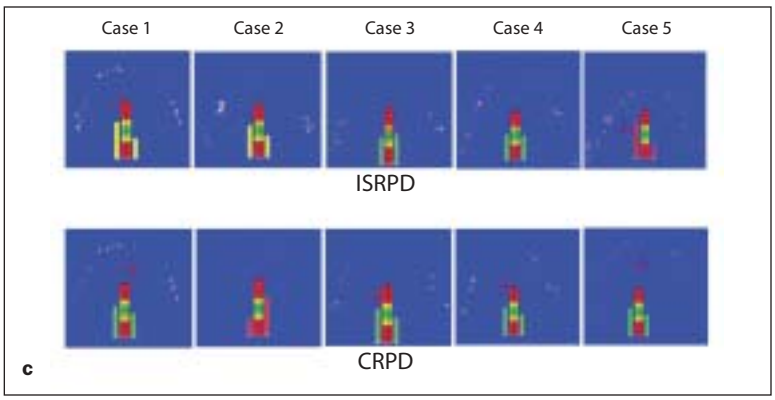


Fig 4 Total occlusal force (a), summative area of active contact points (b), and changes of the contact points and the center of occlusal force, indicated by red crosses (c) in the RPD area and in the full dental arch.

the ISRPDs tended to move more distally compared to the CRPDs (Fig 4c). There were 2- to 7-mm differences between the 2 types of dentures.

The patients preferred the ISRPD for all the criteria, ie, retention, comfort, stability, and chewing (Fig 5). The VAS showed that the patients' satisfaction was significantly improved (stability: $Z = -2.023$, $P = .043$; chewing: $Z = -2.023$, $P = .043$; retention: $Z = -1.761$, $P = .078$; comfort: $Z = -1.826$, $P = .068$) by the implant support.

DISCUSSION

Ohkubo et al[17] suggested that implant support helped prevent the displacement of distal-extension RPDs and decreased the pressure on the soft tissues in vitro. In this continuing investigation, the differences in oral comfort and function were assessed in vivo between distal-extension RPDs with and without implant support.

In previous clinical research on implant overdentures,[23,24] the differences between the 2 types of dentures were evaluated between presurgical conventional complete overdentures and postsurgical implant overdentures. Although this research method can evaluate the actual state of both types of dentures, there is a substantial amount of time between the measurements for each denture. In contrast, both dentures described in this study could be measured on the same day by changing the connection between the implant and the denture base after implant placement; in other words, there is no effect of time difference on the measurements.[25] However, the true condition of the conventional RPD could not be determined in this study because there was no connection between the soft tissue and the denture base on the implant. The measurements were made in 1 day, as in the previous in vitro study.[17]

A connection between the implant and tooth by means of an implant-supported fixed prosthesis is not recommended because the displacement under the occlusal force is quite different. Although an osseointegrated implant is not mobile under occlusal force, natural teeth have at least 30 μm physiologic mobility.[26,27] However, no scientific evidence-based research that completely negated the need for the connection between implants and natural teeth was found. In ISRPDs, the connection between the clasps and the abutment teeth, and the connection between the denture base and the implant, are more flexible than that of cement-retained or screw-retained fixed prostheses. Thus, ISRPDs would be quite safe even if there were rigid connections between the implant and natural teeth from the denture base and clasps.

The remarkable differences in displacement between the implant and soft tissues should also be considered. To compensate for these differences, the denture base and healing abutment must be fitted with autopolymerized acrylic resin under strong masticatory force using the overlay technique. Naturally, the maintenance of this connection has to continue to keep these displacement differences correct.

The mean time and coefficient of variation of each phase were measured and recorded because the duration of the chewing cycle and percentage of each phase in the chewing cycle are affected by denture stability.[18,25] If their values are low, the masticatory movements can be considered fast and smooth by a stable denture without much displacement. Although the mean time and coefficient of variation of the masticatory movements were not significantly ($P > .05$) affected by implant support, both the mean time and coefficient of variation for the ISRPDs were less than for the CRPDs, except for the coefficient of variation of the "opening" phase (Figs 3a and 3b). These findings may indicate that a small number of implants can improve the stability and chewing provided by conventional distal-extension RPDs. Additionally, the findings about the ISRPD may support the VAS results that patients' satisfaction about chewing was greater than for the CRPD.

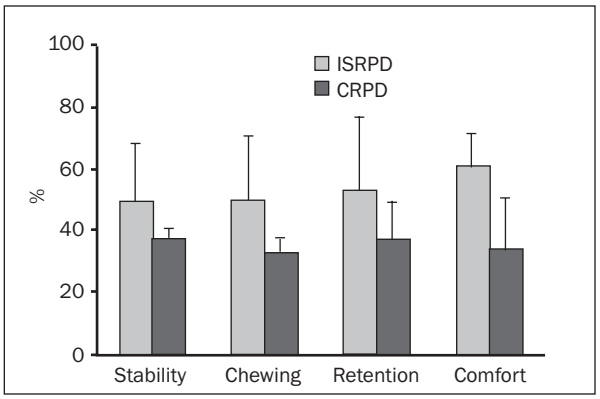


Fig 5 Patients' preferences for the 4 criteria in the VAS.

Regarding the occlusal force, greater force was found for the ISRPDs than for the CRPDs (Fig 4a). A patient can bite strongly using an RPD until the denture is displaced when the pain threshold of the abutment teeth or soft tissue is reached. The authors' previous study indicated that the ISRPD had less denture displacement (approximately 40 μm) compared to the CRPD under loads up to 5 kg.[17] Therefore, the patient can theoretically bite with greater force using the ISRPD compared to the CRPD. Also, the contact area was significantly increased by the implant support (Fig 4b). These phenomena occurred because of the small displacement of the distal-extension RPD with implant support. Both the stronger occlusal force and the greater contact area may contribute to the improved chewing capacity of the ISRPD. Generally, the center of the occlusal force gradually moved mesially in the dental arch with the molar and premolar missing.[9] The missing occlusal contact in the distal area would usually cause temporomandibular joint (TMJ) syndrome.[28] Using a distal-extension RPD, distal occlusion support can be obtained, and the burden on the TMJ will decrease.[29] Furthermore, by placing few implants in the second molar region, the center of occlusal force similar to that of an implant-supported fixed prosthesis would be obtained (Fig 4c). The ISRPD ensures that denture deviation is kept to a minimum during chewing, thus offering an alternative method of implant treatment for partially edentulous patients with severe ridge resorption. If implant-supported fixed prostheses cannot be

applied because of anatomic or economic reasons, ISRPDs are recommended.

In this study, the VAS indicated that all the patients preferred the ISRPD for the 4 criteria compared to the CRPD (Fig 5). Therefore, patient satisfaction improved with the implant support. However, the VAS scores for the ISRPD were not much higher (approximately 50% to 60%). Thus, the limitations of ISRPD function compared to implant-supported fixed prostheses must be disclosed to the patient before ISRPD treatment. As Keltjens et al[12] reported, the advantages of the ISRPD over an implant-supported fixed prosthesis are that the procedures are simple and the cost is low. However, compared to the CRPD, the ISRPD requires surgical treatment, and the cost is high. For example, a unilateral placement of 2 implants and a fixed partial denture probably costs the same as a bilateral ISRPD. In addition, an existing RPD can be retrofitted. The limitations of this pilot study were that few subjects participated, and the ISRPDs were evaluated only at an early stage after denture insertion. Thus, the number of patients rehabilitated with ISRPDs should be increased in a subsequent study. In addition, a longitudinal study on ISRPDs is necessary in which the survival rate of the implant, the conditions of the terminal abutment teeth, and the edentulous ridge resorption are re-evaluated at various intervals.

CONCLUSIONS

To assess implant-supported RPDs in vivo, 5 patients with posterior mandibular edentulism were treated with removable partial dentures that were either supported or not supported by endosseous implants. The masticatory movements, occlusal force, contact points, center of occlusal force, and patients' preferences were measured to compare the ISRPDs with conventional RPDs. Within the limitations of this pilot study, these conclusions were drawn:

1. The implant-supported RPDs tended to have lower values for mean time and coefficient of variation of masticatory movement compared to the conventional removable partial dentures, except for the opening phase.
2. The implant-supported RPDs had greater occlusal force than the conventional RPDs. The center of occlusal force of the implant-supported RPDs was positioned distally compared to the conventional RPDs.
3. All the patients in this study preferred the implant-supported RPDs for all criteria (comfort, chewing, retention, and stability).

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