Review Article
Mandibular Kennedy Class I implant-tooth-borne removable partial denture: a systematic review

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SUMMARY The purpose of this systematic review is to evaluate the use of implant-tooth-borne removable partial dentures in prosthetic rehabilitation of Kennedy Class I partially edentulous arches. A comprehensive search was performed in MEDLINE, EMBASE, Cochrane Oral Health Group's Trials Register, Cochrane Central Register of Controlled Trials, UK National Research Register, Australian New Zealand Clinical Trials Registry (ANZCTR), conference proceedings and abstracts up to 25 August 2009. Searching the reference list of the selected articles and hand searching of several journals were also performed. A total of nine studies were included. Of these, two were randomized, three were retrospective and four were case reports. All but two had a low reporting quality (level IV on a four-level hierarchy of evidence). Nevertheless, the improvement in function, aesthetics and stability has been demonstrated in all studies with minimal prosthetic care. Within the limitations of this study, implant-assisted/supported removable partial denture may provide a simple, economical and less invasive treatment modality. The predictability of such approach in the management of bilateral distal-extension situation is, however, still questionable. A higher quality of published studies namely with a focus on long-term randomized clinical trials are needed.

KEYWORDS: implant-assisted removable partial denture, implant-supported removable partial denture, Kennedy Class I, patient satisfaction, prosthetic maintenance, systematic review

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Introduction

In the last decade, industrialized countries have shown a significant improvement in oral health and dental care. Data collected from studies conducted by several health organizations including the US National Health, Nutrition Examination Survey (NHANES), UK Adults Dental Health Survey, Fourth German Oral Health Study (DMS IV), and Australia’s National Oral Health Plan revealed a considerable reduction in the percentage of edentulous adults (1–4). The demand for treatment with different partial denture prostheses will therefore increase, as more individuals will have more teeth when they get older (5, 6).

There are several treatment options for rehabilitation of partial edentulism including the use of conventional or implant-retained fixed prostheses. However, such prosthetic options cannot always be possible because of compromised general and oral health (i.e. loss of supporting tissues, medical reasons and extensive surgical protocol) as well as the affordability of patients (6). Several authors considered a well-constructed removable partial denture (RPD) as cost-effective and acceptable alternative treatment option for rehabilitation of partially dentate patients (7–11).

Based on the location of edentulous spaces, Kennedy classification (12) has been proposed to enhance the planning of the RPD design as well as the communication between dental practitioners and technicians. However, Kennedy did not take into consideration the quality of the remaining ridges and axial position of teeth as well as the condition of the opposing dental
arch. Distal-extension RPDs (Kennedy Class I and II) were associated with several problems related to its limited stability, retention, aesthetics and masticatory efficiency (13–16). In addition, a high percentage of failure was reported because of caries and periodontal disease, needed regular replacement, did not improve eating, had poor retention and poor stability and did not achieve patient satisfaction and oral comfort (15, 17).

Another common problem is combination syndrome, which is found in patients wearing mandibular bilateral distal-extension RPD opposing a maxillary complete denture. This condition, first described by Kelly in 1972 (18), is characterized by overgrowth of the maxillary tuberosities, papillary hyperplasia in the hard palate, resorption of the anterior part of the maxilla, extrusion of the mandibular anterior teeth, resorption under the RPD bases and marked tipping of the occlusal plane (18, 19). The relationship between combination syndrome and distal-extension RPD is still controversial. While Shen and Gongloff (20) recognized such relationship and showed that 24% of the patients wearing a maxillary complete denture opposing a distal-extension RPD developed those signs, others questioned the evidence that such a relationship exists and expressed that combination syndrome lacked adequate reasons to be considered a true medical syndrome (21, 22).

It has been suggested that the proper placement of one or more implants in conjunction with RPD may overcome some of the common problems with conventional RPD (CRPD). Implants incorporated into RPD provided support through the use of healing caps, hence the term implant-supported. The term implant-assisted described the use of resilient attachment to improve retention. Implant-supported/assisted RPDs offered equality in force distribution and enhanced the aesthetics by avoiding the buccal retentive clasps. Placing two distal implant abutments has been recommended to transform Kennedy Class I to a Kennedy Class III situation to improve the RPD design (13). The aim of the current review is to systematically evaluate existing evidence to identify whether implant-supported RPD (ISRPD) or implant-assisted RPD (IARPD) provided a better performance compared to other treatment modalities.

Materials and methods

This systematic review was developed according to the PRISMA (preferred reporting items for systematic reviews and meta-analyses) statement (23). The review question was formulated using the PICO (participant, intervention, comparison and outcome) approach (24):

1. Participant: partially edentulous patients.
2. Intervention: mandibular bilateral distal-extension ISRPD or IARPD.
3. Comparison: CRPD or other forms of prosthetic treatment.

Search methodology

Electronic searching was performed in the following databases

1. MEDLINE (1969 to 25 August 2009)
2. EMBASE (1980 to 25 August 2009)
3. The Cochrane Oral Health Group's Trials Register (to 25 August 2009)
4. The Cochrane Central Register of Controlled Trials (CENTRAL)
5. UK National Research Register
6. Australian New Zealand Clinical Trials Registry (ANZCTR)
7. ISI Proceedings for relevant conference abstracts


Selection criteria

The literature review and data extraction were performed by the two authors (R.S., M.A.), with any disagreements resolved through discussion. Studies were eligible for inclusion in the review if they met the following criteria:

1. English-language publication.
All types of in vivo studies, ranging from randomized controlled trials to case reports.

The intervention included rehabilitation of partially edentulous patients with a bilateral distal-extension ISRPD or IARPD, in which implants are not splinted to the remaining teeth.

Only mandibular situations were included. In addition, no restriction on the length of the follow-up period was applied. A data extraction form was developed to collect general information (title, year of publication, location of the study, site and number of implants used, implant system, implant length and diameter, outcome variable, prosthetic complications and follow-up period). In addition, the National Health and Medical Research Council (NHMRC) hierarchy of evidence was used to evaluate the quality of the selected studies (Table 1) (25). In case of possible duplication, only the most recent publication was included.

Results

The electronic search identified 404 titles (Fig. 1). Based on the review of the titles and abstracts, 15 articles were selected for more evaluation. Further, seven articles were excluded from the review, of which two studies reported on maxillary IARPD (26, 27), two described a unilateral distal-extension condition (28, 29), two assessed implant-retained fixed partial dentures (30, 31) and one had duplicate data (32). Masking was not attempted during the assessment as it was suggested that masked assessment did not affect the overall results of systematic reviews (33). A total of nine studies (34–42) were included in the review (Table 2). Among these, one article was retrieved from conference abstracts (42). The hand search did not provide any additional studies.

Description of studies

Among the included nine studies, three were retrospective studies (35, 39, 40), one was part of multicentre, randomized clinical trial (42), one was a randomized crossover pilot study (41). The remaining four studies were case reports (34, 36–38). All the included studies were poorly rated in terms of quality of its evidence as only two studies (41, 42) had a moderate level of evidence. However, ISRPD/IARPD may be considered as a promising treatment approach as the selected studies described its advantages as follows:

1. Enhanced stability and retention (36, 38, 41).
2. Improved aesthetic results (34, 35).
3. Facilitate oral hygiene maintenance (34).
4. Reduced bone resorption under the denture base (36, 37, 40).
5. Easily converted to CRPD in case of implant failure (34).
7. Improved patient satisfaction (37, 40, 41).
8. Prosthetic maintenance is less required than a CRPD (34).
9. Reduced extension of the RPD base (40).
10. Reduced cost compared to implant-supported fixed prosthesis (34, 37).
11. Reduced likelihood of combination syndrome (37).

The data included a total of 183 implants placed in 94 subjects with follow-up period between 3 weeks and 120 months. All the selected studies placed the implant in the most distal position in the molar region to modify the Kennedy Class I in the mandible to a more favourable Kennedy Class III arch configuration. Nevertheless, a more anterior position of the implant, adjacent to the existing abutment has been suggested (35). Moreover, improved patient satisfaction and masticatory efficiency were also reported in all the studies.

Fields and Campfield (34) were the first to report the use of an implant in conjunction with CRPD in the

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Study design</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A systematic review of randomized controlled trials</td>
</tr>
<tr>
<td>II</td>
<td>A randomized controlled trial</td>
</tr>
<tr>
<td>III-1</td>
<td>A pseudorandomized controlled trial (i.e. alternate allocation or some other method)</td>
</tr>
<tr>
<td>III-2</td>
<td>A comparative study with concurrent controls: Non-randomized, experimental trial</td>
</tr>
<tr>
<td>III-3</td>
<td>A comparative study without concurrent controls: Historical control study</td>
</tr>
<tr>
<td>IV</td>
<td>Case series</td>
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</tbody>
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treatment of the bilateral distal extension of mandible. The authors used endosseous blade implant on one side, while the other side of the partially edentulous mandible had the usual denture base coverage and was used as a control. To lower the rotational point of prostheses, the height of the post was reduced to half, and a lingual plate was used as a major connector. On the control side, a stress-relieving hinge was adopted. The hinge could prevent unnecessary stress on the remaining teeth or implant, while allowing a distal extension to move during the function. Despite a relatively short 7-month follow-up period, it was reported that no bone loss was detected around the implant and the tissue around the implants remained healthy.

Grossmann et al. (35) reported a retrospective study of 35 patients treated with both unilateral and bilateral distal-extension ISRPsDs/IARPsDs. The most common arch configuration was mandibular Kennedy Class II (10 patients) followed by mandibular Kennedy Class I (eight patients). A total of 67 implants were placed to provide support using healing caps or retention using resilient attachments. An overall survival rate of 97.1% was achieved during a mean follow-up period of 35.4 months.

Halterman et al. (36) described an ISRPD, in which the RPD was made of nickel–chromium alloy with 18-gauge wrought wire clasps. The healing caps on fixtures were used to support the RPD. The authors failed to report the length of the follow-up period but showed that combining the implant and natural teeth in supporting RPD is more likely to reduce the posterior occlusion collapse compared to CRPD.

Keltjens et al. (37) reported two cases of mandibular implant-tooth-borne RPDs opposing full denture prostheses. The first case was an ISRPD, where a $3 \times 3 \times 10$ mm implant was used, and the metal framework had a cup-shaped cavity resting on a rounded implant head. In the second case (IARPD), a $3 \times 10$ mm implant was used and magnets placed over the implants to provide additional retention. The authors stated that the risk of combination syndrome was reduced by preventing the resorption in the anterior maxilla.

Kuzmanovic et al. (38) reported a case of mandibular distal-extension IARPD in which a chromium–cobalt RPD was fabricated using a modified intracoronal attachment method of the channel shoulder pin system in metal ceramic crowns on mandibular canines. Ball attachments with gold matrices on the mandibular RPD were used to provide retention and support of the IARPD. Minor prosthetic maintenance in the form of simple activation of the gold matrices was reported after 2-year follow-up.

Mijiritsky et al. (39) followed up 15 partially edentulous patients wearing IARPDs for a period of 2–7 years. Both Kennedy Class I and II were included. Ball attachments and bar designs were used in conjunction
<table>
<thead>
<tr>
<th>Study design</th>
<th>Fields &amp; Campfield (34)</th>
<th>Grossmann et al. (35)</th>
<th>Haltermann et al. (36)</th>
<th>Keltjens et al. (37)</th>
<th>Kuzmanovic et al. (38)</th>
<th>Mijiritsky et al. (39)</th>
<th>Mitrani et al. (40)</th>
<th>Ohkuba et al. (41)</th>
<th>Payne et al. (42)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>United States</td>
<td>Israel</td>
<td>United States</td>
<td>The Netherlands</td>
<td>New Zealand</td>
<td>Israel</td>
<td>United States</td>
<td>Japan</td>
<td>New Zealand</td>
</tr>
<tr>
<td>No. of participants/ no. of implants</td>
<td>1/1</td>
<td>35/67</td>
<td>1/2</td>
<td>2/4</td>
<td>1/2</td>
<td>15/33</td>
<td>10/16</td>
<td>5/10</td>
<td>24/48</td>
</tr>
<tr>
<td>Implant system</td>
<td>Endosseous blade implant</td>
<td>Zimmer Dental</td>
<td>Sulzer Calcitek*</td>
<td>IMZ implant†‡</td>
<td>ITI implants†‡</td>
<td>Not clear</td>
<td>Brånemark††</td>
<td>ITI implants†‡</td>
<td>Brånemark††</td>
</tr>
<tr>
<td>Implant length (mm)</td>
<td>Not clear</td>
<td>Not clear</td>
<td>13</td>
<td>10-0, 10-5</td>
<td>12</td>
<td>≥10</td>
<td>Not clear</td>
<td>8-5–11-5</td>
<td>10-0, 10-5</td>
</tr>
<tr>
<td>Implant diameter (mm)</td>
<td>Not clear</td>
<td>Not clear</td>
<td>3-25</td>
<td>3-0, 3-3</td>
<td>4-1</td>
<td>≥3-7</td>
<td>Not clear</td>
<td>3-75</td>
<td>3-0, 3-3</td>
</tr>
<tr>
<td>Implant abutment (attachment)</td>
<td>Healing caps post</td>
<td>Healing caps</td>
<td>5-mm healing caps</td>
<td>Case 1: Implant provided support: Implant rounded head</td>
<td>Patrices on implants attached to gold matrices of the RPD</td>
<td>Ball attachments and bar connections</td>
<td>Group 1: modified healing abutment</td>
<td>Healing abutment to simulate an ISRPD situation and healing cap to simulate a CRPD situation</td>
<td>Control group: CRPD</td>
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<tr>
<td></td>
<td></td>
<td>Locator attachment§</td>
<td>O-ring attachment (Zimmer Dental)*</td>
<td>Case 2: Dyna magnets</td>
<td>Patrices on implants attached to gold matrices of the RPD</td>
<td>Ball attachments and bar connections</td>
<td>Group 2: Resilient attachment [OSO, Attachments International; Zaag, Preat; Hader Bar and Clip, Attachments International; or extracoronal resilient attachment (ERA), Sterngold]</td>
<td>Healing abutment to simulate an ISRPD situation and healing cap to simulate a CRPD situation</td>
<td>Test group: ISRPD with healing caps (Stage I) and IARPĐ with patrices (Stage II)</td>
</tr>
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</table>
Table 2. (Continued).

<table>
<thead>
<tr>
<th>Outcomes evaluated</th>
<th>Fields &amp; Campfield (34)</th>
<th>Grossmann et al. (35)</th>
<th>Halterman et al. (36)</th>
<th>Keltjens et al. (37)</th>
<th>Kuzmanovic et al. (38)</th>
<th>Mijiritsky et al. (39)</th>
<th>Mitrani et al. (40)</th>
<th>Ohkuba et al. (41)</th>
<th>Payne et al. (42)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complications (maintenance)</td>
<td>Patient satisfaction Marginal bone loss</td>
<td>Patient satisfaction Masticatory efficiency</td>
<td>Not reported</td>
<td>Patient satisfaction</td>
<td>Prosthetic maintenance</td>
<td>Prosthetic maintenance patient satisfaction</td>
<td>Only one case of rest rupture</td>
<td>Patient satisfaction Masticatory efficiency</td>
<td>Prosthetic maintenance Marginal bone loss</td>
</tr>
<tr>
<td></td>
<td>Adjustment of acrylic base 30 days after insertion</td>
<td>Two failed implants</td>
<td>Not reported</td>
<td>Repeated relining</td>
<td>Activation of the gold matrices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of evidence</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>III-1</td>
<td>III-1</td>
</tr>
<tr>
<td>Follow-up period (months)</td>
<td>7</td>
<td>9–120 months</td>
<td>Not reported</td>
<td>24</td>
<td>24</td>
<td>24–84</td>
<td>12–48</td>
<td>&lt;1 (measurements taken at 3 weeks)</td>
<td>12 months</td>
</tr>
<tr>
<td>Implant survival rate (%)</td>
<td>100</td>
<td>97.1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>93.75</td>
<td>100</td>
<td>100</td>
</tr>
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</table>

RPD, removable partial denture; CRPD, conventional removable partial denture; ISRPD, implant-supported removable partial denture; IARPD, implant-assisted removable partial denture.

*Carlsbad, CA, USA.
†Palm Beach, Gardens, FL.
‡Shlomi, Israel.
§Locator, Zest, Escondido, CA.
¶Friedrichsfeld AG, Heidelberg, Germany.
**Dyna Dental Engineering, Bergen op Zoom, The Netherlands.
††Straumann AG, Waldenburg, Switzerland.
‡‡Nobel Biocare, Göteborg, Sweden.
with 3.7-mm or more diameter implants. The authors evaluated the prosthetic maintenance and patient satisfaction. Inconsiderable complication of only one rest rupture was reported during the follow-up period. Patients showed both improved chewing ability and satisfaction.

Mitran et al. (40) carried out a retrospective study of 10 patients with Kennedy class I and II partially edentulous situations. Two groups of patients were evaluated. In the first group, implants were solely used as vertical stops with single contact points created using dome-shaped healing abutments. In the second group, a resilient attachment was used as a retentive element. More complications were reported in the first group such as pitting of the surface of the healing abutment, screw loosening and framework fracture. The authors, nevertheless, concluded that ISRPD/IARPD improved patient satisfaction, maintained the stability of the peri-implant soft and hard tissues within normal limits.

Ohkubo et al. (41) reported a pilot, randomized study in which five partially edentulous patients (Kennedy Class I) were evaluated for masticatory movements, occlusal forces and patient comfort following placement of ISRPD. The healing abutments were placed to provide support to the RPD, and then the healing caps were used instead of healing abutments to simulate a CRPD situation. The study showed no significant differences between both designs in terms of masticatory movements, whereas the occlusal force and contact area were greater and more distally located in the ISRPD. In addition, patients showed significant improvement when implants were used for support.

Payne et al. (42) reported the results of one treatment center, which was part of a multicenter randomized clinical trial that evaluated the prosthetic maintenance of ISRPD/IARPD. Twenty-four patients were randomly allocated to control (CRPD opposing maxillary complete denture) or test (implant-tooth-borne RPD opposing maxillary complete denture). The patients had healing caps in stage I (ISRPD) and then patrices in stage II (IARPD). The prosthetic maintenance was evaluated after 12 months and included loosening of healing caps in 84% of the patients in the test group (Stage I). Matrix activation or deactivation, adjustment of wrought wire clasp and fracture of denture base were observed in 58.3% of the test group (Stage II).

Discussion

This systematic review followed the recent guidelines of PRISMA in searching for the best available evidence for using implants in assisting/supporting RPD in Kennedy Class I mandibular arches. The prosthetic rehabilitation of mandibular bilateral distal extension partially edentulous patients by the use of ISRPD/IARPD was largely described in the form of clinical case reports (34, 36–38). In addition, three retrospective studies (35, 39, 40) and two randomized trials (41, 42) were identified. However, the majority of the selected studies were poorly reported and failed to mention details such as follow-up period, implant size and length. The level of evidence of the available literature was generally low as two studies (41, 42) were classified as NHMRC level III and seven studies as NHMRC level IV (34–40). Moreover, a quantitative systematic review or meta-analysis was not conducted because of lack of sufficient number of randomized or non-randomized controlled trials in the literature.

Implants have been incorporated in the RPD design to provide support by using healing caps or retention by carrying retentive means (i.e. attachments). The former was associated with complications such as pitting of the surface or screw loosening, which can be overcome by polishing the abutment head and relining as well as the use of antirotational features to avoid abutment loosening. Attachments can be generally categorized into two types: studs or bars. The type of resilient attachment usually used in IARPD is extracoronal resilient attachment (ERA), o-ring system or a similar attachment system (13). Locator abutments have also been recommended (43) because of their availability in different heights in addition to their resiliency and retention. Locator abutment can also be easily repaired and replaced which enhance their durability (44). Cho (45) studied the load transfer characteristics of IARPD and showed that the use of resilient attachment with distal implants reduced the stress concentration around implants and abutment tooth. In contrast, Itoh et al. (46) used a photoelastic model of mandibular bilateral distal-extension implant-tooth-borne RPD and found that both healing abutments and ball attachments provided support to the RPD with no difference in stress concentration. However, there is currently no available evidence to suggest one design over the other in terms of retention and support.
With regard to implant location, distally placed implants were used to transform Kennedy Class I in the mandible to a more favourable arch configuration, namely Kennedy Class III. Finite element analysis (FEA) has, however, showed more tendency to displacement when implants were placed in a second molar position, and suggested a more central position in the arch (i.e. first molar region) (47). On the other hand, Ohkubo et al. (48) showed that implant placement in the second molar region reduced the distal placement and bone resorption. Likewise, Grossmann et al. (35) recommended a second molar location for the implant to enhance support and stability, but also suggested placing the implant adjacent to the distal abutment in case of inadequate posterior alveolar ridge, possible future use for fixed implant-supported prosthesis or to improve aesthetics by avoiding the use of a retentive clasp. Further studies are still needed to evaluate the most effective position of the implant.

The optimal length and diameter of the implants associated with RPD have not been determined yet. In a biomechanical study, Verri et al. (49) created six models and used FEA to examine the dimensions of implants incorporated in the design of RPD. The authors showed that increasing both the length and diameter of implants were likely to reduce the tension values. Yet, it is expected that the implants used to support a RPD can be shorter with smaller diameter than implants supporting a fixed prostheses particularly in sharp mandibular residual ridge.

Several review articles have been published on the use of the ISRPD/IARPD and discussed its clinical procedure, fabrication, indications, advantages and limitations (35, 43, 50). Grossmann et al. (35) and Mijiritsky (50) provided a summary of the current literature regarding the use of implants in conjunction of both maxillary and mandibular RPD. The former also presented an evaluation of retrospective case series along with the review. Chikunov et al. (43) described the clinical procedures and fabrication of IARPD. Resilient attachments were selected through the use of locator abutments, and the implants were placed anterior to the mental foramina (in the premolar site). The authors reported the indications and contraindications as well as the advantages of using such prosthetic design. The current systematic review is different from previous studies in two aspects: first, only studies that reported on mandibular bilateral distal extension partially edentulous situations were included. Second, all types of studies including case reports were summarized in this review.

The numerous difficulties associated with the CRPD are well established, particularly the inability to achieve both a satisfactory patient and oral comfort as defined by the absence of chewing difficulties and compromised aesthetics (51). Nevertheless, CRPD will remain an economically adequate and non-invasive treatment option, particularly in non-industrialized countries, where the patient’s economic status has a profound effect on the prosthodontic choice (17). On the other hand, an implant-supported fixed prosthesis is an adequate alternative and a well-documented treatment modality for the distal-extension edentulous situation (52, 53). However, it is beyond the financial capabilities of some patients (54). The concept of shortened dental arch (SDA) is another treatment option that needs to be considered in treatment planning of partially edentulous patients. The SDA approach provides an affordable treatment modality that may provide an acceptable oral function and improves both oral hygiene and patient satisfaction. When compared with CRPD, SDA showed a long-term oral comfort and functionality (55). Nevertheless, the number of teeth needed to satisfy patients’ functional demands should be individually evaluated. In addition, more research is needed before SDA concept is widely accepted and practised in the prosthodontic community (56, 57).

Although the use of an ISRPD/IARPD lacks research-based evidence, it can be considered, within the limitation of the current review, a possible treatment option to improve stability, aesthetics and preserve the remaining soft and hard tissues. In addition, ISRPD/IARPD maintains the integrity of the vertical dimension of occlusion, thus reducing the risk of combination syndrome and moves the center of the occlusal force distally. Providing a distal occlusal support has been suggested to minimize the onset of temporomandibular joint (TMJ) syndrome and reduce the denture movement during chewing.

Conclusions

Posteriorly placed oral implants can modify the Kennedy classification of partially edentulous arches by converting Class I (tooth- and tissue-supported) to Class III (tooth- and implant-supported). ISRPD/IARPD seems to overcome the numerous problems associated with CRPD in addition to achieving a higher level of

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patient satisfaction. However, there is still no evidence-based research that validated the use of such treatment modality in managing bilateral distal-extension partial edentulism, or supported the use of implants with healing abutment or resilient attachment as means of providing support and retention to the RPD. Long-term randomized controlled studies are needed.

References


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