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Comparison of Stud-Retentor Versus Bar-Clip Attachment as Implant-Supported Systems Used in Overdentures: A Systematic Review and Meta-Analysis

Keywords

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ABSTRACT

This study aimed to perform a systematic review and meta-analysis to analyze the results obtained clinically for bar-clip versus stud-retainers in overdentures. Three databases (PubMed Central, MEDLINE, and BvSalud) were used beyond a manual search. The study followed strictly the inclusion and exclusion criteria, considering the PICO strategy. For the risk of bias and quality assessment of studies, in the case of RCT, there were six domains of analysis, and for non-RCT studies, the Modified Newcastle-Ottawa Scale was performed. A meta-analysis was developed using the available data for marginal bone loss (MBL) and survival rate. 25 studies were included. The stud-retentor had the lowest implant SR (87.6%) and the greatest MBL (1.96 mm). For the bar-clip system, the mean survival rate was 95.91%, with only 4 studies included for this system, and the mean MBL was 1.13 mm. Only 3 studies directly compared both systems quantitatively, showing a significantly greater MBL toward the stud-retention group. The results may not allow determination of the best system for overdenture (stud retentor or bar-clip). Therefore, most of the studies suggested the stud-retentor as a more preferable system due to better distribution of forces, biological peri-implant behavior, low-cost, and ease for removal facilitating the sanitization and/or repair.

INTRODUCTION

Regarding the negative impact of edentulism within the population, which affects the bone dimensions, esthetic, and function, there is a critical demand for a better quality of life, principally in elderly people. This effect is mainly emphasized because of the impairment of oral functions and esthetics, which is frequently not properly and efficiently restored with removable prostheses.[1] In this scenario, within the advent of osseointegration, dental implants have become the current choice to respond to those limitations. Implants provide support, improve prosthetic retention and stability, reduce pain/discomfort during chewing, increase patient satisfaction,[2] and have a high success rate (90%-100%),[3-4] and a favorable prognosis.

Thereby, the implant-fixed prosthesis is currently considered the best option for oral rehabilitation. However, there may be limitations regarding its performance, such as excessive discrepancy dimensions between arches, manual dexterities of the patient to sanitize, skills of the professional, severe bone atrophy, and also socioeconomic problems.[5-7] Observing all these factors and a limited financial resource, implant-supported overdentures seem an adequate therapeutic option, reducing costs and time for treatment.[8]

Overdentures act as a total prosthesis with mucosal support, therefore with an optimized retention and stabilization on the dental implants.[9] It has shown a high success rate to rehabilitate edentulous patients, significantly improving the masticatory function, satisfaction, and self-esteem.[7] The clinician should have an acceptable knowledge about different systems for overdentures retention, such as knowing the advantages and disadvantages, indications and contraindications in order to reach stable results, remembering that there are different types of attachment systems (ball, bar, magnetic, telescopic, and stud-retention)[5,10] to obtain the best response according to the patient's need.[8]

Thus, there are two different retentive classification systems for overdenture, one in which the implants are bar-splinted (by clip or ball); and another one, in which it is a unitary fixation system (non-splinted) retained directly on the implant, like in ball-attachment, magnetic, or stud retention.[11] The bar-clip system offers advantages for patients with atrophied alveolar bone such as good retention capacity and low-maintenance cost.[12] Within the unitary systems, the stud-retention has showed better results compared to the ball-attachment or magnetic system. As such, the stud-attachment is considered the main alternative when the inter-arch distance is inadequate, providing a dual retention feature with a greater retention area,[13] beyond superior clinical results compared to bar-clip, respecting the maintenance of oral functions and prosthetic complications.[14] In addition, it is considered easier to clean and maintain, providing a lower-load transferred to the implants, and consequently, it has a better biomechanical response to peri-implant tissues.[15]

Despite many studies evaluating stud- and bar-retentors for overdentures, there is no review comparing these two systems specifically. Thus, this study aimed primarily to perform a systematic review to analyze and map the criteria of selection for implant-supported overdentures retained by stud versus bar-clip systems, such as marginal bone loss (MBL) and survival rate, and the patient-related outcome measures.

MATERIALS AND METHODS

A Systematic Review was developed according to the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) guidelines,[16] through an extensive electronic search and analysis of scientific articles only published in the English-language in the last 10 years (from January 2010 to, and including, December 2020). The review protocol was registered with the PROSPERO International Prospective Register of Systematic Reviews (CRD42021232040).

FOCUSED QUESTION

The focus question was defined considering the Population, Intervention, Comparison, and Outcome (PICO) strategy, as follows: "Are the patients with edentulous jaws wearing implant-supported overdentures (P) better rehabilitated with stud retention (I) or using a bar-clip attachment system (C) after applied criteria of selection, guaranteeing a satisfactory retention for overdenture (removable implant-supported total prosthesis), lesser marginal bone resorption, and survival/success rate of the dental implants and prosthesis (O)?"

INFORMATION SOURCES AND SEARCH STRATEGY

PubMed Central (PMC)/MedLine and BvSalud were used as online databases, with the keywords described in Table 1 combining Boolean terms ("OR" and "AND"). An additional manual search was performed on the references of included articles to identify relevant publications and also using other specific words such as "equator attachment" OR "equator" (2 articles), "kerator attachment"/"kerator" (2 articles, although one was duplicated), "zest locator attachment"/"zest locator"/"zest" (no article), "straight pop-clicq attachment"/"clicq attachment"/"clicq" (no article).

The publications obtained from the search through all mentioned databases were imported into a reference management software (EndNote X9/Thomson Reuters, Philadelphia, USA) and subsequently screened.

INCLUSION CRITERIA

The inclusion criteria involved human studies published in English-language, with a minimum of 10 patients and 6-month follow-up, such as randomized controlled trial (RCT), clinical prospective and retrospective studies, involving fully edentulous patients rehabilitated with overdenture (total prosthesis over dental implants), detailed information on the implant and system used, reported details regarding survival/success rates and/or marginal bone loss (MBL), an only publication with the longest follow-up was included in case of multiple studies involving the same patient cohort (population).

EXCLUSION CRITERIA

The exclusion criteria were reports based on questionnaires and interviews, editorial letters, systematic reviews and meta-analysis, publications investigating fixed-rehabilitation or overdenture systems different from stud-retentor or bar-clip, repeated data used in longer follow-up (excluded the oldest article), studies with only qualitative analysis, or involving patients with a significant health problem (ASA Physical Status 3 and above).

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Table 1: Search strategy carried out and filters applied.

Database	PubMed Central and BvSalud
#1	POPULATION – Patients with edentulous jaws wearing implant supported overdentures "Dental Implants" OR "Edentulous" OR "Overdenture" OR "Full-Arch Rehabilitation" OR "Implant" OR Dental Implant*
#2	INTERVENTION AND COMPARISON – Rehabilitation with Locator-type or bar-clip system over dental implants "Locator Fixation" OR "Locator Attachment" OR "Locator-type Fixation" OR "Locator-type Attachment" OR "Implant-Supported" OR "Retention" OR "Stud attachment" OR "Stud retention" AND "Bar-Clip Fixation" OR "Bar-Clip Attachment" OR Bar*
#3	OUTCOME – Satisfactory overdenture, Survival/Success rate of the dental implants and prosthesis, Marginal Bone Loss
Search Combination	(#1 AND #2) No combination was done with #3 since the combination with keywords related to context would limit even more the search.
Filters	English, Humans, Clinical studies

* is a truncation symbol to retrieve terms with a common root within the database

SELECTION OF STUDIES

This review was carried out independently by two reviewers (F.M.C.C. and G.Z.M.). Duplicates were excluded and the remaining articles were screened by title and abstract for eligibility. Further examination regarding inclusion and exclusion criteria was subsequently made by full-text analysis. The full-text of any title or abstract that did not provide enough information regarding the inclusion criteria was also obtained. Any disagreement between the reviewers was discussed with a third author (G.V.O.F.). In the case of the article that included works with other systems, only the data of interest were collected. Cohen's kappa test was adopted to evaluate reviewers' agreement on both selection steps.

DATA EXTRACTION AND METHOD OF ANALYSIS

The reviewers extracted the data independently from the selected articles for further analysis using data extraction tables, when available, which included the following parameters: Author(s), year of publication and study design; Mean observation period; Number of patients and implants at the initial stage of the research, mean period follow-up; Type of prosthetic reconstruction; Cumulative percentual implant survival and, implant success rate, and peri-implant MBL (mm); Cumulative prothesis success rate (%).

The meta-analysis involved the comparison of the data obtained for the MBL at a mean observation period of correspondent follow-up and the cumulative survival rate. All analysis was performed with heterogeneity appraisal and the studies were quantified using an inconsistency test (I^2) and values above 75% were considered an indication of substantial heterogeneity. Then, a fixed-effect model at a 5% significance level was used to evaluate each group, and to compare, the random effect was used. For those studies where confidential interval (CI) were not provided, the standard deviation (SD) value was used for the calculation of a CI.

RISK OF BIAS AND QUALITY ASSESSMENT

Two reviewers (F.M.C.C. and G.V.O.F.), independently, assessed the risk of bias and study quality of the included investigations, according to Borges *et al.*[17] For RCT included, there were six domains: sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting, and other bias, which were classified in low, high, or unclear risk. For non-RCT studies, the Modified Newcastle-Ottawa Scale for the risk of bias and quality assessment of studies was done.

RESULTS

STUDY SELECTION

One hundred and ninety-one studies were identified from the electronic database search (Pubmed Central/MedLine: 63; BvSalud: 124; Manual Search: 4), in which 43 duplicates were removed, with 148 remaining to be reviewed by title. The screening resulted in 42 articles to be evaluated by abstract, yielding 36 articles to have a full-text assessment for further evaluation of the inclusion and exclusion criteria. Eleven full texts were excluded based on the criteria, detailed in Table 2. Finally, a total of 25 studies met the inclusion criteria and were included in the current review *(Figure 1, Table 3)* for qualitative analysis and 18 for quantitative evaluation *(Figure 1)*. The kappa values for the inter-examiner agreement between the reviewers were 0.94 for the title/abstract screening and 0.89 for the full-text screening.

Table 2. Excluded studies after full-text read and reason for exclusions.

Author/Year	Title	Reason for exclusion
Borges *et al.*, 2011	Overdenture with immediate load: mastication and nutrition	Articles focused in the masticatory efficiency and nutrition
Chu *et al.*, 2018	Balanced occlusion aided locator abutment retained overdenture with no implant placed within the anterior region: A case report	Without data of interesting
Elsyad *et al.*, 2017	Posterior Mandibular Ridge Resorption Associated with Different Retentive Systems for Overdentures: A 7-Year Retrospective Preliminary Study	It did not aim directly to analyze the systems of retention, evaluating the posterior mandibular ridge resorption comparing two systems
Kappel *et al.*, 2015	Immediate Loading of Two Dental Implants, in Edentulous Mandibles, with Locator® Attachments or Dolder® Bars: First Results from a Prospective Randomized Clinical Study	The same data was used in other study with longer follow-up
Karbach *et al.*, 2015	Oral Health-Related Quality of Life in Edentulous Patients with Two- vs Four-Locator-Retained Mandibular Overdentures: A Prospective, Randomized, Crossover Study	Only compared the oral health-related quality of life (OHRQoL)
Quirynen *et al.*, 2015	Small-diameter titanium Grade IV and titanium-zirconium implants in edentulous mandibles: three-year results from a double-blind, randomized controlled trial	The goal of the article was primarily to evaluate the results of the implants
Matthys *et al.*, 2020	Cost-effectiveness analysis of two attachment systems for mandibular overdenture	Without data of interesting
Mo *et al.*, 2016	Maxillary 3-implant removable prostheses without palatal coverage on Locator abutments – a case series	Without data of interesting
Neto *et al.*, 2012	The influence of mandibular implant-retained overdentures in masticatory efficiency	Articles focused in the chewing experience and masticatory efficiency
Pisani *et al.*, 2017	A qualitative study on patient's perceptions of two types of attachments for implant overdentures	Qualitative analyses of the patient's perception
van der Bilt *et al.*, 2010	Mandibular implant-supported overdentures and oral function	Articles focused in the bite force and masticatory performance in long-term
Zweers *et al.*, 2015	Clinical and radiographic evaluation of narrow- vs. regular-diameter dental implants: a 3-year follow-up. A retrospective study	It aimed to analyze implant diameter with overdenture and it had unprecise data differing MBL between narrow-regular diameter dental implants

MBL = marginal bone loss.

STUDY CHARACTERISTICS AND QUALITY OF ASSESSMENT

All included studies were summarized in Table 4, being subsequently analyzed, and discussed. All included studies had a common characteristic, the full edentulism, and were codified as follow: Tallarico *et al.* (S1),[7] Malmstrom *et al.* (S2),[18] Brandt *et al.* (S3),[19] Guédat *et al.* (S4),[20] Seo *et al.* (S5),[21] Kappel *et al.* (S6),[11] Elsyad *et al.* (S7),[6] Wang *et al.* (S8),[22] Elsyad and Hammouda (S9),[23] Al-Dharrab (S10),[24] Varshney *et al.* (S11),[8] Boven *et al.* (S12),[12] Park *et al.* (S13),[25] Matthys *et al.* 2019 (S14),[1] Schincaglia *et al.* (S15),[26] Elsyad *et al.* (S16),[27] Akça *et al.* (S17),[28] Jabbour *et al.* (S18),[29] Cristache *et al.* (S19),[30] Krennmair *et al.* (S20),[31] Cheng *et al.* (S21),[32] Cakarer *et al.* (S22),[33] Alsabeeha *et al.* (S23),[34] Cune *et al.* (S24),[35] and Kleis *et al.* (S25).[36]

Patients were followed for a mean period of 40.13 months, ranging from 2 weeks to 10 years. Regarding preoperative selection criteria, studies S1, S3, S5-S10, S12-S16, S19, S22, S23, S25 were evaluated for bone availability/quantity, while studies S1, S3, S6-S10, S12, S13, S19, S23 evaluated/exposed the bone quality. For the prosthetic space, this criterion was evaluated in the studies S1, S6, S10, S11, S13, and S16. Only the studies S1 and S19 assessed the economic resources criterium, and only 2 (S7 and S10) performed the appraisal of manual dexterity.

The risk of bias found was low, such as demonstrated in Figure 2 (a and b) for RCT studies and Figure 3 for non-RCT studies, a satisfactory level of evidence-based on the criteria of each scale. Two RCTs out of ten (S6 - Kappel *et al.*, S12 - Boven *et al.*)[11,12] fully described a randomized and blinded selection and assessment of patients, and three (S15 - Schincaglia *et al.*, 2016, S19 – Cristache *et al.*, 2014, S23 – Alsabeeha *et al.*, 2011)[26,30,34] followed all needed parameters to be classified as the lowest risk of bias. Conversely, a great risk was encountered only in the RCT study of Seo *et al.* (S5).[21]

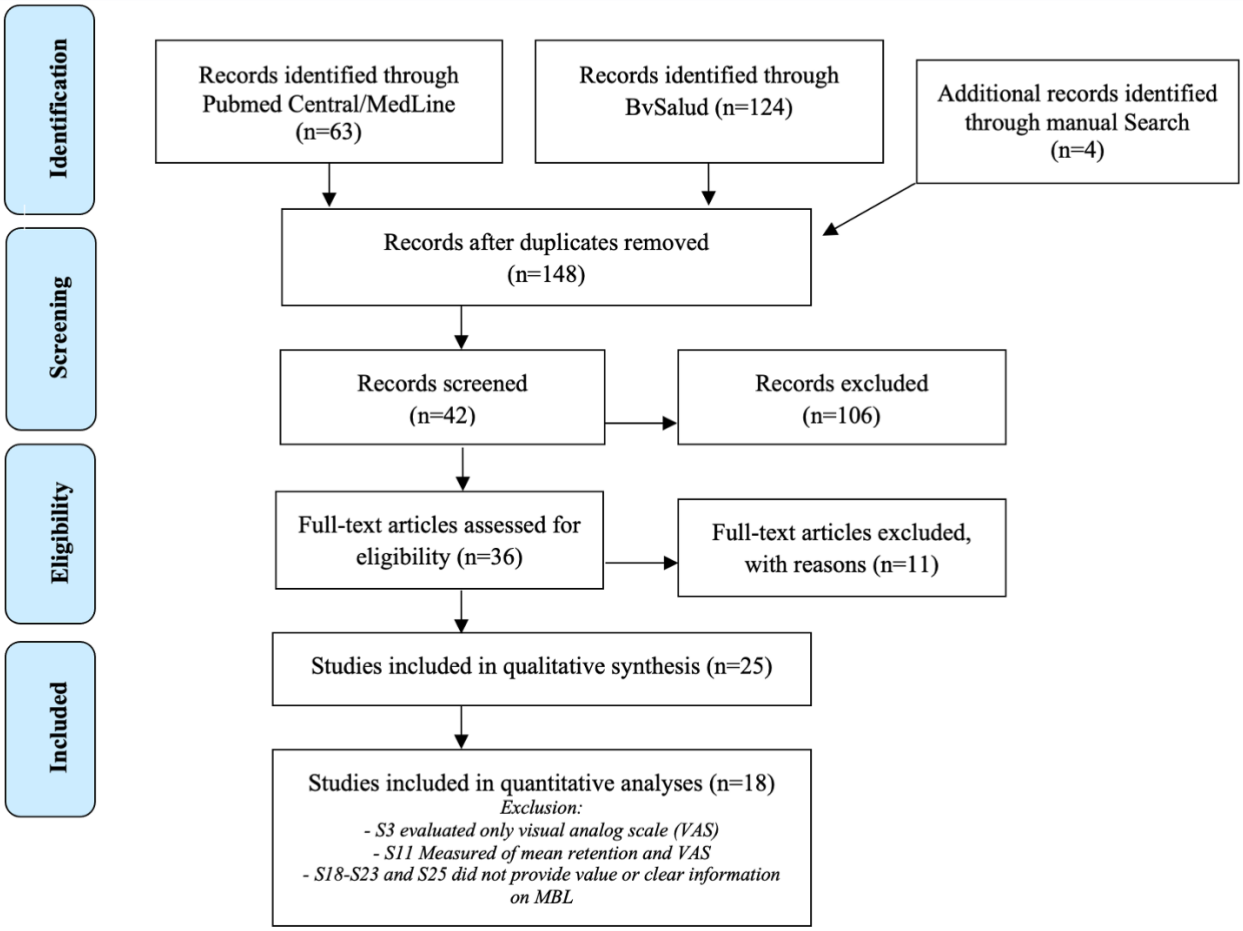

Figure 1: Flow Diagram for the articles screened and included.

Table 3. Types of studies included.

	Author	Year	Title	Type of study
S1	Tallarico *et al.*	2018	Multicenter retrospective analysis of implant overdentures delivered with different design and attachment systems: results between one and 17 years of follow-up	Multicentric Retrospective Study
S2	Malmstrom *et al.*	2015	The two-year success rate of implant-retained mandibular overdentures by novice general dentistry residents	Retrospective Clinical Study
S3	Brandt *et al.*	2019	Locator® versus ceramic/electroplated double-crown attachments: a prospective study on the intraindividual comparison of implant-supported mandibular prostheses	Prospective Clinical Study
S4	Guédat *et al.*	2018	Clinical performance of Locator® attachments: A retrospective study with 1-8 years of follow-up	Retrospective Clinical Study
S5	Seo *et al.*	2016	Clinical evaluation of mandibular implant overdentures via Locator implant attachment and Locator bar attachment	Retrospective and Randomized Controlled Study
S6	Kappel *et al.*	2015	Immediate loading of dental implants in edentulous mandibles by use of Locator® attachments or Dolder® bars: two-year results from a prospective randomized clinical study	Prospective and Randomized Controlled Study
S7	Elsyad *et al.*	2016	Locator versus magnetic attachment effect on peri-implant tissue health of immediate loaded two implants retaining a mandibular overdenture: a 1-year randomized trial	Randomized Controlled Study

Table 3 continued overleaf.....

Table 3. Types of studies included... continued

	Author	Year	Title	Type of study
S8	Wang *et al.*	2015	Maxillary four implant-retained overdentures via Locator® attachment: intermediate-term results from a retrospective study	Retrospective Clinical Study
S9	Elsyad and Hammouda	2016	Expansion of mandibular knife-edge ridge and simultaneous implant placement to retain overdentures: one-year clinical and radiographic results of a prospective study	Prospective Clinical Study
S10	Al-Dharrab	2017	Three-year prospective evaluation of immediately loaded mandibular implant overdentures retained with locator attachments	Prospective Clinical Study
S11	Varshney *et al.*	2018	Retention and patient satisfaction with bar-clip, ball and socket and Kerator attachments in mandibular implant overdenture treatment: an *in vivo* study	Retrospective Clinical Study
S12	Boven *et al.*	2020	Maxillary implant overdentures retained by use of bars or locator attachments: 1-year findings from a randomized controlled trial	Randomized and Controlled Clinical Study
S13	Park *et al.*	2019	Bar versus ball attachments for maxillary four-implant retained overdentures: a randomized controlled trial	Randomized Controlled Study
S14	Matthys *et al.*	2019	Five years follow-up of mandibular 2-implant overdentures on locator or ball abutments: Implant results, patient-related outcome, and prosthetic aftercare	Controlled Clinical Cohort Study
S15	Schincaglia *et al.*	2016	Marginal Bone Response Around Immediate- and Delayed-Loading Implants Supporting a Locator-Retained Mandibular Overdenture: A Randomized Controlled Study	Randomized Clinical Study
S16	Elsyad *et al.*	2014	Marginal bone resorption around immediate and delayed loaded implants supporting a locator-retained mandibular overdenture. A 1-year randomised controlled trial	Randomized Controlled Study
S17	Akça *et al.*	2013	Early-loaded one-stage implants retaining mandibular overdentures by two different mechanisms: 5-year results	Randomized Controlled Study
S18	Jabbour *et al.*	2014	Effect of implant angulation on attachment retention in mandibular two-implant overdentures: a clinical study	Prospective Clinical Study
S19	Cristache *et al.*	2014	Five-year clinical trial using three attachment systems for implant overdentures	Prospective Randomized Controlled Study
S20	Krennmair *et al.*	2012	Patient preference and satisfaction with implant-supported mandibular overdentures retained with ball or locator attachments: a crossover clinical trial	Crossover Randomized Clinical Trial
S21	Cheng *et al.*	2012	Patient satisfaction and masticatory efficiency of single implant-retained mandibular overdentures using the stud and magnetic attachments	Crossover Randomized Clinical Trial
S22	Cakarer *et al.*	2011	Complications associated with the ball, bar and Locator attachments for implant-supported overdentures	Prospective Clinical Study
S23	Alsabeeha *et al.*	2011	Mandibular single-implant overdentures: preliminary results of a randomised-control trial on early loading with different implant diameters and attachment systems	Randomized Controlled Study
S24	Cune *et al.*	2010	Mandibular overdentures retained by two implants: 10-year results from a crossover clinical trial comparing ball-socket and bar-clip attachments	Crossover Randomized Clinical Study
S25	Kleis *et al.*	2010	A comparison of three different attachment systems for mandibular two-implant overdentures: one-year report	Prospective Randomized Clinical Study

S = Study

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Table 4. Detailed data of the included studies.

Study	Objective	Population/ Sample	Methodology	Main Results	Success and Survival Rate
S1	- survival of implants and prostheses - complications - biological parameters - period of analysis: 1 to 17 years	194 rehabilitated patients with 581 implants 132 patients with 403 implants, had stud-type retention	Analyzed: - implant loss - prosthetic failures - marginal bone loss (MBL) - bleeding on probing (BOP) - plaque index (PI) - quality of life through a questionnaire (OHIP-21)	- Total locators' failure in 5 prostheses; 25 complications experienced in 24 patients. Implant failures in 3 out of 40 locators. Prosthesis failure in 4 of 39 locators; complications 10 out of 33. - MBL, among different attachment systems (OT Equator, OT Cap, and Locator [Zest Dental Solutions]) after one-, two-, and five-year follow-up, was no statistically significant differences. - Mean bleeding on probing (BOP): one-year after loading was 0.07 ± 0.10 mm; two years was 0.11 ± 0.17 mm; three years was 0.09 ± 0.18 mm; five years was 0.10 ± 0.17 mm. - Mean plaque index (PI): after one year was 0.12 ± 0.15 mm; two years was 0.12 ± 0.17 mm; three years was 0.12 ± 0.17 mm.	Implant survival rate of 97.4% Implant success rate of 87.6% after 5 years
S2	- clinical success - patient satisfaction with implant-supported mandibular overdentures	50 patients and 100 dental implants (two mandibular implants between mental foramen)	Pre-surgically appraisal: - prosthetic retention, - comfort, - speech, - quality of life The following criteria were observed at 2 weeks, 3 months, 1 year, and 2 years of follow-up: - gingival index, - plaque index, - probing depth, - radiographic bone loss. Prosthetic stability, retention, and esthetics were evaluated on a scale from 0 (poor) to 10 (excellent).	- Total of 100 locators - The average for probing depth was 2.13 ± 0.95 mm - The average MBL was 0.33 mm ± 0.48 mm - No statistically significant regarding gingival or plaque index. - The highest probing depth value was 1.76 ± 0.74 (1-year) and 2.13 ± 0.95 mm after 2 years. - Prosthetic repair needed for overdentures (29%), fracture of the acrylic base (4%), tooth fracture (2%), loosen the retaining screw (2%), loss of male locator retention (11%), increased patient satisfaction index, adjusted prosthesis, and increased chewing capacity	Implant success rate of 97.7% after 2-year follow-up
S3	Interindividual comparison of patient satisfaction	12 patients and 24 dental implants (two implants in the lower canine's region)	Crossover study, with reverse rehabilitation after 3 months. Group A, overdenture retained by the locator; Group B, overdentures retained by double ceramic crowns Patients were evaluated and filled out a questionnaire according to a visual analog scale (VAS; from 0 to 100 points), where they evaluated the criteria: - satisfaction, - retention, - ease of handling, - comfort, - esthetics, - masticatory function, - ease in sanitizing, - stability, and - phonetics.	Group A (group of interesting): - 90.25 points in the VAS questionnaire - 7/12 patients preferred locator at the end of the experimental period - Comfort of 90.25 points - Masticatory function 86.50 points - Hygiene capacity 93.28 points - Phonetics of 92.42 points Concluded in favor of the locator system	-
S4	Long-term performance of the locator-retainer	47 patients and 118 dental implants	- All patients received overdentures with locators and remained in office for a minimum period of 1 year - Groups analyzed: Groups 1, 2, and 4 - All complications were registered and classified according to: - type of prosthesis, number of implants, height of the locator, inclination of the implants, and the amount of wear of the retainer. - Bleeding on probing, probing depth, implant mobility, pain, and peri-implant infection were measured.	- Mechanical complications, loss of retention, and loss of the prosthetic capsule were significant over time (n=106 with a locator-type and total prosthesis) - There was no statistically significant difference for number of implants, and axial inclination of the implants - In patients without signs of loosening of the retainers, 52% had a loss of retention compared to patients who had advanced wear on the retainer, of which 100% had a loss of retention - Wear of the retainer: there was no difference between the types of the prosthesis in the groups, however, there was a greater weakening in the maxilla vs mandible (p=0.028) - Longer pillars showed greater wear (p=0.041) - Significant difference between groups for overall peri-implant plaque score (p=0.007), the bleeding rate on probing (p=0.036); and probing depth (p=0.006)	Implant survival rate was 94.4% (mean period of 54,8 months)

Table 3 continued overleaf.....

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Table 4. Detailed data of the included studies.....continued

S5	Clinical aspects and satisfaction of overdentures retained by locator and locator-bar in mandibles	16 patients and 48 dental implants	Two groups: LIA (locators group) with 2 implants and 2 locators; and LBA (bar group) with 4 implants, bar-locators Criteria evaluated: - Absence of discomfort, infection, mobility, implant survival rate, and bone loss; - MBL, probing depth, bleeding index, peri-implant inflammation, plaque index, and calculus - Prosthetic criteria, satisfaction, esthetics, retention, and masticatory function	- There were no losses or mobility in the implants in both groups after a 4-year follow-up - MBL in the LBA of 1.51 mm ± 0.13mm and for LIA was 1.96 ± 0.20 mm with statistical significance ($p < 0.05$); probing depth of 2.80 ± 0.16 mm for LBA and 2.91 ± 0.24 mm for LIA ($p < 0.05$) - A greater inflammatory profile was observed for LBA (33.3%) compared with LIA (12.5%), further a major plaque index and calculus	Implant survival rate for LIA and LBA was 100% up to 4 years
S6	Survival and incidence of complications for immediate loading with bar attachments or locator	46 patients and 92 dental implants	- All patients received new total prostheses over 2 implants with 10mm in length and torque between 30 and 35 N.cm - They were divided into 2 groups (locators vs. Dolder bar) and the prostheses installed after 72 hours - Follow-up examinations were performed after 3, 6, 12, and 24 months	- n=92 implants distributed for locators and bar-clip showed MBL, after 2 years (between 0 and 2.5mm) - Complications were observed for 2 bars that fractured and for loss of retention, 16-fold were changed or readapted (8 for each group).	For locator and bar-clip, respectively: - Implant survival rate of 93.5% and 89.1% - Implant success rate of 94.7% and 92.1%
S7	Evaluated peri-implant tissue for 2 retainers-type in mandible: overdenture with magnetic or locator	32 patients and 64 dental implants	- 2 groups (magnetic retainers and locators) - 2 implants (3.75 x 13mm) were inserted in canine area through surgical flapless - New prostheses were made for all patients - Follow-up after 2 weeks, 6 and 12 months - Plaque index (PI), bleeding (BI), primary resonance stability (ISQ), interleukin level (IL-1b) by crevicular fluid, probing depth (PD), implant mobility, horizontal bone loss (HBL), and vertical (VBL) were evaluated.	- Locator® group in PD and ISQ increased significantly over time, and BI did not show significant differences - VBL was significantly greater in Group 2 than Group 1 (magnetic) only in T2 ($p < 0.05$); and VBL and HBLO increased significantly at T2 compared to T1 in both groups ($p < 0.05$) - Group 1 recorded a higher IL-1beta at T1 and T2 compared to Group 2.	Locator group had 96.9% survival rate and no statistical difference
S8	Evaluated four stud attachments in maxillary overdentures and test their reliability	26 patients and 104 dental implants	- Four implants were placed; the prosthesis was made with stud-attachment - Plaque index, bleeding index, probing depth, marginal bone level, bone quality, implant position, location (maxilla vs. mandible), and the number of prosthetic complications was evaluated - The mean follow-up time was 46 months (range: 7-73 months).	- MBL between implant placement and impression was 0.8 ± 0.4 mm - Last follow-up, MBL was 1.7 ± 1.1 mm - 14 implants exhibited 2 to 3 mm of radiographic bone loss - Implants in the posterior maxilla were significantly higher compared to implants in the anterior maxilla - Modified plaque index was 13.0 ± 22.3 (%) after delivery of the prosthesis and 12.5 ± 14.0 in the last follow-up - Average pocket probing depth (PPD) was 3.7 ± 1.6 mm in the last control visit, compared to 2.3 ± 0.5 mm in the loading phase ($p = 0.002$) - 26 prosthetic complications occurred (21 capsules were exchanged) - There were 2 losses of the male socket, 2 loosening of the screw, and 2 patients with fracture of the tooth of the prosthesis - No clinical mobility, pain, or sensitivity was observed	Implant survival rate of 95.2% (average 56-month follow-up period)
S9	Evaluated clinical and radiographic results of two implants placed on the mandibular crest in the expanded and unexpanded bone to retain overdenture	30 patients and 60 dental implants	- Control group (CG) received 2 implants in the canine areas without expansion of the crest; in the other group (SG), a horizontal cut was made in the crest and bone expansion procedures with implant insertion - Pillar locators were placed after 3 months - Success rate and radiographic parameters were recorded at the time of prosthesis placement (T0), 6 months (T6), and 12 months (T12) - Plaque index (PI), gingival index (GI), probing depth (PD), implant stability quotient (ISQ), bone loss, and osseointegration through periapical radiographs were evaluated	- There was a significant difference in PI, GI, PD (between T0 and T6), and between T0 and T12 (between CG and SG) ($p <0.05$) - These parameters showed an insignificant difference between T6 and T12 - There was a statistically significant difference in the clinical parameters tested (PI, GI, PD, and ISQ) between the groups at all periods, with the ISQ increasing sequentially with time ($P <0.05$) - SG recorded VBL significantly higher than the GC at T6 and T12 ($P <0.05$)	98.2% for implant success rate; and implant survival rate were 100% and 96.4%, respectively for CG and SG

S10	Evaluated implant survival and peri-implant tissue of patients who received overdenture using locators	24 patients and 48 dental implants	- 2 implants were placed (anterior region of the mandible) with torque between 35 and 45 N.cm, and the Locators were installed - Patients were regularly called for evaluation up to 3 years after implant surgery - Assessments were made immediately after implant placement, at 3 months, and 1-, 2-, 3-year - Implant survival, mobility, marginal bone loss, and modified plaque index were recorded.	- Average of MBL was 0.62 mm (± 0.13 mm), 0.81 mm (± 0.20 mm), and 0.89 mm (± 0.14 mm), respectively for 1st, 2nd, and 3rd year - No loss of dental implants after 3 years of function - Plaque index, after 3 months, 13 out of 24 patients had an MPI score >2, showing the lack of oral hygiene - After 1 year, 4 patients had an MPI score <1, which indicated good hygiene; 14 patients had an MPI score >1, but <2 - After 2 years, 2 patients maintained poor oral hygiene, while enough level of oral hygiene was evidenced in 17 patients, and only 5 patients had good oral hygiene - At the end of the study, 18 patients had MPI >1, but <2; and only 2 patients had poor oral hygiene.	100% for implant survival rate
S11	Assessed the retention and satisfaction of the rehabilitated patient with mandibular implant-supported overdenture (bar-clip, ball, and Kerator)	15 patients and 30 dental implants	- Assessed after placement, at 3 months and 6 months and VAS questionnaire was done	- In group 2 (bar-clip) at 3 months 7.18 ± 0.23 N.cm and 6 months 5.29 ± 0.81 N.cm of retention was obtained (group with the highest loss of retention) - Group 2 VAS questionnaire (bar-clip) was 65.91 ± 4.01 at 3 months and 57.11 ± 1.87 at 6 months, which had the lowest result and the greatest reduction of retention among the 3 groups	-
S12	Superior overdenture retained by the use of locator or bars (1-year randomized controlled study	50 patients and 200 dental implants (four 3.5mm [diameter] maxillary implants in the anterior region of the maxilla, with at least 1 year of observation)	- Two groups: bar-clip group (gold retaining clip) and locator group (pink ones, 13.4 N; medium strength) - The prostheses were made without palate - After one year, the implant and prosthesis survival rate were assessed; Peri-implant hygiene (plaque index, presence of calculus), soft tissue conditions (gingival index, groove, bleeding index, probing depth) and, patient satisfaction (oral health impact profile (OHIP-49), questionnaire complaints of dentures and general satisfaction scale (GSS). The bone assessment was estimated by intraoral radiographs	- for locator and bar-clip group, respectively: MBL = 0.58 (± 0,71 mm) and 0.31 (± 0.47 mm); probing depth was 3.7 (± 1.0 mm) and 4.1 (± 0.9 mm) in T1, which was significantly increased in T12 (respectively, p=0.002 and p=0.009), but with no statistical significance between groups/period - There was a preference by the patients for bar-clip retention - Complications: In the bar-clip group, an acrylic tooth in the total prosthesis came off after 1.5 months; 2 patients requested to tighten the gold retention clips after 6 months; and 3 patients requested the replacement of the nylon capsules after 4.5 and 7 months - No statistically significance regarding prosthetic complications, hygiene and conditions of the peri-implant tissue, and probing depth at T12 - Patient satisfaction was significantly higher in the bar-clip group (OHIP-49 and GSS)	Implant survival rate was 96.7% (locator group) and 97.9% (bar group)
S13	Compared four maxillary implants in overdentures retained with bar or ball fittings on splinted and unsplinted implants	32 patients and 128 dental implants	- 2 groups: bar-clip and ball attachment - 4 maxillary implants/patient - Overdentures were made with palate - Plaque index (PI), bleeding on probing (BOP), and gingival index (GI) were evaluated at T0 (prosthesis installation), 3 months (T3), and 12 months (T12) - Prosthetic maintenance and complications were recorded by frequency - Patient's satisfaction assessed by visual analog scale (VAS) and questionnaires about chewing, phonetics, esthetics, pain, and general satisfaction (T0, T3, and T12) - EVA was expressed on a 10-point rating scale (0 = very poor to 10 = excellent)	- MBL, after 1 year, was 0.34 mm (± 1.03 mm, p=0.988) - PI, GI, and BOP were significantly greater in the bar-clip group (p <0.001) - the most of the implants presented GI and BOP values lower than 1, indicating that the condition of the tissue remained stable with reduced inflammation - Prosthetic complications: 13-fold in the bar-clip group and the most frequent complication involved substitution of the bar-clips due to loss of retention; prosthesis fractures occurred 10 times (6 fractures of the teeth, 3 fractures of the extremities, and 1 involved the base of the prosthesis) - Patient satisfaction showed significant improvement in both groups at T3 and in chewing, pronunciation, and pain in the bar group at T12 (p <0.05) - There was not a significant difference between the two groups in patient satisfaction	Implant success rate was 89.1% and implants' survival rate was 96.3% for the bar-clip group, without statistical difference with another group (p=0.742).
S14	Assessed prosthetic maintenance and cost of overdentures retained by ball or locators-type	116 patients (232 implants); 90 patients were included in the 5-year data registration	- Ball (n = 34) / Locator (n = 56) - Implant survival, bone-to-implant level, prosthetic outcome, technical maintenance, and OHIP-14 were assessed	- Mean for MBL was 1.1 mm; Probing pocket depth 1.92 mm, Bleeding score 0.60; Plaque score 1; Plaque accumulated more on locators (P=.023); OHIP-14 declined from 18.1 to 2.7 independently of attachment - Retention for balls was better (P<.005), locators required more maintenance (P<.001), caused by retention-adjustment (P<.001) or ulcers/pain (P= 014) - Five years of maintenance-cost was 11% of the initial cost, irrespective of attachment - Balls and locators yield stable 5-years implant outcomes and improved Oral Health-Related Quality of Life (OHRQoL)	Implant survival was 98.7%, independently of attachment

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S15	Evaluated 2 unsplinted implants locator-retained mandibular overdenture (12 months), loaded immediately (IL) or after 3 months (DL)	30 patients and 60 implants	- Radiographic Bone Loss (RBL) at 6- and 12-months post-surgery - Implant length, insertion torque, implant failure, prevalence of maintenance visits, and prosthetic complications were recorded	- Mean RBL from baseline to 1 year was 0.54 (± 0.5) mm and 0.25 (± 0.5) mm for DL and IL, respectively (statistically significant difference - Insertion torque and implant length were not correlated with RBL - No difference in frequency of maintenance visits and prosthetic complications was reported between the groups	Implant survival rates of 100% and 94% for DL and IL, respectively
S16	Compare marginal bone loss and clinical outcomes between immediate and delayed loaded implants supporting mandibular overdentures with Locator attachments	36 patients and 72 implants	- Implants loaded in 3 months (delayed, G1) or the same day (immediate, G2) - Locator attachments for all cases - Vertical (VBL) and horizontal (HBLO) bone losses and clinical parameters [plaque scores (PI), gingival scores (GI), probing depths (PD) and implant stability (ISQ)] were assessed at time of overdenture insertion (T0), 6 months (T6) and 12 months (T12)	- All clinical parameters (PI, GI, PD, and ISQ) increased significantly with advance of time; At T12, all clinical parameters (PI, GI, PD and ISQ) did not differ significantly between groups - Vertical bone loss was significantly correlated with PD and HBLO - Immediate locator-retained mandibular overdenture are associated with more vertical bone resorption when compared to delayed group	Implant survival rates of 94.5% after 12 months
S17	Compare the biologic and prosthetic outcomes of implants loaded early to retain mandibular overdentures (ball and locators)	10 patients and 20 implants (locators group) / 19 patients and 38 implants (ball group)	- Marginal bone loss, plaque index, peri-implant infection, bleeding index, prosthetic complications, and Kaplan-Meier survival estimates of the groups were assessed at the 5 years	- Biologic outcomes for ball attachments or locators were comparable - Frequency of prosthetic complications with ball attachments was higher - Survival probabilities of the ball attachment group were higher	Implant survival rates of 100%
S18	Investigate the effect of interimplant angulation, on mandibular two-implant overdentures, on retention of two attachment systems (locator and Retentive anchor) within 1 year	24 patients and 48 implants	- Coronal and sagittal interimplant angulation were measured on posterior-anterior and lateral cephalometric radiographs - Retention was measured at baseline, 1 week, 3, 6, and 12 months	- Mean coronal and sagittal interimplant angulations were 4.6 (SD = 2.9) and 3.5 (SD = 2.6) degrees, respectively - Increased interimplant angulation appears to have higher impact on the retention of locators than of Retentive anchor attachments	-
S19	Compare 3 types of attachment systems for mandibular implant overdenture, focusing on costs, maintenance, and complications for 5-year follow-up	69 patients and 138 implants (mandible) (balls, n = 23; magnets, n = 23; locator, n = 23)	- Maintenance - Cost - Compared results among groups	- Magnetic registered the highest prosthetic success (82.60%), followed by Locators (78.26%), and ball - lowest success rate (50%) - Magnet group had significant higher costs comparing with the other two groups - Magnetic had lower necessity of maintenance than locators	Implant survival rates of 97.1% and prosthetic success rate of 78.3%
S20	Determine patient satisfaction and preference for implant-supported mandibular overdentures retained with ball or locator attachments after 1 year	20 patients and 40 implants	- Patient satisfaction - Patient preference between ball and locator attachments - Peri-implant conditions and prosthodontic maintenance efforts	- Patient satisfaction improved significantly (P<.05) with each of the two attachment types, without differences between ball or locator attachment - No one attachment had a significant patient preference - No differences for peri-implant parameters were noted - Locator attachment required more postinsertion aftercare than the ball anchors, but with no significantly difference	-

S21	To study patient satisfaction and masticatory efficiency of single implant-retained mandibular overdentures (stud and magnetic attachments) crossover design	15 patients and 15 implants; evaluations after 3 months	- Patient satisfaction (comfort, speech, chewing ability and retention) and masticatory efficiency measured by chewing peanuts - Outcomes compared before and after insertion of the attachments and between the two types of attachments	- Patient overall satisfaction, comfort, speech, chewing ability, and retention improved significantly after insertion of both types of attachment bodies ($p < 0.05$) - Masticatory efficiencies also increased in both the Locator and the Magfit groups ($p < 0.05$) - There were no statistically significant differences in patient overall satisfaction, comfort, speech, and retention between the two types of attachments ($p > 0.05$) - The locator attachments performed better in perceived chewing ability than the Magfit ($p < 0.05$), but there was no statistically significant difference in masticatory efficiency ($p > 0.05$). - Clinical outcomes were significantly improved in single implant-retained mandibular overdentures using both attachments	-
S22	Evaluate prosthetic problems and implant failures associated with ball, bar and locator used in implant-supported overdentures, including	36 patients and 95 implants (maxilla and mandible)	- Mean follow-up time = 41.17 months - Prosthetic complications (fractured overdentures, replacements of o-ring attachment and retention clips, implant failures, hygiene problems, mucosal enlargements, attachment fractures, retention loss and dislodgement of the attachments) - Recall visits at 3, 6, 12 months and, annually thereafter	- 14 complications - ball attachment; 7 complications - bar group - No complications were observed in the locator group - 50% of the subjects with no complication - 6 implants had failed - 39 implant overdentures were applied. Three prostheses were renewed because of fractures - Locator system showed superior clinical results than the ball and the bar attachments, when evaluated rate of prosthodontic complications and the maintenance of the oral function	Implant survival was 93.69%
S23	Determine surgical and prosthodontic outcomes of mandibular single-implant overdentures	36 patients and 36 implants (3 groups: control - regular implants and standard ball attachments; 8-mm-wide implants and large ball attachments; regular implants and locator attachments)	- compare wide diameter implant and large ball attachment system with regular diameter implants with standard attachment systems (ball and locator)	- Mean ISQ value of the Southern regular diameter implants (control group) was significantly lower than that of the other two groups ($P < 0.05$). - Prosthodontics success rate - Southern regular implant group (ball, 63.6%); Southern wide implant (ball, 83.3%); Neoss regular implant (locator, 66.7%) - Retreatment (repair) - Southern regular implant group (27.3%); Southern wide implant (16.6%); Neoss regular implant (25%) - Mandibular single-implant overdentures are a successful treatment option using implants of different diameters and with different attachment systems	Implant success was 91.7%, Southern regular implant group with 75% compared with 100% in the Southern wide and 100% Neoss regular (Locators)
S24	Evaluate patient satisfaction and clinical and prosthetic outcomes of two-implant mandibular overdenture (magnet, ball-socket, or bar-clip attachments) after 10 years of function	18 patients and 36 implants; after 10 years, only 14 patients (7 ball-socket and 7 bar-clip attachment)	- The same questionnaire from 10 years before was completed - Subjects were asked to express their overall appreciation of their dentures on a visual analog scale (VAS) - Six scales of denture complaints were constructed - Mean scale and VAS scores between initial evaluation and after 10 years were compared - In addition, marginal probing depths, bleeding index, and radiographic marginal bone loss were assessed	- No difference in satisfaction between ball-socket- and bar-clip-retained two-implant mandibular overdentures - Patients' appreciation of their implant-retained denture was and remained high over time - Clinical parameters revealed healthy mucosal conditions and stable marginal bone levels, determined radiographically - Probing depths around implants provided with ball-socket attachments were slightly shallower than those with bar-clip attachments ($P < 0.05$)	-
S25	Comparison of the locator with two traditional designs (a rotational gold matrix and a rubber O-ring type) in clinical with 1-year of follow-up, for two-implant-retained overdentures	60 patients and 120 implants (Locator = 23 and Ball = 33)	- clinical situation was evaluated: prosthodontic maintenance and biologic complications, subjective patients' experience, and oral health-related life quality (Oral Health Impact Profile [OHIP-G 49])	- Locator system brought up 34 prosthetic complications - Ball group showed 14 complications - Biologic complications and patients' oral health-related life quality showed no significant difference among the 3 experimental groups - Locator showed a higher rate of maintenance than the ball attachments - Patients' oral health-related life qualities as well as the biologic parameters do not differ when using the 3 abutment systems	Implant survival rates of 93.33%

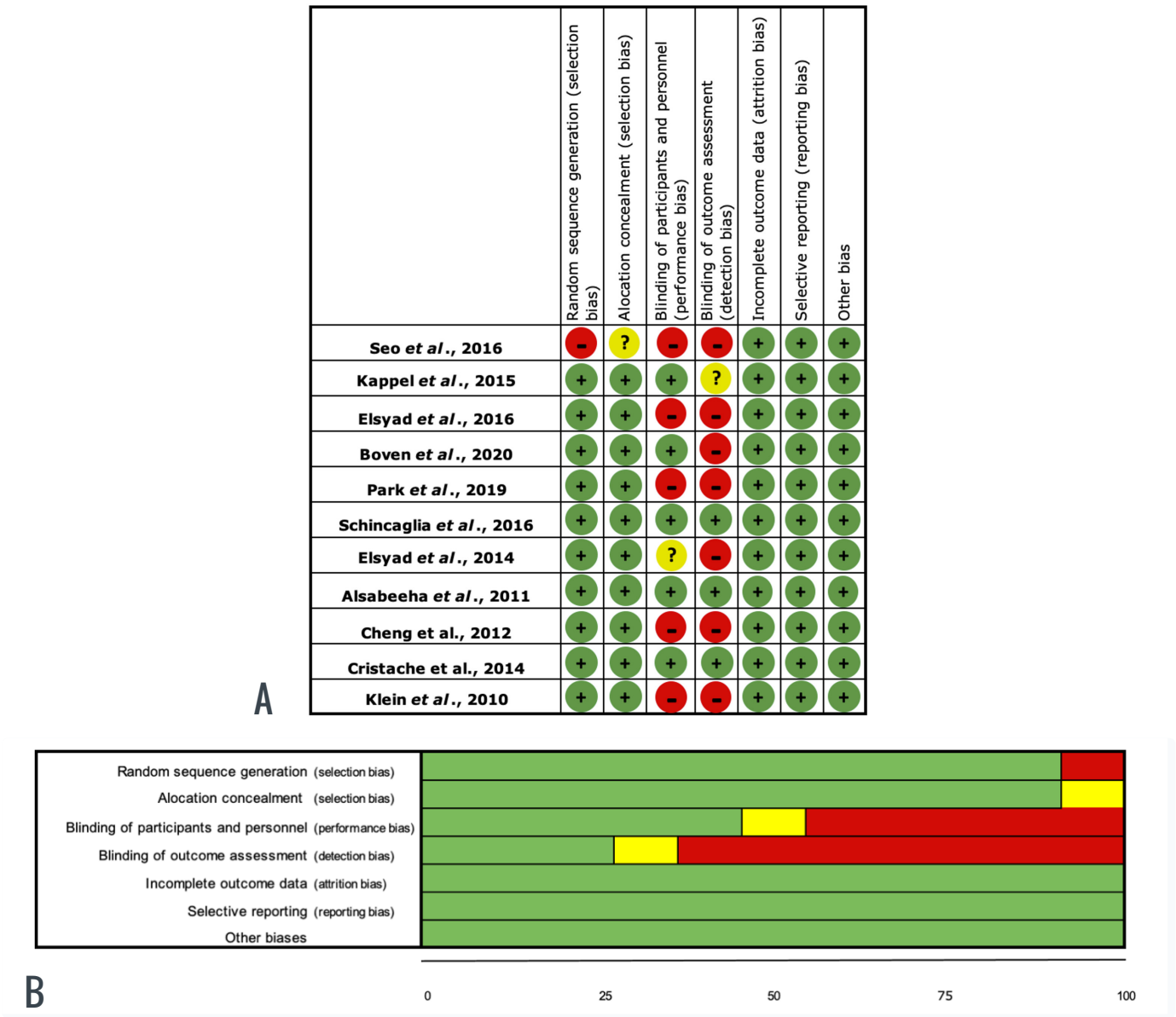

Figure 2: (A and B) Risk of bias for included RCTs. Low (green), unclear (yellow), and high (red) risk of bias according to the systematic review.

When modified-NOS was applied to ascertain the quality of assessment for non-RCT studies (*Figure 3*), six articles were qualified with medium-quality (Brandt *et al.* [S3,19], Varshney *et al.* [S11,8], and Jabbour *et al.* [S18,29], Krennmair *et al.* [S20,31], Cakarer *et al.* [S22,33], Cune *et al.* [S24,35], whilst all others achieved high quality (S1, S2, S4, S8-S10, S14, S17), with a total score ranging from 7 to 9.

EVALUATION ONLY OF STUD RETENTION

Twenty-three studies (S1-S12, S14-S23, S25) used the stud system, enrolling 1602 implants and 635 subjects. The lowest success rate was 87.6% after 5 years, the lowest survival rate was 93.33% after 1 year, and the greatest MBL (1.96 ± 0.20 mm) occurred after 4 years. Just one article used only studs (S16), and only one compared stud-retentor versus magnetic, concluding that the stud was twice preferred by patients than magnetic (S21).

STUD-RETENTOR VERSUS BALL-ATTACHMENT

Nine studies (S1, S11, S14, S17, S19, S20, S22, S23, S25) compared stud-retentor with ball-attachment, which have been reported stability after 5-year implant outcome,[1] with an overall mean MBL of 1.1 mm and probing depth of 1.92 mm, showing the stud system as the greatest plaque accumulator (p=0.023) and as the system that required more maintenance (p<0.001), a fact also observed in the S20 and S25, due to its lower retention. Conversely, S17 showed higher complications for ball-attachment retentor; likewise, S22 also had similar results affirming that 70.6% of the complications existent in the study (n=14) were in the ball group, while S19 had 28.26% lesser prosthetic success for the ball group compared to stud group, but with no difference for costs associated. Already in S20 and S23, the incidence rate of prosthodontic maintenance did not significantly differ between stud or ball-attachment.

	Selection				Comparability	Outcome			
Study/year	Adequate definition of patient cases (maximum ★)	Representativeness of patient cases (maximum ★)	Selection of controls (maximum ★)	Definition of controls (maximum ★)	Control for important or additional factors (maximum ★★)	Ascertainment of exposure (maximum ★)	Was follow-up long enough for outcomes to occur?	Adequacy of follow-up (maximum ★)	Total score (out of 9)
Tallarico *et al.*, 2018	★	★			★★	★	★	★	7
Malmstrom *et al.*, 2015	★	★			★★	★	★	★	7
Brandt *et al.*, 2019	★				★	★		★	4
Guédat *et al.*, 2018	★	★			★★	★	★	★	7
Wang *et al.*, 2015	★	★			★★	★	★	★	7
Elsyad and Hammouda, 2016	★		★	★	★★	★	★	★	8
Al-Dharrab, 2017	★	★			★★	★	★	★	7
Varshney *et al.*, 2018	★				★★	★		★	5
Matthys *et al.*, 2019	★	★			★★	★	★	★	7
Akça *et al.*, 2013	★	★			★★	★	★	★	7
Jabbour *et al.*, 2014	★	★				★	★	★	5
Krennmair *et al.*, 2012	★	★			★★	★		★	6
Cakarer *et al.*, 2011	★	★			★	★	★	★	6
Cune *et al.*, 2010	★				★★	★	★	★	6

Figure 3: Quality assessment using the modified Newcastle-Ottawa Scale (NOS) for the included non-RCT studies.

STUD-RETENTOR VERSUS RETENTIVE ANCHOR / MAGNETIC RETENTION / BAR-ATTACHMENT

Only one article compared a stud-retentor with a retentive anchor (S18) and other two researches (S7, S21) studs versus magnetic retention. Five studies (S5, S6, S11, S12, S22) directly compared stud-retentor with bar-attachment and two articles (S21 and S23) developed a study with one-implant rehabilitation, in the midline of the mandible, comparing the patient satisfaction (comfort, speech, chewing ability and retention) and masticatory efficiency measured by chewing peanuts, beyond comparing before and after insertion of the attachments and also between the two types of attachments (S21), while S23 compared wide diameter implant and large ball attachment system with regular diameter implants with standard attachment systems (ball and stud). In S21, stud attachments performed better in perceived chewing ability than the magnetic system ($p<0.05$), but there was no statistically significant difference in masticatory efficiency ($p>0.05$); while, in S23, the prosthodontics success rate was for regular implant group (ball, 63.6%), the wide implant (ball, 83.3%), and regular implant (stud, 66.7%), with retreatment rate of 27.3% for regular implant group, 16.6% for the wide implant, and regular implant with the stud of 25%. The conclusion for S21 and S23 was that mandibular single-implant overdentures are a successful treatment option using implants.

Furthermore, for Kappel *et al.* (S6), after 2 years, the implant survival rate was 93.5% and 89.1% and the success rate was 94.7% and 92.1%, respectively, for stud and bar; MBL also after 2 years ranging between 0 and 2.5 mm; prosthesis survival rate was 95.7% and 93.5%, respectively, for stud and bar group. For Seo *et al.* (S5) the group using the only stud had a significant greater MBL ($p<0.05$, 1.96 ± 0.20 mm) compared with the bar group (1.51 mm ± 0.13 mm), and also significant difference ($p<0.05$) for probing depth between stud (2.91 ± 0.24 mm) and bar group (2.80 ± 0.16 mm); otherwise, the bar group presented an elevated inflammatory profile (33.3%) compared with stud group (12.5%). For Boven *et al.* (S12), the MBL after 1 year was 0.58 mm (± 0,71 mm) for stud and 0.31 mm (± 0.47 mm) for bar-clip; probing depth was 3.7 mm (± 1.0 mm) for stud and 4.1 mm (± 0.9 mm) for bar group in T1, which was significantly increased in T12 (respectively, $p=0.002$ and $p=0.009$), but with no statistical significance between groups/period; there was a preference by the patients for bar-clip retention; implant survival rate was 96.7% for stud and 97.9% for the bar group. Moreover, S22 concluded that the stud system showed superior clinical results than bar attachments.

BAR-CLIP SYSTEM

Seven articles (S5, S6, S11, S12, S13, S22, S24) evaluated this retentor, involving 120 patients, and 368 implants were assessed, four included studies (S11, S13, S22, S24) compared the bar-clip with ball-attachment, and only one study (S24) compared bar-clip with magnetic retentor. Park *et al.*[25] reported an implant success rate of 89.1% and implants a survival rate of 96.3% for the bar-clip group ($p=0.742$). MBL, after 1 year, was 0.34 mm (± 1.03 mm, $p=0.988$). On the other hand, the plaque index, gingival index, and bleeding on probing were significantly greater in the bar-clip group. The highest MBL found, after 10 years, was 2.1 mm (± 0.6 mm) (S24). Whereas Varshney *et al.*[8] concluded that the bar-clip group resulted in major loss of retention observed after 6 months and the worst result regarding the visual analog scale (VAS).

QUANTITATIVE ANALYSIS

Marginal bone loss

For quantitative analysis of MBL *(Figure 4)*, S3, S4, S11, S18-S22, S25 were not included because S3 and S11 evaluated only visual analog scale (VAS), S11 the mean of retention, and S4, S18-S23, and S25 did not provide value or clear information on MBL. Moreover, it was only possible to develop quantitative analysis for the studies with 1 year of follow-up, due to the limited number of studies.

Then, MBL for the stud group *(Figure 4)* accounted for a mean loss of 0.77 mm (95% CI 0.48-1.07 mm) at 1-year post-loading period, with low-statistical heterogeneity (I^2) among the studies observed and was achieved based on the date of 9 studies (1 year). At 1 year, there was a standardized MBL among the groups.

The quantitative analysis of the implant survival rate, was performed from studies that provided this information *(Figure 5)* and which used the variance time. After assessment of the data, a regular standard involving all studies and similar survival rate when compared stud and bar-retentor was observed, with considerable homogeneity as demonstrated in the funnel plot *(Figure 6)*.

DISCUSSION

Dental implant treatment is an excellent alternative to substitute a removable total prosthesis (denture), improving patients' self-esteem and also retention, stabilization, and consequently more satisfaction,[37] and a better chewing performance.[12,38] Thereby, implant-supported overdentures have been proposed as the first choice to treat edentulous patients,[39] being considered a reliable treatment protocol,[40,41] providing an attachment system with a retentive force that is strong enough to prevent displacement.[42,43] Therefore, the current literature involving aspects like retentive force and wear of attachment systems is relatively scarce.[44]

Attachments are classified as splinted (bar-attachment) or unsplinted systems (o-ring/ball/spherical types, magnets, telescopic crowns, or stud attachments),[45] as already aforementioned. Therefore, comparing splinted bar-clip and non-splinted stud-retentor, which are the most valuable in retention and stabilization,[46,47] the bar attachment is considered to be an excellent anchorage system and its results and efficiency are well-documented in the literature. It corrects severe unparalellisms, enabling better force balance by its splinting effect,[47-49] therefore requires more intermaxillary space than individual attachments.[50] In this aspect the stud attachments, which do not need to be splinted and are designed to provide correct seating and adequate retention by self-aligning, widely used in implant support overdenture, with the lowest profile height (3.7 mm) compared to any other systems, and easier to sanitize.

Thus, the goal of this investigation was to analyze and compare implant-supported overdentures retained by stud versus bar-clip systems, verifying the MBL and survival rate found in the literature to provide a scientific base to help clinicians to plan and solve difficult clinical cases. After applying the criteria of selection, 25 studies were enrolled in which all used titanium implants (11 RCT and 14 non-RCT studies).

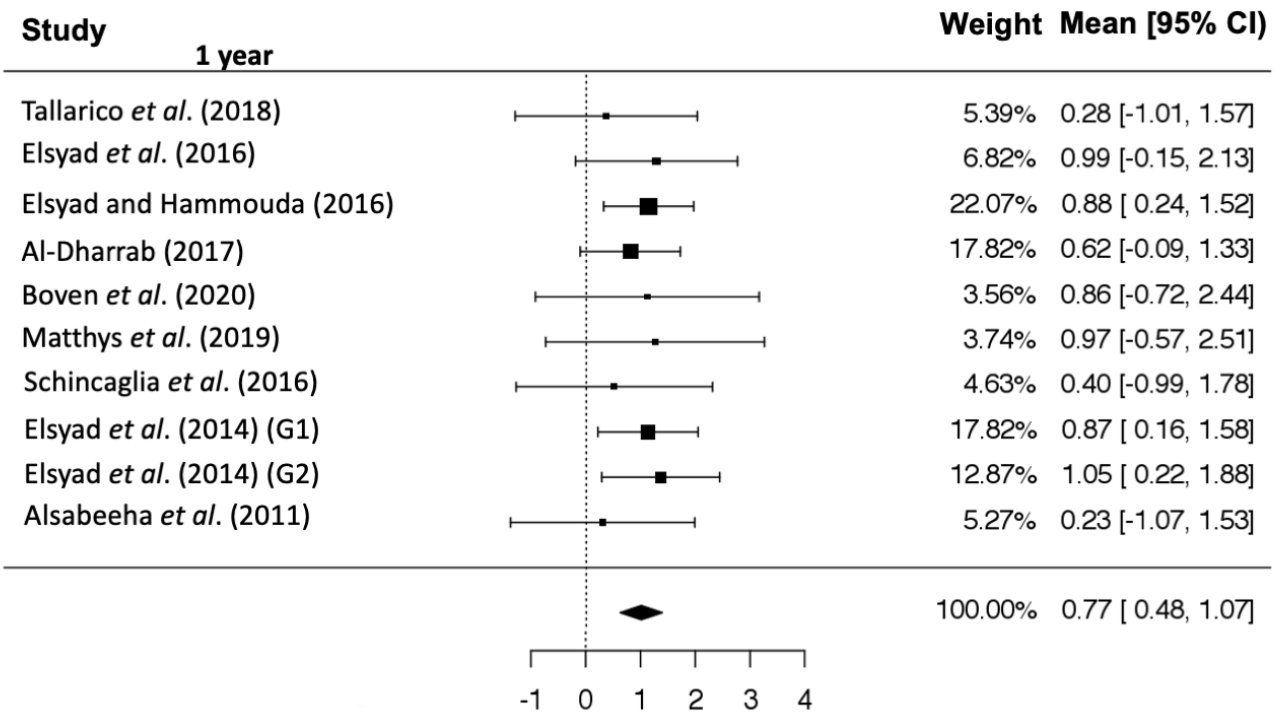

Figure 4: Forest plot for peri-implant marginal bone loss (MBL) at one year for the stud group. (FE Model: Fixed Effect Model).

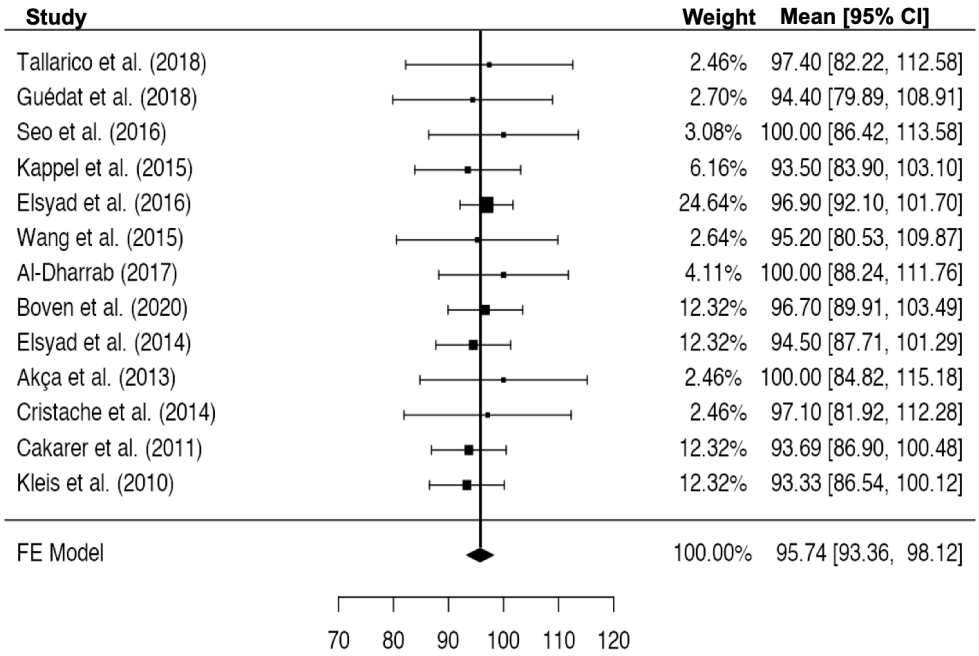

Figure 5: Forest plot for peri-implant MBL for the bar-clip group with moderator time. (FE Model: Fixed Effect Model).

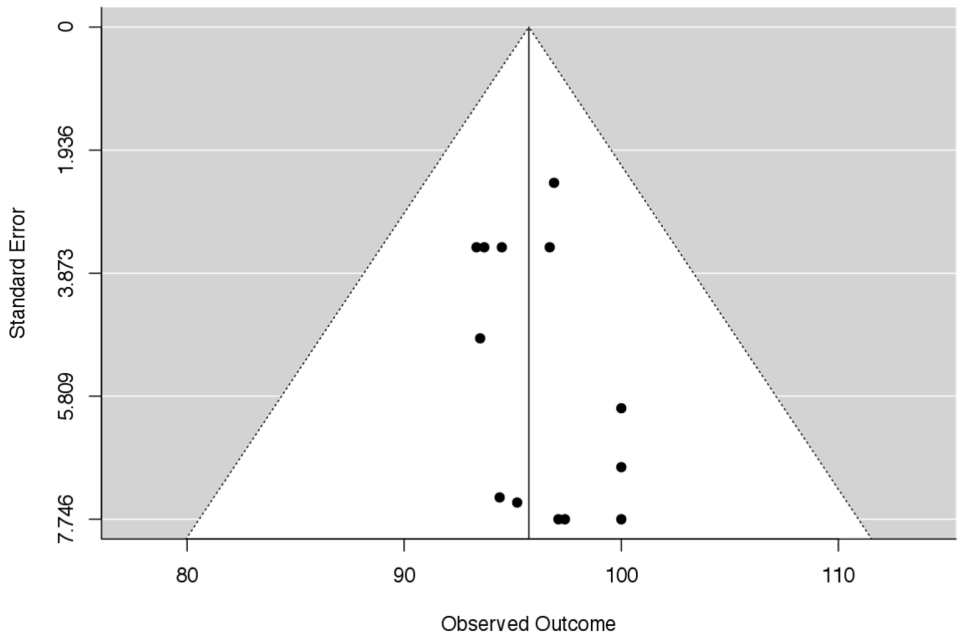

Figure 6: Funnel plot showing homogeneity among the studies when compared the implant survival rate.

Thereby, patient-reported outcomes are an important metric factor to analyze success or failure, beyond clinical results, which are essential for a comprehensive evaluation of treatment outcomes involving implant-supported overdentures.[51] Few studies have evaluated patient-reported outcomes. Significant improvement was reported by Emami *et al.*[52] through the scores of questionnaire items assessing patient satisfaction for overdentures. Concerning patient satisfaction for articles included in this study, S5 showed both groups were satisfactory in addition to a good relationship in terms of retention, esthetics, and chewing, in contrast with S3, which showed that the stud-type attachment included better support for the total prosthesis, better masticatory function, and presented a better sense of security and retention to the patient, achieving a high score in the VAS questionnaire, in which the patient was satisfied mainly with masticatory, phonetic function, and hygiene capacity, besides of the low financial cost.

Overdentures in oral rehabilitation are subjected to axial and non-axial stresses, such as observed by masticatory forces, in which the resultant forces are transferred to the implant through the superstructure attached.[53] However, a key factor for implant success/survival or failure is dependent on

the way the stresses arrive and are transferred to the peri-implant bone. Regarding the implants success and survival rates found, respectively, stud group ranged between 87.6% and 100% between 93.33% and 100% (1 up to after 5 years); while the survival rate for bar group ranged from 89.1% to 100% (1-4 years). This aspect of variance may be explained by the differences among professionals, abilities, and difficulties to control external varieties such as gender, masticatory, and muscular patients' behaviors. Thereby, the influence of different types of attachments on peri-implant stress has already been investigated [54,55]. In this scenario, it leads to observe two important factors: MBL and retention/attachment.

Approaching the retention-type, Uludag *et al*. (2014)[56] concluded that stud-type attachments provided better retention than Hader bar with a yellow clip. Indeed, Sadig (2009)[57] reported that stud attachments provided the greatest level of retention for implant-supported overdentures. In this review, S1 demonstrated that stud-retainers had a higher number of complications and prosthetic failures, while S2 showed 29% of overdentures with studs that needed to be fixed after 2 years, either due to screw loosening, repairing the base, or changing the retaining tap. Even though the patient satisfaction rate remained high in the same period. Sultana *et al*. (2017)[58] showed that the stud-type system lost almost 70% of the initial retention after the first 2000 cycles which is equivalent to 1 year of use. In concordance with both previous studies cited, Evtimovska *et al*. (2009)[59] concluded stud attachments had the highest mean peak load-to-dislodgement (8.25 ± 1.61 kg) against the Hader bar and clips which reached the lowest mean peak load-to-dislodgement (1.44 ± 0.30 kg), showing 5.72-fold greater resistance. However, Matthys *et al*. (2019)[1] warned that stud-type required more maintenance and, consequently, may result in lower retention.

From the studies included in this systematic review, only 4 (S5, S6, S11, and S12) directly compared both systems, presenting no significant difference for success rate and probing depth, although for survival rate S5 had 100% for both groups and S6 had 4.4% more for studs-type than bar attachment. An *in vitro* study[60] directly compared studs versus bar attachment and reported that stud-types are more reliable to retain maxillary overdentures than Dolder bar, due to higher retention and stability (between 14.24 Ncm and 43.66 Ncm), with major values than required for the minimum acceptable for patient satisfaction (10-20 Ncm). The reduced retention by Dolder bar attachments is in concordance with Williams *et al*. (2001)[61] findings, who found the lowest retention values for Hader-type clips and added that even with an increased number of clips, they did not influence significantly the retention values of attachments. Therefore, Guédat *et al*. (2018)[20] showed that the main complication of the stud system is the loss of retention, with wear more pronounced in the maxilla than in the mandible, justified by the difference related to the anatomical shape of the alveolar ridges.

Finally, a recent systematic review and meta-analysis[62] published in 2018, compared splinted and unsplinted overdenture attachment systems, achieving similar results for MBL, implant survival rate, and prosthetic complications. Therefore, from 9 studies included in the qualitative and quantitative analysis, no study applied stud retentors (e.g., Locator, Kerator), impairing the comparison to results obtained in this work. Furthermore, the meta-analysis aforementioned [62] verified a lesser MBL for the bar-clip group comparing to the stud-retentor.

Within the limitations of this study and considering carefully all data obtained due to methodological divergences, a lack of standardized period of evaluation and sample size, there were low differences between the systems studied which may not allow determining the ideal retention system for overdentures. Otherwise, most of the studies showed stud retentor as preferable due to a better distribution of forces, biological peri-implant behavior, low-cost, and ease for removal and performing sanitization and/or repair. For bar-clip systems, a greater quantity of inflammation was observed, but it was considered as a good clip-retentive system. Thus, it is suggested that more clinical studies with long-term follow-up and selective criteria are required to help clinicians precisely on the indication of the most effective system to treat patients.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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SUPPLEMENTARY TABLE:

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	
	23b	Discuss any limitations of the evidence included in the review.	
	23c	Discuss any limitations of the review processes used.	
	23d	Discuss implications of the results for practice, policy, and future research.	
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	26	Declare any competing interests of review authors.	
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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