

Protocols for the Maxillary Implant Overdenture: A Systematic Review

Steven J. Sadowsky, DDS¹/Nicola U. Zitzmann, DDS, PhD²

Purpose: To evaluate patient-related outcomes in restoring the edentulous maxilla with an implant overdenture. **Materials and Methods:** A comprehensive systematic review of the literature was conducted. Publications reporting patient-based outcomes with concomitant data on implant and/or prosthetic success were selected using predetermined inclusion criteria that were agreed upon by the two reviewers. **Results:** Twenty-three publications related to 20 study cohorts were identified to meet the inclusion criteria for maxillary implant overdentures: two randomized controlled trials (RCTs), 13 prospective case series including two crossover trials, and five retrospective studies. **Conclusion:** An implant overdenture offers a stabilized removable solution for the edentulous maxilla, which provides increased patient satisfaction and quality of life improvement. A palateless design supported by four to six implants with a wide anteroposterior span has been successfully applied in some investigations. A higher failure rate was experienced with machined implants, particularly with short implants (length < 10 mm). Although both splinted and solitary anchorage systems are advocated, maintenance is higher for solitary attachments and inflammation is increased beneath the bars. Long-term maintenance care is essential for all designs. Well-designed RCTs with larger sample cohorts with longer follow-up periods are required to amplify patient- and clinician-based outcomes. INT J ORAL MAXILLOFAC IMPLANTS 2016;31(SUPPL):s182–s191. doi: 10.11607/jomi.16suppl.g5.2

Keywords: implant/prosthetic survival/success, maintenance, maxillary implant overdentures, patient satisfaction

Implant overdenture treatment in the edentulous maxilla (max IOD) was first reported in the 1980s.^{1–3} Notably, this prosthetic design was frequently applied as a rescue operation when the implant number was limited after early failures and fabricating a fixed restoration was no longer feasible.^{4–6} Hence, the max IOD has been considered a second choice offering limited retention and comfort compared with implant-supported fixed dental prostheses (IFDP). The max IOD was originally selected in cases of severe vertical bone resorption that allowed only short implants in dominantly cancellous bone, and offering minimal primary stability for implants with machined surfaces in early studies.^{4,7} Because the max IOD was often not planned at the outset of treatment but selected after implant failure, risk factors were potentiated, leading to higher implant failure rate and prosthetic complications. For instance, interarch

space allowance, interimplant distances, and angulations were frequently not considered, which led to material fatigue and inadequate bar clip length.

After the introduction of the max IOD, its application has evolved over the last two decades to offer specific advantages over fixed implant restorations. A removable implant design may circumvent extensive and costly augmentation procedures required for fixed restorations. More than a third of patients are unwilling to undergo autologous grafting even from an intraoral donor site.⁸ In addition, it has been reported that treatment with IFDP is accompanied with higher patient expectations.⁸ For some patients, the max IOD is most appropriate because it provides facial scaffolding; covers the prosthesis-tissue junction, particularly in patients with a wide smile and/or high smile line; assists in reconciling adverse ridge relations or discrepancies; and allows more latitude in adjusting palatal contour for phonation.^{9,10} Further, cleaning the implants restored with an IFDP in patients with severe maxillary resorption can be challenging.¹⁰ Rosén and Gynther¹¹ reported phonetic disturbances in 42% and esthetic problems in 37% of patients treated with four to six implants supporting an IFDP. Reinforcing patient preferences, a removable implant design was more often selected over a fixed prosthesis, in a crossover study, because of ease of cleaning and improved speech.¹² Moreover, patients with heavy parafunction may benefit from removing their prosthesis nocturnally as well as allowing greater ease in repair compared with a fixed restoration.

¹Associate Professor, Department of Integrated Reconstructive Dental Science, University of the Pacific, Arthur A. Dugoni School of Dentistry, San Francisco, California, USA.

²Professor, Clinic for Periodontology, Endodontology and Cariology, School of Dental Medicine, University of Basel, Basel, Switzerland.

Correspondence to: Dr Steven J. Sadowsky, University of the Pacific Arthur A. Dugoni School of Dentistry, 155 5th Street, San Francisco, CA 94103. Email: ssadowsky@pacific.edu

©2016 by Quintessence Publishing Co Inc.

The incidence of edentulism has been shown to occur earlier and more frequently in the maxilla than in the mandible (40% vs 27% in patients > 65 years of age).^{13,14} Patients with complete dentures must make accommodations for palatal coverage and a sensitive interaction of several retention mechanisms at the periphery which is facilitated by tongue pressure during function. Therefore most conventional denture users remain satisfied and only a small percentage opt to pursue implant treatment.¹⁵ When comparing quality of life (QoL) outcomes in a systematic review of complete dentures and max IODs, no significant differences were found in overall ratings.¹⁶ Furthermore, a crossover study failed to yield substantive functional differences.¹⁷ Despite these findings, patients may be motivated to undergo a max IOD restoration when anatomic deficiencies are linked to inadequate retention and/or stability, when gagging is refractory because of palatal coverage, and/or there is a psychogenic barrier to palatal coverage.¹⁸ Zitzmann and Marinello¹⁹ investigated psychosocial embarrassment stemming from the use of a conventional removable prosthesis. Significant self-esteem improvements were documented with implant treatment supporting fixed or removable restorations. Factors excluding subjects from implant therapy include financial constraints (despite the fact that cost estimates are less in removable compared with fixed prostheses¹⁹), unwillingness to undergo surgery or medically compromised for surgery, and the possibility of achieving marked improvements in the conventional prosthesis to meet patients' expectations.²⁰

In addition to implant and prosthetic survival and success, patient satisfaction with the restoration and QoL effects are significant outcomes and described as patient-reported outcome measurements. McGrath et al²¹ underscored the subjective nature of patient perceptions, which should complement clinical outcome data rather than be a standalone reflection of treatment. The purpose of this study was to complete a systematic review of articles evaluating patient-based outcomes after max IOD treatment.

MATERIALS AND METHODS

Search Strategy and Procedures

A critical review of the literature including relevant articles published in English was conducted. The most recent article included in this search was published before August 2014. The search was performed using the MEDLINE (PubMed) electronic database. Key words were maxillary implant overdentures, patient satisfaction, implant/prosthetic survival, success, and complications.

A hand search was also conducted for publications from 1986 to the present. The following journals were culled: *Clinical Oral Implants Research*, *Journal of Prosthetic Dentistry*, *International Journal of Prosthodontics*, *Clinical Implants and Related Dental Research*, *British Dental Journal*,

International Journal of Oral & Maxillofacial Implants, *Journal of Clinical Periodontology*, *Practical Periodontics and Aesthetic Dentistry*, *Clinical Oral Investigation*, *Journal of Periodontology*, and *Vital Health Statistics*.

The levels of hierarchy of evidence accepted were randomized controlled trials, prospective studies, and retrospective studies. When multiple studies used the same population, only the more pertinent publication was entered into the database. The original search was limited to studies of human subjects published in English that included max IOD treatment and reported patient-based outcomes with concomitant data on implant and/or prosthetic success. Reporting of as little as a 2-month follow-up was accepted in crossover studies.

Full-text analysis of 40 initially retrieved articles was performed, and 20 publications relating to 18 study cohorts were identified as reporting max IOD patient-related outcomes. Two articles each reported data from a similar group.^{7,22-24} In addition, three articles were retrieved by hand searching and were related to two study cohorts.^{12,19,25} Among the 20 study cohorts, only two study designs were RCTs.^{26,27} Thirteen were prospective case series,^{12,17,19,22,23,28-35} and five were retrospective studies.^{9,36-39}

Data Analysis

The studies included varied in the design of the questionnaires in terms of the wording of the questions and measures applied. In general, the most common items identified to assess patient-related outcomes were general satisfaction, comfort, stability/retention/fit, function, esthetics, ability to speak/phonetics, ability to chew (hard and soft food), ease of cleaning, food retention, lip, cheek and tongue biting, ease of removing and inserting prosthesis, self-esteem, and embarrassment. Additional data retrieved in some studies included incidence of food retention under prosthesis and impaired confidence in the retention of the max IOD.^{7,35} Some studies recorded the patients' willingness to undergo treatment again, or recommend it to a friend or relative, and the preference of a fixed or removable implant restoration.^{7,19,39}

Studies with longer observational follow-up indicated an unchanging perception of the evaluated parameters, or even a slight improvement in comfort and phonetics, which has been related to additional adaptation over the years.^{7,22} The same investigators compared patients' and practitioners' assessments of esthetics and phonetics and documented slightly better scorings by professionals.^{7,22}

Potential for Error

Questionnaires inherently do not account for language or cultural differences, especially when psychosocial issues are investigated. For example, when patients are asked whether intimacy is affected by prosthesis removal, their answer may be guarded or misinterpreted.

The strategy of assessing patient-mediated outcomes after prosthesis delivery can be problematic because of an inadequate adaptation period. A number of studies did not specify the time point at which the questionnaires were administered. Furthermore, assessing only post treatment data allows cross-sectional analysis, but not comparisons before and after treatment. Baseline patient perceptions before treatment, assessment of prosthetic status, how long patients used conventional dentures, and whether adjustments were made before their evaluation, all were not standardized among studies, which may lead to confounding of the outcome measurements. The methodologies of the investigations also differed in terms of being prospective or retrospective, measuring patient-based data as primary or secondary outcomes, and how the treatment was selected (preselected or after within-subject comparisons). Within-subject patient assessment may be influenced by cognitive dissonance if additional implants were placed for one design which the patient may attempt to justify.¹² Finally, individualized psychometric response scales were used in studies assessing patient satisfaction which may not allow for uniformity in a cross-sectional analysis. Because most outcomes relevant to patient satisfaction with a max IOD cannot be directly measured by a binary scale (yes/no response), instruments for subjective assessment were favored such as the visual analogue scale (VAS), or Likert scale. Using the VAS, respondents specify their level of agreement with a statement by indicating a position along a continuous line between two endpoints.^{17,19} The endpoints should be clearly defined (eg, "worst possible pain," "no pain"). The Likert scale records levels of agreement by having patients select different numbers relating to their finding (eg, a three-point rating for degree of satisfaction or dissatisfaction).²⁹ Other studies^{24,27} used a version of the Oral Health Impact Profile (OHIP or OHIP Edent) with selected domains to identify the impact of the prosthetic result on their QoL.

RESULTS

The 20 publications identified which met the inclusion criteria of studies in English reporting both patient- and clinician-based data are enumerated in Table 1. Three additional publications reporting data from the same study group are included in the same row as the selected pertinent article. The indicated number of patients treated relates to the study cohort on which outcome data are documented, thereby excluding dropouts or double registration. A total of 530 patients had been treated with max IOD prostheses between 1993 and 2014. Although a range of 1 to 10 implants was used for prosthesis retention or support, most concepts used 4

to 6 implants. Prosthesis retention was mainly designed with bars, either milled or using prefabricated bar segments. In four studies, different retentive elements were applied, one study used ball attachments only, and one study used solely double crowns (Table 1).

The earliest report on patient-related outcomes with max IOD was made by Smedberg et al^{7,22} who treated 28 patients with a bar and additional CEKA REVAX attachment (Alphadent NV). A questionnaire with VAS ratings was given to the patients immediately after treatment and after a 2- and 6-year period, but no baseline data before implant treatment were available. Although overall satisfaction was high, some patients perceived uncertainty with the retention of the IOD and preferred a fixed implant restoration. Over time the subjective assessment of phonetics improved, which may be related to the adaptive capacity. Using machined implant surfaces, implant survival was 84% and most failures were related to short implants (7 mm in length). Stomatitis was the most frequent biological complication and affected 50% of patients.^{7,22} In a report on 30 patients treated with bar-retained max IOD, Watson et al³³ found that more than 80% had mucosal problems. During the observation period of 5 years, each patient had on average one occasion per year of superstructure maintenance complications (such as clip activation or fracture, bar fracture, acrylic resin fracture, relining).³³ High incidence of technical and mucosal complications were also reported by Pieri et al³⁴ who performed immediate implant loading with bar-retained max IOD on four to five implants. Although comfort, chewing ability, esthetics, ability to speak, and general satisfaction were improved after treatment, cleaning feasibility was rated lower compared with the pretreatment assessment. Visser et al³² summarized the prosthodontic aftercare as 443 minutes per patient over a 10-year observation period, albeit with a milled bar mesostructure.

In a retrospective study with a mean observation period of 2.5 years, Ekfeldt and coworkers³⁷ treated 38 patients with max IODs initially, and after four withdrawals divided them into group A (n = 7), originally planned for max IOD, and group B (n = 27), originally planned for IFDP but restored with IOD. The implant success rate in group A was 87.9% and in group B, 79.3%. Prosthodontic complications were mainly related to change of clips and more prevalent in group B. Most of these maintenance incidents occurred in bruxers (62%). Patient reactions to treatment with max IOD using a VAS were positive regarding esthetics, but more negative views were registered in group B in response to function and retention, and were possibly related to their initial expectation for a fixed restoration.

Slot et al²⁸ reported performing max IOD service on six implants, connected with a bar, with implants either

placed in the anterior (incisal and premolar region) or posterior region (canine to molar) with 25 patients each in a 1-year prospective case series. Group assignment was based on the bone volume and the intermaxillary space in the anterior region. The antagonist was a natural dentition. The authors found 98% implant survival (11 mm length) in the anterior sites and 99.3% in the posterior region (12 mm length). High patient satisfaction was recorded for both regimens. The same research group conducted a randomized trial among 49 fully edentulous patients and provided them with four or six implants in the anterior maxillary region.²⁶ After 1 year, one implant was lost in the six-implant group, bone resorption around the implants was similar in both groups, and overdenture survival was 100% in both groups. In addition, patient satisfaction had improved similarly irrespective of whether the max IOD was supported by four or six implants.²⁶

Zou and coworkers²⁹ evaluated three different anchorage systems to retain a max IOD on four implants. Ten patients each were designed with telescopic crowns, bar, or Locator attachments (Zest Anchors). After 3 years, all patients were seen for recall. The implant survival and success was 100% for all groups. The Locator system had the least postinsertion visits for maintenance. Using a Likert scale, four patient-mediated parameters were recorded: facial contour, comfort, phonetics, and functional results. No significant differences were found in patient satisfaction among the groups. Double crowns (telescopes) for max IOD support were also used by Bernhart et al,³⁵ who observed biological (peri-implantitis) or technical complications (veneering fracture and retention loss of cemented telescopes) during the 2-year observation period.

Al-Zubeidi and associates²⁷ treated 40 patients with a three-implant max IOD using different attachment systems and palatal coverage designs, opposing a mandibular two-implant overdenture. Patients were randomly assigned to groups with either splinted (bar) or unsplinted (ball attachments) retentive systems and patient satisfaction was evaluated after 2 years of service. The OHIP-14 showed patients significantly more satisfied with the max IOD than with their pretreatment maxillary denture, whereas no differences were found between the two retentive systems. After the first year in function, the palatal coverage of the max IOD was reduced. Approximately 80% of patients preferred this palatally reduced design over a complete coverage.²⁷

de Albuquerque et al¹⁷ conducted a crossover trial to assess patient preferences for a long-bar max IOD with and without palatal coverage opposing a mandibular IFDP. Thirteen participants experienced both designs after a 2-month evaluation period. General satisfaction was high and VAS results showed no significant differences between the two treatments. Of note, the ratings

for the long-bar max IOD were no better than those for a new conventional denture. The length of service with a conventional denture before implant placement was not reported.¹⁷ The same research group conducted a within-subject crossover trial, in which 16 patients received either a max IOD supported by a long-bar or an IFDP on four to six implants. Prostheses were changed after a 2-month period and patient assessment recorded after another 2-month period.¹² Patients were on average more satisfied with the removable long-bar IOD and rated their ability to speak and ease of cleaning as better. Nine patients chose to keep the removable prosthesis and four preferred to keep the IFDP.¹² Removable and fixed maxillary implant restorations were also compared by Zitzmann and Marinello,¹⁹ who conducted a self-selected trial, in which patients received a treatment recommendation based on their anatomic situations and need for lip and cheek support. Although patients treated with max IOD had poorer pretreatment ratings of their overall satisfaction and functional and psychological parameters, outcomes after treatment were similar in both groups with 10 patients each. So comfort and retention, function, esthetics and appearance, taste, speech, and self-esteem were significantly improved 6 months after rehabilitation compared with their pretreatment assessment.¹⁹ Allen et al²⁰ also found that patients requesting dental implants perceive their impairment to be greater than those asking for new complete dentures. Sanna et al³⁸ compared patient satisfaction with bar-retained max IOD and IFDP in 44 patients provided with four to six implants. High ratings were given to all parameters except food impaction which affected both groups. Retention and fit of the restoration was rated better with IFDP than with IOD (Table 1). Although IOD supported by four to six implants revealed implant survival rates of 99% at 15 years, more implant failures were observed when only two implants were used either splinted (83% at 22 years) or unsplinted (74% at 17 years).³⁸

Although Sanna et al³⁸ did not report patient-related outcome measures from the 12 additional patients treated with two implants, this design was also applied by Zembic et al^{23,24} who assessed patient satisfaction with a VAS questionnaire and OHIP-20E. Before implant placement, edentulous patients received new complete dentures or relining of the existing dentures to have comparable conditions for the pretreatment questionnaire. A within-subject comparison was conducted and two implants were restored with max IOD with palatal coverage, which was removed after a 2-month period. Comparison of patient satisfaction before implant treatment, after restoration with IOD with palatal coverage, and without palatal coverage revealed improvements after IOD treatment for most parameters except for cleaning ability, comfort, and esthetics.

Table 1 Studies Evaluating Patient-Centered Outcomes for Implant Overdentures in the Maxilla (Max IOD)

Authors	Study design	Aim/comparison	Time of follow-up (assessment of PROM after max IOD insertion)	No. of patients assessed/No. of implants in the maxilla/length
Smedberg et al (1999) ²² (1993) ⁷	Prospective	Max IOD with bar and Ceka	Obs: 82 mo for pilot group, 35 mo for routine group; questionnaire given immediately after prosthesis delivery and after 2 y	28 (14 in pilot group from 1993; 14 in routine group)/2–6/7–13 mm (machined); 2 additional in pilot group lost all implants and received a CD (no IOD Tx)
Ekfeldt et al (1997) ³⁴	Retrospective	Group A: max IOD (originally planned) vs group B: max IOD (initially planned for IFDP); bar or ball attachments	Mean obs: 30 mo	38/1–4/10–18 mm (machined)
Watson et al (1997) ³³	Prospective (9 centers)	Max IOD with bar	Obs: 5 y; questionnaire given before Tx, after 1 mo, after 5 y	30 (16 available at 5 y)/3–4/7–15 mm (machined)
Naert et al (1998) ³⁰	Prospective	Hinging max IOD on rigid cast bar	48 mo	13/4/7 mm (1x), 10 mm (14x), 13 mm (17x), 15 mm (20x), 18 mm (1x) (machined)
de Albuquerque et al (2000) ¹⁷	Prospective; within-subject crossover	Max IODs with long-bar; with vs without palatal coverage, opposed by mand IFDP	2 mo after new CDs and 2 mo after each long-bar max IOD (with/without palatal coverage) for crossover	13/4/length not defined
Zitzmann & Marinello (2000) ¹⁹ (2000) ²⁵	Prospective; self-selected Tx; fixed (n = 10) vs OD bar (n = 10)	Max IOD with bar vs IFDP	Obs: 39 mo fixed, 27 mo IOD; questionnaire before and 6 months after treatment	10/5 to 10 (plus 10 patients with IFDP)/ 10 mm (11x), 11.5–13.5 mm (39x), 15–18 mm (21x) (mainly machined)
Närhi et al (2001) ³⁶	Retrospective	Max IOD retained by splinted vs unsplinted implants	Bar-retained max IOD: mean Obs 32 mo; ball-retained max IOD: 54 mo	16/4–7/at least 12 mm
Heydecke et al (2003) ¹²	Prospective; within-subject crossover trial	Long-bar IOD vs IFDP	2 mo with each prosthesis	13/4–6/length not indicated (machined)
Raghoobar et al (2003) ³¹	Prospective	Augmented maxilla (3 mo before implant placement), loading after 2 mo, milled bar and Ceka	12 mo (questionnaire before and after Tx, timepoint not specified)	10/6 or 8/≥ 10 mm (moderately rough)
Kronström et al (2006) ⁹	Retrospective	Planned max IOD (group 1) vs max IOD originally planned for IFDPs (group 2); rigid cast bar (with ball attachments)	12-month cycles	19/mean of 3.3 implants in planned max IODs, mean of 3.7 in cases of max IODs originally planned for fixed/length not defined
Krennmair et al (2008) ³⁹	Retrospective	Max IODs with 4 implants in anterior (group 1) vs 3–4 bilaterally in posterior (group 2) with sinus graft; rigid milled bar	42 months	34/4 anterior, 6–8 posterior/13–16 mm (anterior)/13 mm (posterior)
Visser et al (2008) ³²	Prospective	Max IODs with milled bar, mesostructure with Ceka	10 y	39/6/10–15 mm (machined)
Pieri et al (2009) ³⁴	Prospective	Immediate loading with bar-retained max IOD; rigid-cast bar with a < 10 mm distal cantilever	Pre-Tx: 2 mo; post-Tx: 12 mo	22/4–5/10–15 mm (moderately rough)
Sanna et al (2009) ³⁸	Retrospective	Max IOD with bar, comparison to fixed group (IFDP)	Obs: 1–22 y (average 9 y); timepoint of questionnaire not specified	44/4–6 (32x), 2 implants with bar (n = 8), 2 implants single attachments (n = 4)/> 6–18 mm (machined)
Al-Zubeidi et al (2012) ²⁷	Prospective RCT	Max IOD on 3 implants with splinted vs unsplinted ball attachments; opposing mand IOD on 2 implants	24 mo	39/3/10 mm (34x), 11.5 mm (17x), 13 mm (15x), 15 mm (51x) (roughened)
Bernhart et al (2012) ³⁵	Prospective	Max IOD with double crowns	2 y, no information about timepoint of questionnaire	12/4.4/range 3–6 mm (moderately rough)

Max = maxillary; IOD = implant overdenture prosthesis; PROM = patient-reported outcome measurement; CD = complete denture; Tx = treatment; Obs = observation time; VAS: visual analog scale; mand = mandibular; IFDP = implant fixed dental prosthesis; OD = overdenture; CAT = category scale; GI = gingival index; PI = plaque index; NA = not applicable; RCT = randomized controlled trial; BoP = bleeding on probing; ND = not defined; OHIP = oral health impact profile.

PROM measure	Outcomes PROM	Survival of implants and prosthesis/complications
10 questions yes/no (related to esthetics, phonetics, comfort, satisfaction, chewing, easily removable, and reinsertable, cleaning (0 = total discomfort; 10 = total satisfaction); and VAS esthetics 8.0/8.6, phonetics 9.3/9.7, comfort 8.3/- (filled out by patient/examiner); immediately after and 2 years after Tx	Most patients completely satisfied with reconstruction; improvement in phonetics and comfort after 2 y compared to prosthesis delivery; uncertainty related to IOD retention (n = 6); food sticking under IOD (n = 10); preferred fixed (n = 6); 1999 similar results in the VAS as in 1993, only phonetics improved at 6 y to 9.2/9.9	84% (pilot), 85% (routine); most failures with 7-mm implant length/24 adjustments, in 50% stomatitis
VAS (10-point scale) appearance, mastication, retention, esthetics, function	Group A: 8.5–9.1; group B: 7.1–9.0; group B had more negative experiences regarding ability to chew and retention	Group A: 85%, group B: 56.4%/prosthetic complications (n = 8, group A; n = 20, group B); retentive clip fractures (n = 7, group A; n = 5, group B); retentive clip changes; all single implant-retained overdentures failed (n = 4)
Questions with VAS (1 = very bad; 5 = average; 9 = excellent) overall satisfaction, retention/stability, function in chewing and speech, appearance; frequency of prosthesis removal because of discomfort	Retention, stability, chewing ability, speech improved	78% at 5 y/81% had mucosal problems, each patient had on average 5 occasions for maintaining superstructure complications (fractures denture, relining, bar fracture, clip fracture, or activation)
VAS questionnaire (0–9 Likert scale)	General satisfaction 8–9, ease of chewing 8–9, appearance 4–9 (most responses 8–9), retention 8–9, speaking ability 8–9	88.6%/ technical (n = 32), mucosal complications (n = 11)
VAS questionnaire and CAT scale, general satisfaction, stability, retention, esthetics, comfort, ease of cleaning, speaking ability, eating ability	No significant difference in long-bar max IOD with or without palate and new conventional dentures except for chewing nuts which was significantly better with implant support	96.7%
VAS questionnaire assessing comfort & retention, function, esthetics & appearance, taste, speech & self-esteem	All parameters improved in both groups, greatest improvements in self-esteem; IOD patients experienced greater differences between pre- & post-Tx scores for esthetics, taste & speech; Tx costs per unit significantly higher for fixed than OD	IFDP: 98%, IOD: 94% IOD; time until retreatment after prostheses insertion was 23.4 mo for fixed and 19.8 mo for IOD/higher GI and PI with IOD than with fixed
4-point Likert scale (0–3)	General satisfaction, esthetics, phonetics, chewing ability, pain, fit all not significantly different between bar/ball anchorage system	92%/most Obs times were within 2 y of treatment; hyperplasia (n = 9); inflamed soft tissue (n = 8); prosthetic adjustments (n = 7)
VAS for psychometric measurements of general satisfaction, comfort, ability to speak, stability, esthetics, ease of cleaning and occlusion; chewing ability with 7 types of food; CAT questions related to patients' physical & psychological function and general health (4-point Likert scale)	IOD higher VAS ratings of general satisfaction, ability to speak, & ease of cleaning than fixed; greater negative impact on psychological function of fixed, importance of esthetics & speech; 9 patients selected IOD, 4 preferred IFDP	NA
VAS (1–10) for overall satisfaction; 5-point rating scale (very satisfied to very dissatisfied) for 8 items (satisfaction with function of prosthetic construction & with esthetics)	VAS mean satisfaction with total Tx 7.9 ± 0.9 (1.85 ± 0.9 with previous denture); 5-point rating scale 7.9 ± 0.9	95.6%
VAS questionnaire (10-point scale), mastication, phonetics, esthetics, retention, satisfaction	Group A: 7.1–9.7; group B: 6.0–8.3, both groups had similar outcomes with patient satisfaction but speech problems more prevalent in group B	Not defined/5 patients lost all implants before 19 patients selected for study
Likert scale (1 = not satisfactory, 2 = adequate, 3 = satisfactory, 4 = good, 5 = excellent)	Mean scores were 5.0 for general satisfaction, chewing ability, denture stabilization, 4.6/4.7 for esthetic results and speech respectively with no difference between groups	Group A: 98.4%, group B: 97.4%/low prosthodontic complication rate (possibly because of rigid bar/metal reinforced prosthesis); adjustment of denture margin (n = 11); matrix activation (n = 8); abutment screw loosening (n = 6); fracture/renewal of antagonist denture (n = 5); no significant difference between group A and B
VAS for overall satisfaction (score 0 = low, 10 = high); 4 questions yes/no on more satisfied than with CD, Tx worthwhile, Tx again, advise to friends	Overall satisfaction 8.9 ± 1.1 (median 9, range 7–10)	86% at 10 y/more intensive pros aftercare (443 min/patient) than surgically (40 min/patient)
Questionnaire with VAS	At 2 mo and 12 mo significant increase in comfort, chewing ability, esthetics, ability to speak, and general satisfaction, but significant decrease in cleaning feasibility	97%/technical (n = 20), mucosal complications (n = 6)
Satisfaction only evaluated among the OD 4–6; questionnaire: comfort, ability to speak, stability, ease of cleaning, ability to chew soft & hard food (0 = totally dissatisfied; 10 = satisfied; 0–10 Likert scale)	Ratings of ≥ 8 , except of food impaction (rating of 6) in both groups (fixed and IOD); better rating of retention/fit with fixed (9.7/9.8) vs IOD (8.9/8.6); no data on 2-implant IOD	99% at 15 y with 4–6 implants; 83% with 2 splinted implants at 22 y; 74% at 17 y with 2 unsplinted implants; 24% BoP
VAS pain reduction, comfort, stability and function; OHIP-14, OHIP-20	Post-Tx significantly more satisfaction; no difference between splinted and unsplinted groups; patient preferred reduced palatal coverage (1st year with palatal coverage, subsequent years reduced palatal coverage)	ND
Function & esthetics rated by patient & practitioner on a numerical rating scale (0–10)	Patient reported high satisfaction with function & esthetics	78% implant-supported IOD after 2 y/biological (peri-implantitis) & technical complications (veneering fracture, loss of cemented telescopes)

Table 1 Continued Studies Evaluating Patient-Centered Outcomes for Implant Overdentures in the Maxilla (Max IOD)

Authors	Study design	Aim/comparison	Time of follow-up (assessment of PROM after max IOD insertion)	No. of patients assessed/No. of implants in the maxilla/length
Slot et al (2013) ²⁶	Prospective RCT	Max IOD with bar	Obs: 1 y; questionnaire given pre-Tx and 12 mo post-Tx	49/4 vs 6/≥ 11 mm (moderately rough)
Zembic et al (2015) ²³ (2014) ²⁴	Prospective	Within-subject comparison of max IOD with and without palatal coverage; ball attachments	2 mo with each IOD design; before implant placement (n = 12); new set of CDs (n = 9) relining or rebasing of existing CDs	21/2/length not indicated (moderately rough)
Zou et al (2013) ²⁹	Prospective	Max IOD with telescopic crowns vs bars vs locator attachments	36 mo	30/4/10–12 mm
Slot et al (2014) ²⁸	Prospective	Max IOD with implants placed in anterior or posterior region, opposed by natural dentition; bar	12 mo	50/6/11 mm (anterior), 12 mm (posterior)
Sum of 20 study cohorts (23 publications)	2 RCTs, 13 prospective, 5 retrospective studies	14 bar retention (milled or prefabricated); 3 bar or single; 1 balls; 1 telescopes, 1 bar or locator or telescopes	2 mo–22 y	530/1–10 (mainly 4–6 mm)

Max = maxillary; IOD = implant overdenture prosthesis; PROM = patient-reported outcome measurement; CD = complete denture; Tx = treatment; Obs = observation time; VAS: visual analog scale; mand = mandibular; IFDP = implant fixed dental prosthesis; OD = overdenture; CAT = category scale; GI = gingival index; PI = plaque index; NA = not applicable; RCT = randomized controlled trial; BoP = bleeding on probing; ND = not defined; OHIP = oral health impact profile.

A better perception of taste was documented for the IOD without palatal coverage than with palatal coverage. Although 16 patients chose an open palate, five selected palatal closure.

Krennmair and associates³⁹ conducted a retrospective study with a mean observation period of 42 months to compare a group of 16 patients with four implants placed in the anterior region with a group of 18 patients with six to eight implants placed in augmented posterior sites. A split milled bar was used in the posterior region whereas a continuous bar was used in the anterior site. No differences were seen in implant survival. The rigid construction using milled bars led to healthy soft tissue indices and low mechanical maintenance. General satisfaction, prosthesis stability, and esthetics all scored high on the VAS in both groups.³⁹ A similar design was applied by Raghoobar et al,³¹ who placed six to eight implants in the augmented sinuses of 10 patients in a two-stage procedure and inserted a max IOD on bilateral milled bars with Ceka attachments. After 1 year, three implants were lost (implant survival 95.6%), but overall patient satisfaction was high.

Kronström et al⁹ retrospectively compared two groups of patients (group 1 with 10 patients planned for max IOD and group 2 with nine patients planned for IFDP) with a mean follow-up of 6 to 7 years. Patients planned for a max IOD reported fewer speech problems than those planned for a fixed prosthesis. Some patients restored with IFDP reported cleansing difficulties. No other significant differences were discerned.

Naert and coworkers³⁰ conducted a prospective study on 13 patients restored with four implants with a rigid bar and a hinging max IOD design. After a mean loading time of 3 years, a cumulative implant success rate of 88.6% was reported. Attachment servicing was the most frequent maintenance problem. Strong improvement in patient satisfaction was recorded compared with the previous conventional denture.

Narhi et al³⁶ retrospectively compared splinted and unsplinted implants in max IOD prostheses in 16 patients with a mean follow-up of 32 to 54 months. Eleven patients were treated with a bar design (three to six clips) and five patients were restored with two to six ball attachments. Both palatal and reduced palatal coverage was split among the subjects. Notwithstanding a small sample size and lack of implant number standardization, no differences in marginal bone loss between the groups were noted. Cumulative implant survival after 72 months was 90%. Outcomes of patient satisfaction, esthetics, comfort, and phonetics were similar. The bar group expressed more difficulty in hygiene.

DISCUSSION

Despite the heterogeneity of the studies included, in terms of sample size, follow-up periods, implant macro- and microstructure, number of implants, prosthetic design, anchorage system, and method of data collection, trends were identified assisting the practitioner in treatment planning for max IODs.

PROM measure	Outcomes PROM	Survival of implants and prosthesis/complications
Questionnaire with 54 questions and 4-point rating (0 = no complaints, 3 = severe complaints) focused on complaints (functional problems with lower and upper denture, complaints in general, facial esthetics, accidental lip, cheek & tongue biting, esthetic of denture plus chewing ability questionnaire (0 = good, 2 = bad)	In both groups: all scores improved significantly between pre-Tx and 12 months post-Tx, but no group differences	100% with 4 implants, 99% with 6 implants
VAS (satisfaction and perception of IOD); and OHIP-20E on functional limitation, physical pain, psychological discomfort, physical, psychological & social disability & handicap; questions on cleaning ability, general satisfaction, speech, comfort, esthetics, stability, chewing ability	No significant differences between IOD with & without palatal coverage for any of the OHIP domains; higher satisfaction for esthetics & taste without palatal coverage; open palate (n = 16); palatal closure (n = 5); better results for IOD than for adjusted CD except for cleaning ability, better results for IOD than for new CD except for cleaning ability, comfort, and esthetics	100% (not specifically indicated) Caveat: Mainly patients with well-preserved alveolar ridges
Likert scale (0–2) with 0 = unsatisfied and 2 = fully satisfied, evaluating facial contour, comfort, pronunciation, and functional results	No differences detected between 3 groups; all patients recorded fully satisfied except 1 which was partially satisfied	100%/locator group had least prosthetic complications and telescopic group the most; telescopic crowns (n = 8), bar (n = 7), locator (n = 4); most common was denture margin adjustment
VAS comfort, esthetics, general satisfaction	No significant differences between anterior/posterior groups; satisfaction indices of max IOD comparable to data on mand IODs	98% anterior group, 99.3% posterior group
VAS, Likert scales, OHIP	Patient satisfaction and QoL	Implant survival, complications

Investigations using turned/machined surfaces demonstrated reduced implant survival. This was borne out by results from Jemt et al,⁴ Widbom et al,⁶ Naert et al,³⁰ Ekfeldt et al,³⁷ and Bergendal et al.⁴⁰ A recent Cochrane analysis⁴¹ evaluated the clinical impact of microstructure of implants and noted that implants with turned surfaces tended to fail early more often than did implants with moderately rough surfaces and an additional surface coating after loading. However, rough implants tended to have a 20% increase in risk of peri-implantitis 3 years after loading (relative risk, 0.80; 95% confidence interval 0.67–0.96).⁴¹ Overall, implants with moderately rough surfaces demonstrate a higher survival rate than those with machined surfaces.

Many of the studies that included short implants of less than 10 mm demonstrated lower implant survival rates than those that restricted placement to implants longer than 10 mm.^{4,5,37,40,42} When two-thirds of the implants were 7 mm in length, the 5-year cumulative implant success rate was only 72.4%.⁴³ This was in contradistinction to the results reported with implants longer than 10 mm.^{28,39} However, there appears to be a link between short/machined implants and implant loss. Meriscske-Stern et al,⁴⁴ Kiener et al,⁴⁵ and Mangano et al⁴⁶ all used less than 10-mm long moderately rough implants and reported better outcomes than the studies that used short machined implants. Van Assche et al⁴⁷ designed two extra-short (6 mm) moderately rough posterior implants and four longer (10–14 mm) anterior implants for a maxillary overdenture and also achieved good implant survival over the short term (2 years),

though the 6-mm implants did display more marginal bone loss. The use of moderately rough implants of sufficient length (> 10 mm) and diameter may provide a higher survival rate after successful osseointegration.³⁹

With regard to the minimum number of implants and anchorage system recommended for a max IOD, early studies on machined implants (< 4 implants) clearly demonstrated that less was not more.^{37,40} Payne et al⁴⁸ reported using three-implant maxillary IODs and noted that short-term survival was less than 85% even with moderately rough implants. Sanna et al³⁸ demonstrated significant differences in long-term survival between six implants and two, though the latter anchorage system was unconnected. A number of studies have shown no difference in implant outcomes between splinted and unsplinted designs, but the sample sizes were low and the outcomes may be tied to other variables such as recall regimen, implant length, anteroposterior span, or suprastructure design.^{27,29,36,44} Rigid milled bar designs appear to have lower implant failure and prosthodontic aftercare maintenance (mechanical and soft tissue indices) compared with resilient bars for max IODs or solitary anchors.^{32,39} Raghoobar et al,⁴⁹ in a systematic review, reported an increased risk of implant loss when 4 or less implants with an unsplinted anchorage were used, while implant and max IOD survival rates were higher with splinted anchorage with 4 or more implants. Parel and Phillips⁵⁰ have reported that more than four implants may be appropriate for patients with associated risk factors such as reduced bone quality, opposing

natural dentition, and parafunction when assessing implant success with maxillary implant-fixed prostheses. Although there is no distinct evidence that implant splinting with a bar is superior to single attachments in terms of implant survival, the bar design facilitates compensation of nonaligned implant angulations, particularly in patients with severely resorbed maxillae with reduced arch circumference. As a consequence, detrimental forces, for example, from removing the prosthesis with uneven forces, are more likely to occur with stud abutments than with a bar providing an equal path of insertion. Care must be taken that the bar, either individually milled or prefabricated, is designed in a way to enable cleaning underneath to avoid mucosal inflammation.

Patients have demonstrated preference for reduced palatal coverage in the area of esthetics and taste reflected in the OHIP.^{23,27} Successful outcomes have been demonstrated using a metal reinforcement with larger sample sizes.²⁶ On the other hand, horseshoe-shaped maxillary IODs do not offer the flexibility that palatal coverage offers if an implant is lost, but possibly can be adjusted accordingly.

Patient-based outcomes can best be assessed when a pretreatment questionnaire is used to elaborate the patient's requirements and select the appropriate rehabilitation. According to Zitzmann and Marinello,¹⁹ patients were asked to indicate their preference between fixed or removable (with or without palatal coverage) and 80% wished to receive the fixed restoration. Based on their requests but taking the clinical indications into account, a recommendation was given with comprehensive informed consent. Among those initially requesting a fixed restoration, 38% were inclined to accept a max IOD after their specific local factors were reviewed. It has to be noted that post treatment patient-based outcomes are best documented after a 2- to 6-month follow-up period to allow for adaptation to the new restoration, and to overcome potential burdens of a long phase with temporary prostheses.

CONCLUSIONS

Outcomes

- A max IOD offers a stabilized removable solution for the edentulous maxilla that provides increased patient satisfaction and oral health QoL.
- A higher failure rate is experienced with machined implants.
- Four to six implants are widely applied in successful cohort studies.

- When four or less implants are used for max IODs, unsplinted designs have a higher implant/prosthetic failure rate than splinted implants.
- In general, both splinted and solitary anchorage systems are advocated. Maintenance may be higher for solitary attachments. Increased soft tissue inflammation has been reported under bars.
- Palateless design offers better patient satisfaction.

Guidelines (Consensus Group 5)

- When considering a max IOD design, the practitioners' team and the patient must understand the importance of long-term regular maintenance care.
- In the diagnostic phase, clinicians must identify systemic, local (eg, vertical space requirements) and patient-based factors to best select the adequate treatment regimen.
- The max IOD prosthesis should be designed to be maintainable, retrievable, repairable, or replaceable.
- Placing a minimum of four implants with a wide anteroposterior distribution of optimal support is recommended. Consider more implants when associated risk factors are present. Implants less than 10 mm in length challenge initial stability but implants with moderately rough surfaces may provide similar success rates irrespective of implant length.

ACKNOWLEDGMENTS

The authors declare no conflicts of interest related to this systematic review.

REFERENCES

1. Parel SM. Implants and overdentures: The osseointegrated approach with conventional and compromised applications. *Int J Oral Maxillofac Implants* 1986;1:93–99.
2. Parel SM, Balshi TJ, Sullivan DY. Modifications of existing prosthesis with osseointegrated implants. *J Prosthet Dent* 1986;56:61–65.
3. Watson PA, Listrom RD, Symington JM. Treatment of the edentulous maxillary arch using osseointegrated implants supporting a fixed-removable prosthesis. *J Can Dent Assoc* 1988;54:119–121.
4. Jemt T, Book K, Lindén B, Urde G. Failures and complications in 92 consecutively inserted overdentures supported by Brånemark implants in severely resorbed edentulous maxillae: A study from prosthetic treatment to first annual check-up. *Int J Oral Maxillofac Implants* 1992;7:162–167.
5. Palmqvist S, Sondell K, Swartz B. Implant-supported maxillary overdentures: Outcome in planned and emergency cases. *Int J Oral Maxillofac Implants* 1994;9:184–190.
6. Widbom C, Söderfeldt B, Kronström M. A retrospective evaluation of treatments with implant-supported maxillary overdentures. *Clin Implant Dent Relat Res* 2005;7:166–172.
7. Smedberg JI, Lothigius E, Bodin I, Frykholm A, Nilner K. A clinical and radiological two-year follow-up study of maxillary overdentures on osseointegrated implants. *Clin Oral Implants Res* 1993;4:39–46.

8. Hof M, Tepper G, Semo B, et al. Patients' perspectives on dental implant and bone graft surgery: Questionnaire-based interview survey. *Clin Oral Implants Res* 2014;25:42–45.
9. Kronström M, Widbom C, Soderfeldt B. Patient evaluation with maxillary implant-supported overdentures. *Clin Oral Implants Res* 2006;8:39–43.
10. Zitzmann NU, Marinello CP. Treatment plan for restoring the edentulous maxilla with implant-supported restorations: Removable overdenture versus fixed partial denture design. *J Prosthet Dent* 1999;82:188–196.
11. Rosén A, Gynther G. Implant treatment without bone grafting in edentulous severely resorbed maxillas: A long-term follow-up study. *J Oral Maxillofac Surg* 2007;65:1010–1016.
12. Heydecke G, Boudrias P, Awad MA, De Albuquerque RF, Lund JP, Feine JS. Within-subject comparisons of maxillary fixed and removable implant prostheses: Patient satisfaction and choice of prosthesis. *Clin Oral Implants Res* 2003;14:125–130.
13. Dye BA, Tan S, Smith V, et al. Trends in oral health status: United States, 1988–1994 and 1999–2004. *Vital Health Stat* 11 2007;11:1–92.
14. Wu B, Liang J, Plassman BL, Remle C, Luo X. Edentulism trends among middle-aged and older adults in the United States: Comparison of five racial/ethnic groups. *Community Dent Oral Epidemiol* 2012;40:145–153.
15. Henry PJ. A review of guidelines for implant rehabilitation of the edentulous maxilla. *J Prosthet Dent* 2002;87:281–288.
16. Thomason JM, Heydecke G, Feine JS, Ellis JS. How do patients perceive the benefit of reconstructive dentistry with regard to oral health-related quality of life and patient satisfaction? A systematic review. *Clin Oral Implants Res* 2007; 18(suppl 3):168–188.
17. de Albuquerque Júnior RF, Lund JP, Tang L, et al. Within-subject comparison of maxillary long-bar implant-retained prostheses with and without palatal coverage: Patient-based outcomes. *Clin Oral Implants Res* 2000;11:555–565.
18. Zitzmann NU, Marinello CP. Fixed or removable implant-supported restorations in the edentulous maxilla: Literature review. *Pract Periodontics Aesthet Dent* 2000;12:599–608.
19. Zitzmann NU, Marinello CP. Treatment outcomes of fixed or removable implant supported prostheses in edentulous maxilla. Part I: Patients' assessments. *J Prosthet Dent* 2000;83:424–433.
20. Allen PF, McMillan AS, Walshaw D. Patient expectations of oral implant-retained prostheses in a UK dental hospital. *Br Dent J* 1999;186:80–84.
21. McGrath C, Lam O, Lang N. An evidence-based review of patient-reported outcome measures in dental implant research among dental subjects. *J Clin Periodontol* 2012;39(suppl 12):193–201.
22. Smedberg JJ, Nilner K, Frykholm A. A six-year follow-up study of maxillary overdentures on osseointegrated implants. *Eur J Prosthodont Restor Dent* 1999;7:51–56.
23. Zembic A, Tahmaseb A, Wismeijer D. Within-subject comparison of maxillary implant-supported overdentures with and without palatal coverage. *Clin Implant Dent Relat Res* 2015;17:570–579.
24. Zembic A, Wismeijer D. Patient-reported outcomes of maxillary implant-supported overdentures compared to conventional dentures. *Clin Oral Implants Res* 2014;25:441–450.
25. Zitzmann NU, Marinello CP. Treatment outcomes of fixed or removable implant-supported prostheses in the edentulous maxilla. Part II: Clinical findings. *J Prosthet Dent* 2000;83:434–442.
26. Slot W, Raghoobar GM, Vissink A, Meijer HJ. A comparison between 4 and 6 implants in the maxillary posterior region to support an overdenture: 1-year results from a randomized controlled trial. *Clin Oral Implants Res* 2014;25:560–566.
27. Al-Zubeidi MI, Alsabeeha NH, Thomson WM, Payne AG. Patient satisfaction with maxillary 3-implant overdentures using different attachment systems opposing mandibular 2-implant overdentures. *Clin Implant Dent Relat Res* 2012;14(suppl 1):1–9.
28. Slot W, Raghoobar GM, Vissink A, Meijer HJ. Maxillary overdentures supported by anteriorly or posteriorly placed implants opposed by natural dentition in the mandible: A 1-year prospective case series study. *Clin Implant Dent Relat Res* 2014;16:51–61.
29. Zou D, Wu Y, Huang W, et al. A 3-year prospective clinical study of telescopic crown, bar, locator attachments for removable four implant-supported maxillary overdentures. *Int J Prosthodont* 2013;26:566–573.
30. Naert I, Gizani S, van Steenberghe D. Rigidly splinted implants in the resorbed maxilla to retain a hinging overdenture: A series of clinical reports for up to 4 years. *J Prosthet Dent* 1998;79:156–164.
31. Raghoobar GM, Schoen P, Meijer HJ, Stellingsma K, Vissink A. Early loading of endosseous implants in augmented maxilla: A 1-year prospective study. *Clin Oral Implants Res* 2003;14:697–702.
32. Visser A, Raghoobar GM, Meijer HJ, Vissink A. Implant-retained maxillary overdentures on milled bar superstructures: A 10-year follow-up of surgical and prosthetic care and aftercare. *Int J Prosthodont* 2009;22:181–192.
33. Watson RM, Jemt T, Chai J, et al. Prosthodontic treatment, patient response, and the need for maintenance of complete implant-supported overdentures: An appraisal of 5 years of prospective study. *Int J Prosthodont* 1997;10:345–354.
34. Pieri F, Aldini NN, Fini M, Marchetti C, Corinaldesi G. Immediate functional loading of dental implants supporting a bar-retained maxillary overdenture: Preliminary 12-month results. *J Periodontol* 2009;80:1883–1893.
35. Bernhart G, Koob A, Schmitter M, Gabbert O, Stober T, Rammelsberg P. Clinical success of implant-supported and tooth-implant supported double crown-retained dentures. *Clin Oral Investig* 2012;16:1031–1037.
36. Närhi TO, Hevinga M, Voorsmit RA, Kalk W. Maxillary overdentures retained by splinted and unsplinted implants: A retrospective study. *Int J Oral Maxillofac Implants* 2001;16:259–266.
37. Ekfeldt A, Johansson LA, Isaksson S. Implant-supported overdenture therapy: A retrospective study. *Int J Prosthodont* 1997;10:366–374.
38. Sanna A, Nuytens P, Naert I, Quirynen M. Successful outcome of splinted implants supporting a planned maxillary overdenture: A retrospective evaluation and comparison with fixed full dental restoration. *Clin Oral Implants Res* 2009;20:406–413.
39. Krennmair G, Krainhöfner M, Piehslinger E. Implant-supported maxillary overdentures retained with milled bars: Maxillary anterior versus maxillary posterior concept- a retrospective study. *Int J Oral Maxillofac Implants* 2008;23:343–352.
40. Bergendal T, Engquist B. Implant-supported overdentures: A longitudinal prospective study. *Int J Oral Maxillofac Implants* 1998;13:253–262.
41. Esposito M, Ardebili Y, Worthington HV. Interventions for replacing missing teeth: Different types of dental implants. *Cochrane Database Syst Rev* 2014;7:CD003815.
42. Suzuki Y, Osada H, Kobayashi M, et al. Long-term evaluation of implant over denture. *J Prosthodont Res* 2012;56:32–36.
43. Jemt T, Chai J, Harnett J, et al. A 5-year prospective multicenter follow-up report on overdentures supported by osseointegrated implants. *Int J Oral Maxillofac Implants* 1996;11:291–298.
44. Mericske-Stern R, Oetterli M, Keiner P, Mericske E. A follow-up study of maxillary implants supporting an overdenture: Clinical and radiographic results. *Int J Oral Maxillofac Implants* 2002;17:678–686.
45. Keiner P, Oetterli M, Meriske E, Meriske-Stern R. Effectiveness of maxillary overdentures supported by implants: Maintenance and prosthetic complications. *Int J Prosthodont* 2001;14:133–140.
46. Mangano C, Mangano F, Shibli JA, et al. Morse taper connection implants supporting "planned" maxillary and mandibular bar-retained overdentures: A 5-year prospective study. *Clin Oral Implants Res* 2011;22:1117–1124.
47. Van Assche N, Michels S, Quirynen M, Naert I. Extra short dental implants supporting an overdenture in edentulous maxilla: A proof of concept. *Clin Oral Implants Res* 2012;23:567–576.
48. Payne AG, Tawse-Smith A, Thomson WM, Duncan WD, Kumara R. One-stage surgery and early loading of three implants for maxillary overdentures: A 1-year report. *Clin Implant Dent Relat Res* 2004;6:61–74.
49. Raghoobar GM, Meijer HJ, Slot W, Slater JJ, Vissink A. A systematic review of implant-supported overdentures in the edentulous maxilla, compared to the mandible: How many implants? *Eur J Oral Implantol* 2014;7(suppl 2):S191–S201.
50. Parel SM, Phillips WR. A risk assessment treatment planning protocol for the four implant immediately loaded maxilla: Preliminary findings. *J Prosthet Dent* 2011;106:359–366.