Review Article

Review of Implant Support for the Distal Extension Removable Partial Dentures

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Abstract

Partially edentulous patients with missing premolars and molars have been conventionally rehabilitated using the free-end removable partial dentures (RPDs). With the advancements in implant dentistry, the benefits of implant-retained/supported mandibular implant overdentures relative to conventional mandibular dentures with bilateral extensions (Class I Kennedy) have now been extensively investigated with well-documented long-term clinical studies. Two prominent advantages of implant-retained mandibular dentures are additional prosthetic retention and stability. This review article highlights the numerous factors affecting the retention and stability of RPDs and demonstrates their advantages over conventional mandibular removable dentures.

ABBRIEVATIONS


INTRODUCTION

Many years have now passed since the free-end removable partial denture (RPD) was considered the gold standard for missing teeth [1]. Originally used to achieve primary stability, prevent tooth migration and restore patient occlusion, their main limitation is gradual ridge resorption due to pressure areas between the tooth-fibro mucosa and support system [1-3]. The continual resorption of the residual ridge negatively impacts the stability, retention and support of RPDs, thus placing patients in a loop of continual change towards inferior stability and discomfort. Furthermore, bone loss on the alveolar ridge also modifies the occlusal conditions most notably in the distal-extension of RPDs, thus further contributing to bone loss by causing premature contacts and uneven occlusal forces [4]. Kelly was one of the first to report cases of patients with an edentulous maxilla rehabilitated by a complete denture opposing a Kennedy Class I deflection lower arch [5]. In all cases, it was demonstrated that the free-end RPDs led to gradual and continual bone loss in the alveolar ridge under the base of RPDs causing changes in the occlusal planning and thereby creating anterior teeth overload [6,7]. This condition, where overload contributes to the resorption of anterior area and changes the force and position of mandibular teeth, has since been termed ‘Kelly’s syndrome’.

To prevent the rotational movements of RPDs, precise attachments or telescope systems have been used on the remaining teeth, and an altered cast technique has been applied to offset different displacement between the remaining teeth and soft tissues during function [8-12]. These studies have led to the discovery and innovation of many new systems used to treat class I Kennedy defects in the mandible [13-15]. A series of variable alternative options are presented in Table (1).

All systems present their advantages and disadvantages and numerous modifications of each have been realized in order to meet patient satisfaction.

Of the listed options in Table (1), the implant-supported removable partial dentures are an alternative to traditional RPD and are now a well-accepted treatment modality [16]. The use of dental implants has become widely accepted and many studies have demonstrated that the association of RPDs with implants improves the prosthetic biomechanics, resulting in greater patient satisfaction [17-20]. Decades have now passed since implants and RPDs have been utilized in combination [15,21]. Standard RPDs were not originally designed to accommodate a posterior implant load point [22]. Due to this limitation, a potentially destructive mismatch of strain distribution was identified between the acrylic and metal framework, which was originally depicted as a...
Table 1: Prosthetic options for Kennedy Class I/II defect.

<table>
<thead>
<tr>
<th>Options</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Survival rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removable partial denture</td>
<td>Low cost, less time consuming</td>
<td>Damage to support system (teeth and fibromucosa) [2]</td>
<td>71.3% - 76.6% (5-year)</td>
</tr>
<tr>
<td>Implant-supported removable</td>
<td>Stable and reliable occlusion, good retention, improved satisfaction,</td>
<td>long time of procedure, more discomfort than ISFP</td>
<td>Implant: 93.75%</td>
</tr>
<tr>
<td>partial denture (ISRPD)</td>
<td>aesthetics and function [15]</td>
<td></td>
<td>RPD: 100% (8-year) [103]</td>
</tr>
<tr>
<td>Implant-supported fixed</td>
<td>Easy to use, high masticatory efficiency, comfort, long life span,</td>
<td>High cost, long time of procedure, suffer more</td>
<td>94.5% (5-year) [104]</td>
</tr>
<tr>
<td>prostheses (ISFP)</td>
<td>improved aesthetics and function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precise attachment with</td>
<td>Stable and reliable occlusion, good retention, improved satisfaction,</td>
<td>Dental lab-reliable, need experienced dentist, time consuming</td>
<td>65% (15-year) [105]</td>
</tr>
<tr>
<td>RPD</td>
<td>aesthetics and function</td>
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It has previously been shown that implant placement at the residual alveolar ridge at the location of the second molar decreases the stress around teeth [28], mainly the first premolar, which was considered to improve the stress distribution and retention [29-31]. Compared with implants placed at other positions distal to the last missing tooth, it was found that implants located in the region of the second bicuspid presented the lowest value for maximum tendency for displacement of the abutment tooth when compared with other regions [32-34]. It has since been confirmed by other case reports demonstrating the benefit of placing implants at the anterior region, which were considered to fulfill the functional and aesthetic requirements of the patient without jeopardizing the natural teeth [17, 35-37]. On the other hand, distally-placed implants were proved to increase the displacement levels near and surrounding the support tooth which may do harm to the abutment tooth [38]. It was reported that an inadequate posterior ridge dimension could restrict implant placement to a more anterior place [23, 39]. 5-year follow-up of these cases did not reveal any type of biomechanical or functional problem [39]. Furthermore, an 8-year follow-up study showed that the placement of implants placed anteriorly allows the maintenance of a compromised residual dentition for the support of RPDs [24]. Within the limits of these studies, it was demonstrated once again that the placement of implants adjacent to the abutment tooth showed favorable results. In the future, the patient might select to restore the edentulous ridges with fixed implant-supported restorations [23].

Of the removable prostheses used in conjunction with natural teeth, implant survival rates were found ranging from 71.3% to 83.7% in the maxilla and 83% to 100% in the mandible [40]. In one retrospective investigation with mandibular ISRPDs by telescopic double crowns, 100% survival rate of implants was observed [41]. Another retrospective study showed 95.5% survival with implants placed in both the maxilla and mandible [3]. Some differences in success rates have been observed.
between the maxilla and mandible however these were mainly due to the interaction between the bone quality and quantity [42,43].

Inclination of implants in ISRPD

There is a consensus that, the location and magnitude of occlusal forces affect the quality and quantity of induced strains and stresses in all components of the bone-implant prosthesis complex [44,45]. An axial force is considered more favorable than a bending force, which distributes stress more vertically throughout the implant to the bone obliquely and generates a high level of traction and decreases compression [46-48]. Furthermore, it has been demonstrated that straight or slightly inclined implants represent less biomechanical risks and optimized load-bearing devices [38]. Therefore, the selection of the appropriate inclination of an implant and the position of implantation are vital critical factors for long-term success [49]. Reports have documented that excessive occlusal load is generated when an implant is excessively inclined [50, 51]. This causes microcracks in the bone surrounding the implant and causes the implant fastening screw to loosen, and eventually causes fractures of the implant body [49]. In order to study the stress of implants placed in the mouth, both vertical and horizontal forces should be calculated as stress patterns seem to play an important role in cortical bone microfractures, implant fractures and/or implant failures. Theoretically, the production of torque is dependent on the position and direction of the force relative to the position of the implant and future research in this area may provide greater clinical success [52]. As such, it has been demonstrated that changing the inclination of an implant body has a considerable effect on the amount and distribution of stress along the implant bone interface and is less favorable for stress distribution [53-55]. It was found that due to effects of torque on the implant body, the compressive stresses on the side of inclination of the implant body, and tensile stresses on the other side were not even. This reflects that the force was not directed towards the long axis of the implant creating uneven distribution which in turn leads to an increase in stress magnitudes and possible future implant failure [49].

It's reported that an ISRPD associated with an implant may allow some implant inclination in distal alveolar ridge because the force distribution from implant to bone tissue is reduced in comparison to a fixed partial prosthesis which was stated above[38]. Straight or slightly inclined implants (5° and 15°) did not represent such biomechanical risks.

With respect to the retentive forces, it has previously been shown that the highest retentive force was observed when the implant was placed at a 0 degree angle. In this clinical situation, the various attachment systems were all shown to maintain the retentive forces at a 0 degree angle [56]. Whereas at a 30 degree implant inclination, implants loaded onto ball attachment systems reduced their force [57]. Similarly, systems using magnetic attachments performed significantly worst when compared to their smaller degree inclination [56,58]. Therefore, having an angled implant or abutment is less favorable for stress distribution [53] and lateral forces will be increased instead [56].

Unfortunately, it is not always possible to place implants vertically. This may be due to the fact that some form of inclination is needed in order for the implant to be embedded in bone [59]. Nowadays an abutment with a bent neck of an implant body is commercially available, and is widely applied clinically. It may be effective for facilitating the implant/denture connection however the stress distribution on the inclined implant retains additional torque forces. Future research in this area is necessary to optimize this clinical scenario.

Diameter and length of implants in ISRPD

It is now widely accepted that increasing the length of the implant has a great influence on decreasing the displacement and von Mises tension values. Interestingly however, increasing the diameter of the implant also has a great influence on von Mises tension values but did not influence displacement values [30]. With increases in implant diameter and length it was observed that less stress values were detected for cortical bone and more effective stress distributions for cancellous bone [60]. In cases of low bone quality, the optimum increase in the implant length and diameter should be taken into account to achieve higher primary stability [61]. With respect to implants placed for distal extension RPDs, it is recommended to maximize the length and diameter of implants [62,63]. Several studies report that the implant survival rate of ISRPDs whose implant length ranged from 8 to 13 mm was between 98-99% [15,17,64]. Other investigators have however found that the implant length did not have as much of an influence as the diameter with regard to stress distribution [65]. Interestingly, a recent systematic review has shown that short implant survival is supported by numerous clinical trials as long as the diameter is well chosen [66]. In a prospective, consecutive, controlled, time series clinical study to evaluate the change in oral health quality of life by incorporating short implants with RPD therapy, when 6 mm implants were placed in the first or second molar positions, high initial survival rates were revealed [67]. The increased diameter also reduced the tension values observed within the implant and healing abutment [68]. Recently, the advantages of using wide diameter implants have been well documented in the literature [62,65,69-71]. Variations in the length and diameter of the implant have also been the subject of much research [30]. The survival rate is decreased in cases where short length and small diameter implants were placed for anatomical reasons, and unexpectedly high forces were applied to the implant by bruxism and tooth contact habit [8].

Surface of dental implants

A great deal of research has been placed on modifications of surface topography to improve the healing and loading protocols of dental implants [72]. In the early 90s, it was found that new bone apposition directly to the surface of implant materials was largely triggered by increased surface topography [69]. Dental implants manufacturers have developed a variety of surfaces with different compositions and degrees of roughness. Numerous reports have shown that both the early fixation and long-term mechanical stability of the prosthesis can be improved by a high roughness profile compared to the originally designed smooth surfaces [72-75]. Moderate roughness of 1-2 μm has been advocated for successful implant bio-integration, thereby
reducing the risk of peri-implantitis and ionic exchange [76]. Various methods have been developed in order to create a rough surface and improve the osseointegration of titanium dental implants, including titanium plasma-spraying, blasting with ceramic particles, acid-etching and anodization [77-81].

Although a variety of techniques exist to increase surface roughness such as titanium plasma-spraying (TPS) [73], grit-blasting with hard ceramic particles, including alumina, titanium oxide and calcium phosphate particles and via acid-etching using HCl, H$_2$SO$_4$, HNO$_3$ and HF [82,83], the combination approach seems to favor the most bone formation to date. Sandblasted and acid-etched (SLA) implant surface modification has become an imperative ‘gold-standard’ of surface modifications while further enhance implant osseointegration [84]. A number of long term studies report a high level of success rates (96.4%-100%) following numerous years post-implantation [85-88]. Furthermore, more recently, the development of modifications to surface chemistry has shown to be an excellent contributor of bone healing. The increased surface hydroxylated titanium content and the greater spatial and functional roughness parameters improve bone to implant contact and decreases loading times [89].

The attachment of implant overdenture in ISRPD

It is well documented that implants placed at the distal extension of the denture base will minimize the resultant denture displacement. However, there are great differences in settling during a chewing load between the implant and mucosa under the denture base [3]. To protect implants from excessive force, stress-breaking attachments have been manufactured as conventional commercial attachments [90]. The initial retention of a mandibular Kennedy class I implant-assisted removable partial denture retained by two stud attachment systems indicates its clinical predictability and performance and influences patient acceptance [91]. However, these attachments do not fully compensate for the different amount of pressure displacement of the mucosa due to individual variations [92,93]. Many different attachments may be used to connect implants such as cover screws, healing caps, stress-breaking ball attachment and O-ring attachments. Several studies have evaluated the retention of attachments in implant-retained Overdences [90,94-96]. The O-ring is a stud attachment that can be used to increase the retention of implant complete and partial overdentures [13]. It includes many advantages such as ease of use, low cost, and possible elimination of a superstructure bar. Its main disadvantage is its wear over time which would decrease its retention over time as well requiring future replacement [97].

Although O-ring attachments are considered the simplest attachment for clinical application, it has been shown that IARPDs with locator attachments demonstrate initial retentive characteristics almost three times greater than those with O-ring attachments [91]. Furthermore, the locator attachments have dual external and internal retentive features, self-aligning design and low vertical height [94]. For these reasons, the locator attachment may be selected as the attachment of choice in the most demanding situations where poor residual ridge anatomy may be compromised [91].

Other investigators have also been interested in the initial retention of IARPDs using various systems. Gharahchahi et al., reported that the precise selection of attachments with or without clasp assemblies may affect the clinical success of mandibular IARPDs [91]. The assembly with locator attachments and suprabulge clasps was shown to provide the highest retentive values compared to O-ring attachments with clasp designs (suprabulge, infrabulge, no clasp) or locator attachments with other clasp designs (infrabulge, no clasp). The overall implant survival was 91.6% [98]. Meanwhile, in another study the O-ring attachments assemblies revealed the lowest retentive forces [91]. The highest retentive force was also observed in the locator blue attachment, followed by the locator black, ball, flat-type and self-adjusting magnetic attachments respectively [56].

To protect implants from excessive force, stress-breaking ball (SBB) attachments have been manufactured as conventional commercial attachments. These attachment types have been shown to not fully compensate for the different amounts of pressure displacement of the mucosa in vivo [92,93]. They typically consist of a flat-top ball head male and O-ring female [99]. Despite these, the advantages of SBB attachments over conventional attachments are as follows: (1) they prevent the implant from excessive occlusal force, (2) they are ready-made, (3) they show appropriate retention, and (4) they can easily be mounted on the denture base. The disadvantages of these attachments include (1) they are approximately 1mm higher than conventional ball attachments and (2) the retentive force cannot be adjusted (Figure 1).

Future perspectives of implant in RPD

Many advances have been made over the past two decades for the application of implant RPDs. Implants over a free-end RPD were shown to result in smaller swallowed median particle size and improved nutrient than conventional RPDs [100]. As dental implants are made more and more aware by dentists worldwide, their application in RPDs is also becoming more and more prominent [101]. The position, length, diameter, surface modification, inclination and attachment of implants have all been determined parts in their success and many research activities have characterized their role in implant supported RPDs. As the number of aging people continues to rise, the use of implant supported RPDs are becoming more prominent and more research is necessary to improve patient care in this population [98]. The use of implants in class I Kennedy edentulous patients is subject to retain alveolar bone however this has not been well studied over time. Furthermore, for those patients who have lost significant bone over time by using conventional RPDs are subject to receiving bone enhancement procedures using a combination of bone grafts, membranes and/or growth factors. It remains to be investigated what effect these procedures have on overall patient satisfaction in patients following therapy in combination with future IARPD. Another area which requires attention is the cost of implant supported RPDs versus that of conventional RPDs. As dental implants become increasingly popular, their cost have also decreased with time and their increased longevity when compared to remaining natural teeth such as premolars at the distal extension of class I edentulous patients are subject to additional risk of tooth loss which would necessitate either
modifications to their pre-existing conventional RPDs or complete new ones. Thus, with all these issues being contributing factors to the overall costs of both systems, the total cost of providing implant overdentures is not as large as one might expect when compared to conventional RPDs.

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REFERENCES


measurements on maxillary implants supporting a fixed prosthesis


Cite this article