Review
Improving masticatory performance, bite force, nutritional state and patient’s satisfaction with implant overdentures: a systematic review of the literature

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SUMMARY Oral function with removable dentures is improved when dental implants are used for support. A variety of methods is used to measure change in masticatory performance, bite force, patient’s satisfaction and nutritional state. A systematic review describing the outcome of the various methods to assess patients’ appreciation has not been reported. The objective is to systematically review the literature on the possible methods to measure change in masticatory performance, bite force, patient’s satisfaction and nutritional state of patients with removable dentures and to describe the outcome of these. Medline, Embase and The Cochrane Central Register of Controlled Trials were searched (last search July 1, 2014). The search was completed by hand to identify eligible studies. Two reviewers independently assessed the articles. Articles should be written in English. Study design should be prospective. The outcome should be any assessment of function/satisfaction before and at least 1 year after treatment. Study population should consist of fully edentulous subjects. Treatment should be placement of any kind of root-form implant(s) to support a mandibular and/or maxillary overdenture. Fifty-three of 920 found articles fulfilled the inclusion criteria. A variety of methods was used to measure oral function; mostly follow-up was 1 year. Most studies included mandibular overdentures, three studies included maxillary overdentures. Implant-supported dentures were accompanied by high patient’s satisfaction with regard to denture comfort, but this high satisfaction was not always accompanied by improvement in general quality of life (QoL) and/or health-related QoL. Bite force improved, masseter thickness increased and muscle activity in rest decreased. Patients could chew better and eat more tough foods. No changes were seen in dietary intake, BMI and blood markers. Improvements reported after 1 year apparently decreased slightly with time, at least on the long run. Treating complete denture wearers with implants to support their denture improves their chewing efficiency, increases maximum bite force and clearly improves satisfaction. The effect on QoL is uncertain, and there is no effect on nutritional state.

KEYWORDS: Dental Prosthesis, Implant-Supported, Denture, Complete, quality of life, patients’ satisfaction, mastication, bite force

Accepted for publication 15 September 2014

Background
Missing teeth, which are not replaced with prosthesis, result in a poor quality of life (QoL) comparable with the effects of cancer and renal disease on physical well-being scales (1). When patients are provided with conventional dentures (CDs), improvements are reported with regard to overall satisfaction, aesthetics,
comfort and speech, while the improvement in functional outcomes is often unsatisfactory (2). Usually, the functional outcome and patient’s satisfaction is increased when implants are placed to retain the mandibular (3) and/or maxillary (4) denture. Many studies on patients’ appreciation of implant overdentures (IODs) use questionnaires to rate whether patients are satisfied with the current situation or not (5–7). For this purpose, a wide variety of questionnaires is available, either validated (8–12) or non-validated (13, 14). In addition, treatment effect of IODs is measured with testing chewing efficacy, bite force, muscle activity and muscle anatomy. The assumption is made that improvement in these items also reflects greater patients’ satisfaction (13, 15, 16).

Reviews on certain aspects of patients’ appreciation of treatment with implant-supported overdentures are available. For patients’ satisfaction, reviews are done to assess dentist- and patient-mediated preferences (17), the efficacy of mandibular IODs from the patient’s perspective (18), a comparison between treatment with CDs and IODs in elderly patients (19), the outcome of terms of (oral health-related) QoL (20) and to assess the association between the oral health status and health-related QoL (21). For the restoration of the edentulous mandible with IODs or CDs, there is an accumulating body of evidence on the effect of treatment choice. Providing edentulous patients with implant-supported complete dentures contributed to improved health-related QoL. Some articles show a significant association between oral health status and health-related QoL. Although mandibular IODs may be more satisfying for edentulous patients than new CDs, the magnitude of the effect is still uncertain. Even with implant treatment presenting higher patients’ satisfaction and improvement of QoL, it was not possible to establish a direct comparison between studies due to differences in adopted methodologies. Better designed, long-term studies are required to further explore differences in patient acceptance to each treatment intervention (CD, IOD and fixed prosthesis) for the edentulous mandible.

Evidence suggests that edentulous individuals lack specific nutrients and, as a result, may be at risk for various health disorders. Some reviews about the effect of treating edentulous subjects with IODs or CDs on nutritional and physical state (22, 23) are done. The effect on the nutritional state in edentulous subjects treated with implant therapy is similar to the one obtained with conventional removable dentures. This is not an optimum nutritional state, which also depends on other factors not related to prosthodontics treatment. The authors (24, 25) suggest that mandibular prostheses supported by only two implants might offer a solution to the lack of intake of healthy, hard-to-chew foods by people wearing CDs.

A lot of different questionnaires and different ways of measuring function as a parameter of satisfaction are reported. A systematic review describing the outcome of the various methods to assess patients’ appreciation has not been reported. Therefore, the aim of the present systematic review on edentulous patients treated with IODs is to assess patients’ appreciation of the situation before and after treatment after an observational period of at least 1 year with respect to satisfaction, chewing (patterns), bite force and nutritional state measured by various methods.

Methods

Information sources and search strategy

A thorough search of the literature was conducted and was completed on 1 July 2014. The primary database used was Medline (via PubMed). Additional databases used were Embase and The Cochrane Central Register of Controlled Trials. The search was supplemented by hand-searching (checking references of the relevant review articles and eligible studies for additional useful publications). The search strategy was a combination of MesH terms and free text words. The strategy has been depicted in Table 1.

Eligibility criteria

The studies had to meet the following requirements:

1. Type of participants: Patients who received an implant-retained mandibular and/or maxillary IOD replacing a CD.

2. Types of intervention: Placement of root-form implants to support a removable complete overdenture in de mandible and/or maxilla replacing a conventional complete denture. There were no restrictions with respect to type of implant, number of implants, attachment system and immediate or conventional loading.

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Comparison: Outcomes should be a comparison between before and at least 1 year after treatment for the same patient.

Principle outcomes: Principle outcome is from methods assessing changes of at least one of the following parameters: patients’ satisfaction (with a range of parameters); QoL; oral health-related QoL; function (with a range of parameters); bite force; ability to chew; nutritional state; and any other parameters to measure whether the amount of initial complaints has changed.

Study design: All types of prospective studies were considered for evaluation.

Inclusion criteria

1. Publications must be reporting in English
2. Treatment of the patients has to be initially planned for an overdenture replacing a conventional complete denture
3. Detailed information on IODs; in case of combined data for IODs and implant-supported fixed complete dentures, extraction of data for the overdentures must be eligible.
4. Measurements for the same patient must be done pre-treatment and after 1 year or longer.

Exclusion criteria

1. Less than 10 patients treated with overdentures.
2. Articles describing other studies.

Validity assessment and data extraction

Initial screening of the abstracts was performed by one reviewer (G.C.B.), based on the criteria above. Full-text documents were obtained for all articles meeting the inclusion criteria. Full-text analysis was performed by two reviewers (G.C.B., H.J.A.M.) independently.

Methodological quality and risk of bias were assessed independently by the reviewers using specific study design-related checklists designed by the Dutch Cochrane Collaboration as described by Offringa et al. (26) for each of the obtained full-text papers. Agreement was reached by a consensus discussion and if necessary, a third reviewer (G.M.R.) was consulted.

Results

Study selection

The results of the primary search for the period till 1 July 2014 was 917 hits for the Medline search, 194 hits for the Embase search and 109 hits for the Cochrane search (Fig. 1). Using this strategy, 1220 papers were initially identified, of which 276 articles appeared to be double and of which 31 were review articles and as such contained no new data. These papers were excluded.

After scanning of titles and abstracts a further 837 papers were excluded because they did not meet the inclusion and exclusion criteria. This approach
resulted in 76 papers to be evaluated by full-text analysis. The amount of excluded articles with reasons for exclusion is found in Fig. 1. Reference checking of relevant reviews and included studies revealed five additional articles that met the criteria. The remaining 53 studies were filed electronically. The data were recorded and reported in annotated form (Table 2).

**Results of individual studies**

Of all the studies found, most studies used patients’ satisfaction as a parameter (Table 2). A few were (also) evaluating chewing, bite force or other types of parameters. Most studies reported on mandibular overdentures, only three studies included maxillary overdentures.

Generally an improvement in satisfaction was seen after treating patients with CDs with IODs.

Five of the seven studies on chewing reported improvement. All four studies that reported on bite force reported an increase in bite force. Chewing patterns seemed to improve, and no change in BMI and blood plasma levels was seen.

A summary of the studies and outcomes is given in Table 2. A more detailed description of the individual studies (methods and results) can be found in the Supporting Information.

**Chewing evaluation**

All studies reporting on masticatory performance showed a higher increase after IOD treatment than after CD treatment. Patients were able to chew better (27, 28) needed less chewing cycles to reach the same result (15) and were able to eat more tough foods (29) after IOD treatment. One author (13) found no differences in mixing ability between patients treated with CDs or IODs.

**Bite force evaluation**

Two authors (13, 29) described an improvement of the average maximum bite force after IOD treatment, and this improvement remained established after 10 years (15). However, the average maximum bite force obtained with IODs was still significantly lower than that of dentate subjects (16).
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<td>Awad (72)</td>
<td>2012</td>
<td>CD, n = 127</td>
<td>128</td>
<td>0, 6, 12</td>
<td></td>
<td>and habits</td>
<td>Food preparation, ability to chew: no change</td>
<td>+</td>
<td>For both groups</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IOD, n = 128</td>
<td></td>
<td></td>
<td></td>
<td>questionnaire</td>
<td>Blood plasma levels</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Buttel (49)</td>
<td>2012</td>
<td>20</td>
<td></td>
<td>0, 6, 24</td>
<td></td>
<td>General satisfaction score</td>
<td>General satisfaction score (0–10)</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Gjengedal (14)</td>
<td>2013</td>
<td>IOD, n = 30</td>
<td>30</td>
<td>0, 3, 24</td>
<td></td>
<td>Custom-made</td>
<td>++, HRQoL no change</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RCD, n = 30</td>
<td></td>
<td></td>
<td></td>
<td>questionnaire, SF-36, WHO-five well-being index, BACQ, OHIP-20</td>
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<td></td>
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<tr>
<td>32</td>
<td>Guljé (50)</td>
<td>2012</td>
<td>12</td>
<td></td>
<td>0, 12</td>
<td></td>
<td>Vervoorn questionnaire, overall satisfaction rate</td>
<td>Vervoorn questionnaire, overall satisfaction rate (0–10)</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Jofre (56)</td>
<td>2013</td>
<td>CD, n = 15</td>
<td>15</td>
<td>0, 12</td>
<td></td>
<td>OHIP-EDENT</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Krennmair (58)</td>
<td>2012</td>
<td>20</td>
<td></td>
<td>0, 3, 6, 12</td>
<td></td>
<td>McGill</td>
<td>++, HRQoL no change</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Kronstrom (55)</td>
<td>2012</td>
<td>2 impl, n = 17</td>
<td>36</td>
<td>0, 12, 36</td>
<td></td>
<td>denture satisfaction instrument</td>
<td>McGill denture satisfaction instrument</td>
<td>+</td>
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<tr>
<td>36</td>
<td>Martinez-González (66)</td>
<td>2013</td>
<td>IOD, n = 20</td>
<td>20</td>
<td>0, 12, 24, 60</td>
<td></td>
<td>OHIP-14, custom-made questionnaire</td>
<td>OHIP-14, custom-made questionnaire</td>
<td>+</td>
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</tr>
<tr>
<td>37</td>
<td>Jofre (56)</td>
<td>2013</td>
<td>SDL, n = 15</td>
<td>15</td>
<td>0, 12</td>
<td></td>
<td>OHIP-EDENT</td>
<td>+</td>
<td>+</td>
<td></td>
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<tr>
<td>Trial number</td>
<td>First author</td>
<td>Year</td>
<td>Groups</td>
<td>Sample size</td>
<td>Follow-up in months</td>
<td>Chewing</td>
<td>Bite force</td>
<td>Patients’ satisfaction</td>
<td>Other</td>
<td>Outcomes</td>
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<tr>
<td>38</td>
<td>Khoo (60)</td>
<td>2013</td>
<td></td>
<td>43</td>
<td>0, 3, 6, 12</td>
<td></td>
<td></td>
<td>Patient denture complaint questionnaire</td>
<td>BMI, Serum albumine levels</td>
<td>After new CD +, after IOD ++, No change</td>
</tr>
<tr>
<td>39</td>
<td>Malmstrom</td>
<td>2013</td>
<td></td>
<td>50</td>
<td>0, 2 week, 3, 12, 24</td>
<td></td>
<td></td>
<td>Custom-made questionnaire</td>
<td>+</td>
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<tr>
<td>40</td>
<td>Müller (13)</td>
<td>2013</td>
<td>IOD, n = 16</td>
<td>16</td>
<td>0, 3, 12</td>
<td>Mixing ability test</td>
<td>+</td>
<td>The self-reported denture satisfaction scale, OHIP-EDENT</td>
<td>BMI – blood marker, nutritional assessment, saliva flow no change in both groups, masseter thickness + for IOD group</td>
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<td></td>
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<td>CD, n = 18</td>
<td></td>
<td>0, 3, 12</td>
<td></td>
<td></td>
<td></td>
<td>BMI, Mini nutritional assessment, blood markers, masseter thickness and saliva flow</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Slot (48)</td>
<td>2013</td>
<td>4 impl, n = 33</td>
<td>66</td>
<td>0, 12</td>
<td></td>
<td></td>
<td>Chewing ability questionnaire, Vervoorn questionnaire, Overall satisfaction score (0–10)</td>
<td>+</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>6 impl, n = 33</td>
<td></td>
<td>0, 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Slot (4)</td>
<td>2013</td>
<td>4 impl, n = 25</td>
<td>50</td>
<td>0, 12</td>
<td></td>
<td></td>
<td>Chewing ability questionnaire, Vervoorn questionnaire, Overall satisfaction score (0–10)</td>
<td>+</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>6 impl, n = 25</td>
<td></td>
<td>0, 12</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

GARS-D, Groningen Activity Restriction Scale–Dentistry; PWSoDP, Psychological Well-being Scale for Denture Patients; HSCL, Hopkins Symptom Check List; LASAM, Linear Analogue Self-Assessment Method, One-item Version; OHIP-20, oral health impact profile – 20 questions; SF-36, short-form 36-item health survey; BACQ, brief approach/avoidance coping questionnaire; OHIP-EDENT, oral health impact profile – for edentulous patients; OHIP-14, oral health impact profile – 14 questions; BMI, body mass index; CD, conventional denture; IOD, implant overdenture; PPS, Pre-prosthetics surgery; impl, implants; BAR, bar mesostructure; BALL, ball mesostructure; TMI, transmandibular implants; AOG, augmentation before placing implants; SHORT, treatment with four short implants; CON, conventional loading protocol; IM, Immediate loading protocol; IMZ, IMZ implant system; BRA, Brånemark implant system; ITI, ITI implant system; HRQoL, Health-related quality of life; RCD, relining of conventional denture; FIX, fixed suprastructure; SDI, Small diameter implants; +, some improvement after treatment; ++, much improvement after treatment; −, The situation after treatment is worse than before.

*In comparison with the other treatment group.

**The degree of satisfaction was correlated neither to increased masticatory efficiency nor to improved oral function.
One-year patients’ satisfaction evaluation

Treating CD wearers with IODs led to obvious improvements of patients’ satisfaction with their oral status as seen from custom-made questionnaires (3, 4, 16, 30–48), the general satisfaction scores (4, 27, 33, 40, 44, 48–50), the Vervoorn questionnaires (4, 48, 50, 51), the OHIP-20 (46, 52–54), the OHIP-EDENT (13, 55, 56) and the McGills denture satisfaction questionnaire (57, 58), the self-reported denture satisfaction scale (13, 53, 59) and the patient denture complaint questionnaire (60). The improvement in satisfaction did not necessarily lead to improvement in general QoL (32) or health-related QoL (46).

Two authors (32, 51) described improvement of psychological factors and less activity restriction for patients treated with implants to support their dentures. One author (57) described that patients are less satisfied with overdentures than fixed bridges. However, overdentures score better on ease of cleaning. The Short-Form Health Survey with 36 questions (SF-36) (46), World health organization Well-being Index (WHO-Five) (46) and Brief Approach/Avoidance Coping Questionnaire (BACQ) (46) showed no difference between treatment with a CD or IOD.

Five-year patients’ satisfaction evaluation

As seen from the custom-made questionnaires (37, 61–66), general satisfaction scores (63), verbal questions (29), the self-reported denture satisfaction score (59), OHIP-20 (59) and OHIP-14 (66) treating CD wearers with implants to support their dentures led to obvious improvements of patients’ satisfaction with their oral status. All authors described that improvements reached after 1 year are stable for the first 5 years.

One author (66) described that the amount of satisfaction of edentulous patients differs depending on prosthetic type. Patients rehabilitated with fixed prostheses obtained a generally higher level of satisfaction than patients wearing overdentures, except for the parameter for oral hygiene (halitosis and ease of cleaning).

Ten-year patients’ satisfaction evaluation

The improvements reached after 1 year were stable for the next 10 years (67–70). If the mean satisfaction score of a treatment group was low at baseline, it stayed lower after the same treatment than for groups with a higher satisfaction score at baseline (68).

Other evaluations

Two authors (27, 71) described changes in mandibular movement after treatment. One author (27) reported an increase in the area covered and more harmonic and efficient chewing movement were seen by another author (71). Chewing muscle thickness increased after IOD treatment (13) and muscle activity during rest decreased (16). No (positive) changes in salivary flow (13), BMI (13, 60) blood markers (13, 60, 72) were seen.

No changes in dietary intake (13, 72) and energy distribution (14) were seen. However, those wearing IODs were significantly more likely to take in their nutrients through fresh, whole fruits and vegetables (72).

Synthesis of results

No outcome measures could be meaningfully combined, so no meta-analysis was carried out.

Discussion

Major findings

This review attempted to identify published articles describing the effect of IOD therapy on elements of chewing efficacy, bite force, QoL, patient satisfaction and other found functional outcomes. The focus of this article was to describe and summarise the outcome of the studies published so far.

Treating CD wearers with implants to support their dentures led to obvious improvements of patients’ satisfaction with their oral status as measured by questionnaires and interviews. One author found no improvement as measured by the SF-36, BACQ and the WHO-five. A part of the explanation for this might be that the SF-36 has limited construct validity for measuring oral health conditions, as stated by Allen et al. (73). This might also be true for the other questionnaires. The improvement in satisfaction did not necessarily lead to improvement in general QoL or health-related QoL. The questionnaire used to measure QoL, did not really focus on oral health, so it
might be that the questionnaire did not measure the impact on the general quality of health if the quality of oral health is improved.

For the parameter of chewing it was found that patients treated with IOD’s could chew better and eat more tough foods. Although patients could eat more tough foods (such as raw fruit, vegetables and nuts), an IOD did not seem to improve dietary intake as measured by interviews, questionnaires and blood samples. A diet is a habit and it seems that by just improving the dental situation, the dietary habit does not change. In one article (13), no improvement in chewing efficiency was found, the explanation given was that they reused the existing dentures with abraded denture teeth. Because their treatment group existed of very old adults, also age-related decline of motor coordination could have contributed to this fact. Remarkably is the loss to follow-up of 56% after 12 months in the CD group, this contributes to the questionability of the results of this study.

As expected, bite force improved after IOD treatment. Because of more usage and training of the m. masseter, the thickness increased. Muscle activity in rest decreased, because there was no longer a need to stabilize the loose denture.

Improvements reached after 1 year seemed to decrease slightly but were stable over time, at least for 10 years.

Limitations

Even though there is a large amount of articles available about patients with CDs treated with IODs, almost all of these articles are about the mandible. In this review, we included only three studies on maxillary overdentures. Thus, conclusions are based mostly on data about mandibular overdentures and might not be applicable for maxillary overdentures. Next to this, only a few articles have a follow-up of longer than 1 year. So, long-term results are based on a small amount of data. Also the methods used in the reviewed studies are various; therefore, it is only partly possible to compare the results of the different studies.

Comparison with existing reviews

In literature, various authors (23–25) suggested that mandibular prostheses supported by only two implants offer a solution to the lack of intake of healthy, hard-to-chew foods by people wearing CDs. In the articles described in this systematic review, no changes in energy distribution and dietary intake were seen. This was also described in the reviews done by Thomason et al. (20) and Sánchez-Ayala et al. (22). Thomason et al. (20) described that without tailored dietary advice, prosthetic rehabilitation did not necessarily result in a satisfactory diet. They suggested a relationship between QoL and dietary selection, which might be justifiable, because in this systematic review, it is found that QoL does not always improve after rehabilitation. Naito et al. (21) did a review on the relationship between satisfaction and QoL and found three articles that confirmed an improvement in QoL after improving the oral health status and four that did not confirm it. This seemed to show that the magnitude of the improvement in QoL is uncertain. Maybe there is some improvement, but no valid data is available due to measuring methods which are not appropriate for measuring the improvement in QoL. Even though an improvement in QoL is not certain, the improvement in satisfaction is obvious. This is in line with the conclusion of Thomason et al. (20) and Assunção et al. (19). Emami et al. (18) described that an improvement in satisfaction was seen, but the magnitude was uncertain. This might be due to poor possibilities to compare the results of individual studies because of all the different measuring methods used.

Conclusions and implications

Treating complete denture wearers with implants to support their denture improves their chewing efficiency, increases maximum bite force, and it clearly improves satisfaction. The effect on QoL is uncertain.

There is little research about maxillary overdentures, so the results of this systematic review are mainly related to mandibular IODs. Because the overwhelming amount of research done on mandibular overdentures with a follow-up of 1 year, future research should focus on long-term results and maxillary overdentures.

Ethical approval

Ethical approval is not applicable for this type of research.
**Funding**

This research was carried out without funding.

**Conflicts of interest**

No conflicts of interest were declared.

**References**


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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1 Chewing.