

Original article

Retrospective study comparing the clinical outcomes of bar-clip and ball attachment implant-supported overdentures

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Abstract: The aim of this study was to compare the clinical outcomes of implant-supported overdentures (ODs) with either bar-clip or ball attachments. The implant, prosthesis failure, and technical complications were the outcomes analyzed in this retrospective clinical study conducted in a specialty clinic. Seventy-five patients with 242 implants supported by 76 ODs (36 maxillary, 40 mandibular) were included in the study and followed up for 88.8 ± 82.9 months (mean \pm standard deviation). Bar-clip and ball attachments were used in 78.9% and 21.1% of the cases, respectively. Forty-three implant failures (17.8%) in 17 prostheses (17/76; 22.4%) were observed in this study. The average period of implant failure was 43.3 ± 41.0 months, and most of them were maxillary turned implants. The bar-clip system demonstrated more complications in the attachment parts compared to the ball attachment system. Poor retention of the prosthesis was similar between the two systems. Loss of implants resulted in the failure of 10 ODs in this study. ODs opposed by natural dentition or fixed prostheses presented with more complications. The Cox proportional hazards model did not show a significant effect on prosthesis failure for any of the factors. These findings indicated that patients with ODs need constant maintenance follow-ups to address the technical complications and perform prosthodontic maintenance regardless of the attachment system used.

Keywords; attachment, dental implant, failure, overdenture, prosthodontic maintenance

Introduction

An overdenture (OD) is defined by the Glossary of Prosthodontic Terms [1] as “any removable dental prosthesis that covers and rests on one or more remaining natural teeth, the roots of natural teeth, and/or dental implants”. When only dental implants are involved, these prostheses are called implant-supported ODs. An implant-supported OD is a natural alternative in cases where patients cannot afford implant-supported fixed prostheses. Alternatively, it may be used when there is a lack of adequate bone available to place a sufficient number of implants to support the fixed prosthesis and the patient is unwilling to undergo grafting or other procedures.

ODs are usually mounted with attachments, which are mechanical devices for the fixation, retention, and stabilization of a prosthesis [1]. The types of attachments used in implant ODs can be categorized as splinted and non-splinted systems. The use of a splinted implant attachment system is considered more beneficial for stress distribution during function compared to the non-splinted system [2]. However, the findings of some clinical studies have shown that the use of either splinted or non-splinted systems does not result in any significant differences in the surgical [3] or prosthodontic outcomes [4]. Nonetheless, implant-supported ODs are not without problems, and their longevity is limited not only by biologic complications but also by prosthetic maintenance requirements [5]. Therefore, it would be of interest to investigate the outcome of this prosthetic option in routine practice by comparing two of the most commonly used attachments in ODs, viz, bar-clips and balls. In this context, the present retrospective study aimed to compare the clinical treatment outcomes of

implant-supported ODs with either splinted (bar) or non-splinted (ball) attachments.

Materials and Methods

Materials

This retrospective study included patients who received dental implants during 1984-2014 at one specialty clinic (Clinic for Prosthodontics, Centre of Dental Specialist Care) in Malmö, Sweden. The patients were treated by specialists in prosthodontics. The study is based on collection of data from dental records and was approved by the Regional Ethical Committee, Lund, Sweden (Dnr 2014/598; Dnr 2015/72).

Definitions

The male part (patrix) was defined as the extension of an attachment system that fits into the recessed extension of the attachment, i.e. the female part (matrix) [1]. In the case of implant-supported ODs, the male part (bar, ball) was usually fixed on to implants or rigidly attached to a bar that was fixed on to implants, while the female part was attached to the OD (clips, O-ring synthetic polymer gasket).

An implant was considered a failure if it presented with signs and symptoms that led to its removal (lost implant). An OD was considered a failure when it was no longer in use due to the loss of supporting implant(s) or the occurrence of complications that led to the decision to abandon its use.

The complications that could occur in the case of the prosthesis, or, more specifically, the implant or attachment are as follows:

- Complications in the prosthesis: loss/fracture of acrylic teeth; damage/fracture of acrylic parts; fracture of the prosthesis superstructure (i.e. prosthesis with complete transversal buccal-lingual fracture); loosening/lack of retention of the prosthesis
- Complications in the implant: failure; fracture of the implant itself; loosening, loss or fracture of connecting/abutment screws; loosening, deformation or fracture of prosthetic abutment; pain
- Complications in the attachment system: loosening or fracture of the alveolar bar; loosening of the ball attachment; loosening, loss, deformation, or fracture of the attachment female part

Inclusion and exclusion criteria

Only ODs that were supported by dental implants using the ball or bar-clip attachment systems and followed for a minimum of six months were included in this study. Additionally, patients who were initially planned to be rehabilitated with fixed full-arch prostheses but eventually received ODs due to early loss of implants—together with the refusal to be submitted to further implants surgeries—were included. Threaded cylindrical- or conical-design implants were included, whereas zygomatic implants were excluded from the study.

Data collection

The data were entered directly into an SPSS file (SPSS software, version 25, SPSS Inc., Chicago, IL, USA) as the dental records of the patients were being read and consisted of several implant-, site-, prosthesis-, and patient-related factors.

The patients were periodically followed-up by a dental hygienist at the clinic with attendance based on individual needs.

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Table 1 Jaw location and follow-up time of the 76 overdentures according to the attachment system used

Attachment	<i>n</i> (%)	Maxilla, <i>n</i> (%)*	Mandible, <i>n</i> (%)*	Follow-up, months, mean ± SD (min-max)
Bar-clip	60 (72.3)	31 (79.5) (9)	29 (65.9)	98.9 ± 88.8 (7.2-403.9)
Ball	16 (19.3)	5 (12.8)	11 (25.0) (1)	51.1 ± 37.3 (13.5-119.6)

n, number; SD, standard deviation. *The number in bold between parenthesis represents the number of failed prostheses

Statistical analyses

The mean, standard deviation (SD), and percentage were calculated for several variables. The following tests were performed: Kolmogorov–Smirnov (to evaluate the normal distribution), Levene’s test (to evaluate homoscedasticity), Student’s *t*-test or Mann-Whitney (for two independent groups, continuous variables), and Pearson’s Chi-squared or Fisher’s exact test (for categorical variables). The clustered log-rank test outlined by Stedman et al. [6] was used to compare the survival distributions of implants between some groups of variables. Univariate Cox proportional hazards models were applied to identify covariates associated with prostheses failure. In order to verify the multicollinearity, a correlation matrix of all the predictor variables with a significant odds ratio (*P*-value cut-off point of 0.1) identified in the univariate models was scanned. Collinearity statistics obtaining the variance inflation factor and tolerance statistics were performed to detect the more subtle forms of multicollinearity. A final multivariable Cox regression model was performed only in cases where more than one variable was moderately associated (*P* < 0.10) with prosthesis failure in the univariate model. The clustering of multiple implants within each patient was accounted for in the Cox models using the methods outlined by Lee et al. (Lee et al., *Survival Analysis: State of the Art*, 237-247, Springer, 1992) and Lin [7]. Data were statistically analyzed using the SPSS software. The clustered log-rank tests and Cox models were performed using the SAS software, version 9.4 (SAS Institute, Cary, NC, USA). The degree of statistical significance was considered <0.05.

This observational study followed STROBE guidelines.

Results

Ninety-one patients (37 men, 54 women) were identified as being rehabilitated with implant-supported ODs. Two patients received two subsequent ODs in the same jaw; among them, one lost all four implants that supported the maxillary bar-clip OD and received two new implants for a second bar-clip OD, while the other patient was first rehabilitated with a mandibular OD and Locator attachments. These attachments presented with many complications within a short period; therefore, the attachment system was changed to a framework (an alveolar bar) with clips. The prostheses that resulted in the subsequent use of different attachment systems or were supported by a complete set of different implants were considered as distinct ODs. A total of 93 ODs were used; 10 of these were followed up for periods of <6 months and excluded from further analyses. Six cases of ODs using Locator attachments and one using magnet attachments were also excluded. Thus, the present study included a total of 76 ODs (36 in the maxillae, 40 in the mandibles) in 75 patients (32 men, 43 women).

The mean ± SD age of these 75 patients was 65.6 ± 12.8 years (min-max, 34.6-90.2) at the time of prosthesis delivery, and was followed up for 88.8 ± 82.9 months (min-max, 7.2-403.9).

With regard to the rehabilitation in the opposite jaw, the ODs were opposed by removable complete prostheses in 25 cases, either natural teeth or tooth- or implant-supported fixed prostheses in 35 cases, and a partially dentate arch with a removable partial prosthesis in five cases. It was not possible to retrieve the information in 11 cases.

Two hundred and forty-two implants (3.2 ± 1.3 implants per prosthesis; min-max, 1-6) were placed to support the 76 ODs. The majority of the ODs were supported by two (*n* = 26; 34.2%) or three implants (*n* = 21; 27.6%). There were 43 implant failures (43/242; 17.8%) in 17 prostheses (17/76; 22.4%). All the implant failures occurred in the Nobel Brånemark turned/machined (35/153; 22.9%) or Nobel MK III TiUnite (8/83; 9.6%) implants. The turned implants did not have a statistically significant higher failure rate than moderately rough surface implants (37/153, 24.2% vs. 8/89, 9.0%; *P* = 0.064; clustered log-rank test). Most of the turned implants were installed in the maxilla (111/153, 72.5%), whereas most of the moderately rough implants were placed in the mandible (65/89, 73.0%). Information

about bruxism was available for patients who received 214 implants, and bruxers presented with a significantly higher (*P* = 0.035) implant failure rate (5/14, 35.7%) than non-bruxers (26/200, 13.0%). Fourteen implants were placed in four patients who presented with bruxism; among them, two patients lost five implants. There was a statistically significant difference (*P* < 0.001; clustered log-rank test) in the number of failures between implants placed in the maxilla (39/135; 28.9%) and those placed in the mandible (6/107; 5.6%). The majority of the implants were placed in the region between the canines. The implants were placed in the following positions (incisors/canine/premolars/molars; failure rate in %): maxilla (62/45/21/7; 25.8/33.3/33.3/14.3) and mandible (57/50/7/1; 1.9/6.7/28.6/0). The implants failed at 43.3 ± 41.0 months (min-max, 6.1-146.2). Table 1 shows the jaw location and follow-up time according to the attachment system used. A total of 60 ODs (78.9%) using the bar-clip attachment system (Round bar, Cendres+Métaux, Biel/Bienne, Switzerland) and 16 cases (21.1%) using the ball attachment (Dalbo system, Cendres+Métaux, Biel/Bienne) were identified. The distribution of implants failure based on the attachment system was as follows: bar-clip (39/199; 19.6%) and ball (4/43; 9.3%).

Fixed full-arch prostheses were initially planned in 15 patients included in the present study; however, these patients lost 28 implants before the prosthetic stage of the rehabilitation. The choice for ODs in these patients came with the patients’ refusal to be submitted to further implant surgeries together with the fact that they were offered another type of rehabilitation with the remaining implants, i.e. ODs. Ten patients were supposed to receive implant-supported ODs from the beginning of the treatment and had lost 14 implants before the prosthetic stage. These losses, however, did not compromise continued rehabilitation with ODs. Six out of 15 (40%) patients who received ODs and were initially supposed to receive a fixed full-arch prosthesis presented with additional implant failures compared to 11 out of 61 patients (18%) who were initially supposed to receive an implant-supported OD (*P* = 0.073, Fisher’s exact test). Three out of the aforementioned 15 patients (20%) eventually lost their OD compared to 7 out of 61 (11.5%) patients who were to receive an OD at the beginning (*P* = 0.309, Fisher’s exact test).

Tables 2 and 3 show the prevalence of complications in the prostheses and implants respectively, particularly the attachment parts, based on the attachment system and bruxism. Fractures of the acrylic teeth or parts were more prevalent in bar-clip ODs, whereas the prevalence of poor retention was similar between both attachment systems (Table 2). Prosthetic and abutment screws were only used in the bar-clip system, thereby limiting the occurrence of screw complications. The bar-clip system usually presented with more complications in the attachment parts compared with the ball attachment system (Table 3).

A total of 10 ODs (13.2%) had failed due to the loss of supporting implants (Table 4). Among them, three were supported by two implants, two by three implants, four by four implants, and one by five implants. All the supporting implants were lost in eight out of the 10 ODs; one ball OD with two implants presented with a loss of one implant, and one bar-clip OD with four implants presented with a loss of three implants. The failure of these ODs occurred after 44.0 ± 45.5 months (min-max, 7.2-130.4). The 66 ODs that did not fail were followed-up for 95.6 ± 85.4 months (min-max, 7.8-403.9). Nine (11.8%) patients who were initially rehabilitated with implant-supported ODs received additional implants for fixed full-arch prostheses, which was provided after 44.5 ± 35.5 months (min-max, 16.8-118.1).

Table 5 shows a comparison between failed and non-failed prostheses based on different factors. According to the Cox proportional hazards model, no factor appeared to affect the probability of prosthesis failure. No multivariable Cox regression model was performed because only one variable was moderately associated (*P* < 0.10) with prosthesis failure in the univariate models.

Table 2 Prevalence of complications (prosthesis, implant) according to the attachment system and habit of bruxism

Complication	Attachment			Bruxism ^a	
	Bar-clip (%) ^b (n) ^c	Ball (%) ^b (n) ^c	Total (%) ^b (n) ^c	No (%) ^b (n) ^c	Yes (%) ^b (n) ^c
Acrylic tooth fractured/lost	11/60 (18.3) (21)	1/16 (6.3) (2)	12/76 (15.8) (23)	7/61 (11.5) (14)	2/5 (40.0) (5)
Fracture/damage of acrylic parts	12/60 (20.0) (28)	1/16 (6.3) (2)	13/76 (17.1) (30)	11/61 (18.0) (16)	2/5 (40.0) (12)
Prosthesis fracture ^d	3/60 (5.0) (4)	2/16 (12.5) (3)	5/76 (6.6) (7)	3/61 (4.9) (5)	0/5 (0) (0)
Prosthesis poor retention	16/60 (26.7) (26)	4/16 (25.0) (6)	20/76 (26.3) (32)	15/61 (24.6) (26)	3/5 (60.0) (4)
Fractured screw	4/60 (6.7) (5)	-	4/60 (6.7) (5)	3/61 (4.9) (3)	1/5 (20.0) (1)
Loose screw	10/60 (16.7) (24)	-	10/60 (16.7) (24)	8/61 (13.1) (15)	0/5 (0) (0)
Loss of screw	6/60 (10.0) (7)	-	6/60 (10.0) (7)	5/61 (8.2) (6)	0/5 (0) (0)
Acrylic relining ^e	20/60 (33.3) (27)	7/16 (43.8) (15)	27/76 (35.5) (42)	22/61 (36.1) (34)	3/5 (60.0) (5)
New prosthesis ^f	8/60 (13.3) (10)	0/16 (0) (0)	8/76 (10.5) (10)	6/61 (9.8) (8)	1/5 (20.0) (1)

^ainformation on bruxism was available for patients with 66 overdentures. ^bat least one occurrence – the same prosthesis may have had more than one event throughout the follow-up. ^cn – total number of events. ^dprosthesis with complete transversal buccal-lingual fracture. ^edue to poor alveolar ridge fit and/or to replace/restore attachments female parts. ^fit refers to change of prosthetic teeth and/or acrylic base (but on the same implants and same attachment system) due to worn out teeth and/or acrylic

Table 3 Prevalence of complications (attachment) according to the attachment system and bruxism habit

Complication	Attachment			Bruxism ^a	
	Bar-clip (%) ^b (n) ^c	Ball (%) ^b (n) ^c	Total (%) ^b (n) ^c	No (%) ^b (n) ^c	Yes (%) ^b (n) ^c
Female part loose	17/60 (28.3) (46)	5/16 (31.3) (7)	22/76 (28.9) (53)	19/61 (31.1) (48)	2/5 (40.0) (4)
Female part loss	12/60 (20.0) (23)	0/16 (0) (0)	12/76 (15.8) (23)	9/61 (14.8) (16)	2/5 (40.0) (6)
Female part deformation/worn out	1/60 (1.7) (1)	1/16 (6.3) (3)	2/76 (2.6) (4)	2/61 (3.3) (4)	0/5 (0) (0)
Female part fracture	19/60 (31.7) (45)	1/16 (6.3) (1)	20/76 (26.3) (46)	16/61 (26.2) (37)	2/5 (40.0) (4)
Alveolar bar loose	3/60 (5.0) (4)	-	3/60 (5.0) (4)	3/61 (4.9) (4)	0/5 (0) (0)
Alveolar bar fracture	7/60 (11.7) (15)	-	7/60 (11.7) (15)	4/61 (6.6) (6)	2/5 (40.0) (5)
Loosening of abutment	-	4/16 (25.0) (8)	4/16 (25.0) (8)	3/61 (4.9) (4)	0/5 (0) (0)
Re-activation of attachments	21/60 (35.0) (41)	5/16 (31.3) (9)	26/76 (34.2) (50)	19/61 (31.1) (40)	3/5 (60.0) (4)
New components ^d	27/60 (45.0) (90)	4/16 (25.0) (19)	31/76 (40.8) (109)	24/61 (39.3) (89)	5/5 (100) (14)

^ainformation on bruxism was available for patients with 66 overdentures. ^bat least one occurrence – the same prosthesis may have had more than one event throughout the follow-up. ^cn – total number of events. ^dreplacement/re-establishment of attachment system parts

Table 4 The number of failed overdentures based on the number of implants in the prosthesis and the attachment system used

Number of implants supporting the overdenture	Number of implants failed/total (%)	Attachment		
		Bar-clip	Ball n (%) (number of prostheses that failed)	Total
1	0/2 (0)	0 (0)	2 (12.5)	2 (2.6)
2	7/52 (13.5)	18 (30.0) (2)	8 (50.0) (1)	26 (34.2) (3)
3	8/63 (12.7)	18 (30.0) (2)	3 (18.8)	21 (27.6) (2)
4	16/56 (28.6)	14 (23.3) (4)	0 (0)	14 (18.4) (4)
5	9/45 (20.0)	7 (11.7) (1)	2 (12.5)	9 (11.9) (1)
6	3/24 (12.5)	3 (5.0)	1 (6.3)	4 (5.3)
Total	43/242 (17.8)	60 (100) (9)	16 (100) (1)	76 (100) (10)

n, number

Table 5 Comparison between failed and non-failed prostheses according to different factors, and the results of the Cox proportional hazards model

Factor	Failed prosthesis (%)	Non-failed prosthesis (%)	Hazard ratio (95% CI)	P value
Sex				
Men	2 (6.2)	30 (93.8)	1	
Women	8 (18.2)	36 (81.8)	2.456 (0.520, 11.611)	0.257
Age				
Increase by 1 year	-	-	0.963 (0.914, 1.014)	0.155
Jaw				
Maxilla	9 (25.0)	27 (75.0)	1	
Mandible	1 (2.5)	39 (97.5)	0.125 (0.016, 1.002)	0.050
Bruxer ^a				
No	7 (11.5)	54 (88.5)		
Yes	0 (0)	5 (100)	c	-
Smoker ^a				
No	6 (15.0)	34 (85.0)	1	
Yes ^b	1 (4.5)	21 (95.5)	0.263 (0.031, 2.203)	0.218
Implant surface				
Turned	8 (18.2)	36 (81.8)	1	
Moderately rough	2 (6.2)	30 (93.8)	0.506 (0.103, 2.478)	0.400
Number of implants				
Increase by 1 unit	-	-	0.988 (0.594, 1.642)	0.962
Attachment				
Bar-clip	9 (15.0)	51 (85.0)	1	
Ball	1 (6.3)	15 (93.8)	0.591 (0.072, 4.817)	0.623
Opposing arch ^a				
Total removable	0 (0)	25 (100)		
Natural/fixed	8 (22.9)	27 (77.1)	c	-
Partial removable	0 (0)	5 (100)		

^athe information about bruxism, smoking habits and condition of the opposing arch was not available for every patient. That is why the number of failed and non-failed prostheses do not add up to the total number of prostheses of the study. ^bsmokers and former smokers included. ^con at least one case, the value of the weight variable was zero. Such cases are invisible to statistical procedures and graphs which need positively weighted cases.

Discussion

The potential benefits of implant therapy must be taken into consideration before using it in the edentulous population. The present study aimed to explore the benefits of this therapy by assessing the clinical outcomes of implant-supported ODs.

The failure rate for implant-supported ODs in the present study (17.8%) was higher than that of all the implant-based treatments in this specialist clinic (6.36%), considering all kinds of prosthetic designs [8]. It is important to note that most of the implant failures occurred in patients who received turned/machined implants, and these present a higher failure rate than the so-called moderately rough surface implants, which is hypothesized to be related to the small differences in the osseointegration process [9]. Fixed full-arch prostheses were initially planned in 15 patients included in the present study; however, these patients lost 28 implants before the prosthetic stage of the rehabilitation and were then presented with the alternative of rehabilitation with ODs. Furthermore, 10 patients who had planned to receive implant-supported ODs at the beginning of the treatment lost 14 implants before the prosthetic stage. This reflects the considerable prevalence of early implant failures that might occur with any oral rehabilitation process [10]. Of the 15 patients who received ODs and were initially supposed to receive fixed full-arch prosthesis, 40% presented with implant failures after the installation of the ODs; alternatively, implant failures were observed in 18.0% of the patients who were initially supposed to receive an implant-supported OD. To some extent, this might suggest that these 15 patients had one or more factors that could negatively affect implant survival [11]. It could also be related to the fact that the rest of the implants—those that survived and were used for an OD—were located in less well-distributed positions in the arch, i.e. in an impaired biomechanical distribution, which might have an impact on the survival of implants and technical complications [12]. Moreover, an association between excessive and unbalanced biomechanical forces and peri-implant bone loss has been reported [13].

Although the number of bruxer patients was small, they presented with a significantly higher rate of implant failure than the non-bruxers, agreeing with the results of recent studies, which show that bruxism has a significantly negative effect on implant failure [14-16]. Considering the statistically higher rate of implant failure in the maxilla compared to the mandible, the treatment of an edentulous maxilla is complicated by problems such as reduced bone quality and quantity [17], divergent implant axes, and offset positioning of denture teeth, which increase the bending moments on implants, unlike in mandibular ODs [18].

Most of the OD failures were due to loss of supporting implants. The failure of an OD was not influenced by the number of implants or the attachment system used but by the restored jaw because most of the failed implants were from the maxillae. However, this result is not conclusive, because most of the turned implants were installed in the maxilla, and turned implants had a significantly higher failure rate compared to moderately rough implants, which were most commonly used in the mandibles. The presence of either natural dentition or a fixed prosthesis (or a combination of both) in the opposing jaw might have a negative influence on the survival rate of the OD. It is believed that the magnitude of the intraoral force transmitted to the OD may be higher when opposed by a fixed dentition/prosthesis compared to a total removable prosthesis. In these cases, ODs opposed by natural dentition or fixed prostheses might be subject to more complications, particularly when these intraoral forces exceed the material resistance—a condition that may result from premature occlusal contacts or interferences and/or misfits of the components or frameworks [19].

In the present study, the two striking differences in technical complications between the ball and bar-clip attachment systems were related to the fracture or loss of attachment of the female part, which was more prevalent in the bar-clip system. In general, these two systems necessitated constant re-activation of attachments, as reported previously [20,21]. Indeed, the most common prosthodontic maintenance issue for implant-supported ODs is related to the matrix–patrix complex [4]. The results of this study concerning the prevalence of clip/matrix deformations between the ball and bar-clip attachments are in agreement with the findings of Karabuda et al. [22], with no clear difference between these two attachments systems. Park et al. [23], in a randomized controlled trial comparing the two

systems, observed that the most frequent prosthodontic maintenance and complication issue was the need to change the bar-clip or O-ring as a result of retention loss. These issues were also very frequently reported for both systems in the present study. On the contrary, MacEntee et al. [24] reported that almost all repairs (90%) for the correction of problems associated with the attachments occurred in the ball group instead of the bar-clip group. Likewise, Naert et al. [25] observed that the bar-clip group presented with fewer prosthetic complications. Alternatively, van Kampen et al. [26] (3 months of follow-up), Burns et al. [27] (12 months of follow-up), and Cune et al. [28] (10 years follow-up) did not observe many maintenance problems with these two systems. The limitation of these previously published studies is that they did not evaluate the prevalence of several very detailed complications, and many of them only assessed the ODs in the mandibles.

These differences between the results of studies evaluating attachments might be a consequence of the influence of many factors other than the difference between the systems used. Based on the conflicting results in the literature, it is difficult to say which attachment system performs better than the other. In the present study, the bar-clip system presented with a higher prevalence and rate of complication than the ball attachment system, suggesting that ODs with the bar-clip system could necessitate a greater number of appointments and chair time for adjustments, thus increasing the maintenance costs for the patient. Moreover, solitary attachments such as the ball system are usually reported to be easier to maintain or repair than splinted attachments like the bar-clip system [29]. Although it was observed in one study that the repair costs of the bar-clip design were comparable to those incurred with the ball attachments [24], balls are considered the simplest and most cost-effective type of attachment for clinical application [30]. In another study, no significant differences between ODs with the ball and bar-clip attachments were found in the mean total treatment time and the costs attributable to the prosthodontist, oral hygienist, oral surgeon, and dental technician [31].

The limitations of the present study include the fact that this is a retrospective study, which inherently results in flaws manifested by gaps in information and incomplete records. The study is based on clinical records, which suffer from unbalanced data for analyses and interpretation of results [32]. The lack of information on biological factors such as oral hygiene status, bleeding on probing, and probing pocket depth, is also related to the retrospective nature of the present study. Last, but not least, the treatment was not standardized in this study due to its retrospective nature.

In conclusion, all failed ODs in the current study resulted from loss of implants, particularly the turned maxillary implants, although no factor was found to be associated with an increase in the probability of prosthesis failure in the Cox regression model. The bar-clip system usually resulted in more complications in the attachment parts than the ball attachment system. The prevalence of poor retention of the prosthesis was similar between the two systems. ODs opposed by natural dentition or fixed prostheses presented with more complications. It is expected that patients with ODs will necessitate constant maintenance follow-ups to address technical complications regardless of the attachment system used.

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Conflict of interest

There is no conflict of interest to declare.

References

1. The glossary of prosthodontic terms: ninth edition (2017) *J Prosthet Dent* 117, e1-e105.
2. Geramy A, Habibzadeh S (2018) Stress distribution in splinted and unsplinted implant-supported maxillary overdentures: a 3D finite element analysis. *Implant Dent* 27, 56-62.
3. Ma S, Tawse-Smith A, De Silva RK, Atieh MA, Alsabeeha NH, Payne AG (2016) Maxillary three-implant overdentures opposing mandibular two-implant overdentures: 10-year surgical outcomes of a randomized controlled trial. *Clin Implant Dent Relat Res* 18, 527-544.
4. Ma S, Waddell JN, Atieh MA, Alsabeeha NH, Payne AG (2016) Maxillary three-implant overdentures opposing mandibular two-implant overdentures: 10-year prosthodontic outcomes. *Int J Prosthodont* 29, 327-336.
5. Payne AG, Solomons YF (2000) The prosthodontic maintenance requirements of mandibular mucosa- and implant-supported overdentures: a review of the literature. *Int J Prosthodont* 13, 238-243.

6. Stedman MR, Gagnon DR, Lew RA, Jung SH, Losina E, Brookhart MA (2011) A SAS macro for a clustered logrank test. *Comput Methods Programs Biomed* 104, 266-270.
7. Lin DY (1994) Cox regression analysis of multivariate failure time data: the marginal approach. *Stat Med* 13, 2233-2247.
8. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A (2018) A retrospective study on clinical and radiological outcomes of oral implants in patients followed up for a minimum of 20 years. *Clin Implant Dent Relat Res* 20, 199-207.
9. Chrcanovic BR, Albrektsson T, Wennerberg A (2016) Turned versus anodised dental implants: a meta-analysis. *J Oral Rehabil* 43, 716-728.
10. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A (2016) Factors influencing early dental implant failures. *J Dent Res* 95, 995-1002.
11. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A (2017) Analysis of risk factors for cluster behavior of dental implant failures. *Clin Implant Dent Relat Res* 19, 632-642.
12. Heydecke G, Zwahlen M, Nicol A, Nisand D, Payer M, Renouard F et al. (2012) What is the optimal number of implants for fixed reconstructions: a systematic review. *Clin Oral Implants Res* 23 Suppl 6, 217-228.
13. Misch CE, Suzuki JB, Misch-Dietsh FM, Bidez MW (2005) A positive correlation between occlusal trauma and peri-implant bone loss: literature support. *Implant Dent* 14, 108-116.
14. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A (2016) Bruxism and dental implant failures: a multilevel mixed effects parametric survival analysis approach. *J Oral Rehabil* 43, 813-823.
15. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A (2017) Bruxism and dental implant treatment complications: a retrospective comparative study of 98 bruxer patients and a matched group. *Clin Oral Implants Res* 28, e1-e9.
16. Chitumalla R, Halini Kumari KV, Mohapatra A, Parihar AS, Anand KS, Katragadda P (2018) Assessment of survival rate of dental implants in patients with bruxism: a 5-year retrospective study. *Contemp Clin Dent* 9, S278-s282.
17. Chrcanovic BR, Albrektsson T, Wennerberg A (2017) Bone quality and quantity and dental implant failure: a systematic review and meta-analysis. *Int J Prosthodont* 30, 219-237.
18. Carlson B, Carlsson GE (1994) Prosthodontic complications in osseointegrated dental implant treatment. *Int J Oral Maxillofac Implants* 9, 90-94.
19. Assaf A, Daas M, Boittin A, Eid N, Postaire M (2017) Prosthetic maintenance of different mandibular implant overdentures: a systematic review. *J Prosthet Dent* 118, 144-152.e5.
20. Gotfredsen K, Holm B (2000) Implant-supported mandibular overdentures retained with ball or bar attachments: a randomized prospective 5-year study. *Int J Prosthodont* 13, 125-130.
21. Naert I, Alsaadi G, Quirynen M (2004) Prosthetic aspects and patient satisfaction with two-implant-retained mandibular overdentures: a 10-year randomized clinical study. *Int J Prosthodont* 17, 401-410.
22. Karabuda C, Tosun T, Ermis E, Ozdemir T (2002) Comparison of 2 retentive systems for implant-supported overdentures: soft tissue management and evaluation of patient satisfaction. *J Periodontol* 73, 1067-1070.
23. Park JH, Shin SW, Lee JY (2019) Bar versus ball attachments for maxillary four-implant retained overdentures: a randomized controlled trial. *Clin Oral Implants Res* 30, 1076-1084.
24. MacEntee MI, Walton JN, Glick N (2005) A clinical trial of patient satisfaction and prosthodontic needs with ball and bar attachments for implant-retained complete overdentures: three-year results. *J Prosthet Dent* 93, 28-37.
25. Naert I, Gizani S, Vuylsteke M, Van Steenberghe D (1999) A 5-year prospective randomized clinical trial on the influence of splinted and unsplinted oral implants retaining a mandibular overdenture: prosthetic aspects and patient satisfaction. *J Oral Rehabil* 26, 195-202.
26. van Kampen F, Cune M, van der Bilt A, Bosman F (2003) Retention and postinsertion maintenance of bar-clip, ball and magnet attachments in mandibular implant overdenture treatment: an in vivo comparison after 3 months of function. *Clin Oral Implants Res* 14, 720-726.
27. Burns DR, Unger JW, Coffey JP, Waldrop TC, Elswick RK Jr. (2011) Randomized, prospective, clinical evaluation of prosthodontic modalities for mandibular implant overdenture treatment. *J Prosthet Dent* 106, 12-22.
28. Cune M, Burgers M, van Kampen F, de Putter C, van der Bilt A (2010) Mandibular overdentures retained by two implants: 10-year results from a crossover clinical trial comparing ball-socket and bar-clip attachments. *Int J Prosthodont* 23, 310-317.
29. Cavallaro JS Jr., Tarnow DP (2007) Unsplinted implants retaining maxillary overdentures with partial palatal coverage: report of 5 consecutive cases. *Int J Oral Maxillofac Implants* 22, 808-814.
30. Cakarar S, Can T, Yaltirik M, Keskin C (2011) Complications associated with the ball, bar and Locator attachments for implant-supported overdentures. *Med Oral Patol Oral Cir Bucal* 16, e953-959.
31. Stoker GT, Wismeijer D, van Waas MA (2007) An eight-year follow-up to a randomized clinical trial of aftercare and cost-analysis with three types of mandibular implant-retained overdentures. *J Dent Res* 86, 276-280.
32. Chrcanovic BR, Kisch J, Larsson C (2019) Retrospective clinical evaluation of implant-supported single crowns: mean follow-up of 15 years. *Clin Oral Implants Res* 30, 691-701